Fiscal Year 2019

Stockpile Stewardship and Management Plan – Biennial Plan Summary

Report to Congress

October 2018

National Nuclear Security Administration
United States Department of Energy
Washington, DC 20585

Message from the Administrator

The Department of Energy/National Nuclear Security Administration's (DOE/NNSA) *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) describes DOE/NNSA's plans to ensure the safety, security, and effectiveness of the U.S. nuclear weapons stockpile and to maintain the scientific and engineering tools, capabilities, and infrastructure that underpin the nuclear security enterprise. The SSMP is a companion to the *Prevent, Counter, and Respond: A Strategic Plan to Reduce Global Nuclear Threats* report, which outlines NNSA's equally vital missions to reduce the threats of nuclear proliferation and nuclear terrorism. In keeping with our commitment to Congress, updated versions of these reports are published each year.

The fiscal year (FY) 2019 SSMP summarizes the activities being performed within DOE/NNSA's national laboratories, production facilities, and security site in support of our enduring national security missions. In particular, this report describes the path to completing production of W76-1 warheads by FY 2019; delivering the first production unit of the B61-12 gravity bomb by FY 2020; delivering the first production unit of the W88 Alteration 370 by FY 2020; and achieving a first production unit of the W80-4 warhead by FY 2025. With four modernization programs underway, NNSA is at its busiest since the Cold War era.

The FY 2019 SSMP also reflects DOE/NNSA's increased commitment to revitalizing and reinvigorating the facilities and corresponding infrastructure that make up the nuclear security enterprise. DOE/NNSA infrastructure has long been underfunded and overdue for the upgrades necessary to create a modern, efficient, nuclear complex that can meet NNSA's national security missions today and into the future. With the assistance and support of Congress, NNSA will be able to continue to halt the growth of deferred maintenance and modernize the nuclear security enterprise. As expressly stated in the *Nuclear Posture Review* (DOD 2018), there is no margin for further delay in the sustainment of a modern, resilient, and responsive infrastructure for the enterprise.

Continued investment in the repair and recapitalization of DOE/NNSA's laboratories, production facilities, and security site are crucial to NNSA's capabilities and most importantly, to our workforce. NNSA's workforce is our greatest asset, and providing quality facilities is necessary to recruit and retain the world-class scientific and engineering talent on which our nuclear deterrent, and indeed the security of the United States, so greatly depends.

In addition to summarizing the achievements and status of the current program of record, the FY 2019 SSMP describes the work that NNSA will execute in support of the *Nuclear Posture Review,* which addresses worsening global threat conditions and underscores the need for a modern, flexible, and resilient nuclear enterprise. DOE/NNSA's program of record for maintaining the nuclear weapons stockpile is being updated in coordination with the Nuclear Weapons Council and the interagency process that weighs and prioritizes missions and resources.

The challenges facing our Nation are real and pressing. The unprecedented range and mix of threats underscore the need for the United States to maintain a diverse set of nuclear capabilities that can provide flexible, tailored options to enhance deterrence and to achieve objectives should deterrence fail. As described in this report, the scientific and technological expertise found at DOE/NNSA's laboratories, production facilities, and other sites is the intellectual backbone through which the United States can continue to deter adversarial aggression and preserve peace for our Nation and our allies.

Pursuant to the statutory requirements, this FY 2019 SSMP is being provided to the following members of Congress:

The Honorable Richard Shelby
Chairman, Senate Committee on Appropriations

The Honorable Patrick Leahy
Vice Chairman, Senate Committee on Appropriations

The Honorable James Inhofe
Chairman, Senate Committee on Armed Services

The Honorable Jack Reed
Ranking Member, Senate Committee on Armed Services

The Honorable Lamar Alexander
Chairman, Subcommittee on Energy and Water Development
Senate Committee on Appropriations

The Honorable Dianne Feinstein
Ranking Member, Subcommittee on Energy and Water Development
Senate Committee on Appropriations

The Honorable Deb Fischer
Chairman, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Joe Donnelly
Ranking Member, Subcommittee on Strategic Forces
Senate Committee on Armed Services

The Honorable Rodney Frelinghuysen
Chairman, House Committee on Appropriations

The Honorable Nita M. Lowey
Ranking Member, House Committee on Appropriations

The Honorable Mac Thornberry
Chairman, House Committee on Armed Services

The Honorable Adam Smith
Ranking Member, House Committee on Armed Services

The Honorable Mike Simpson
Chairman, Subcommittee on Energy and Water Development, and Related Agencies
House Committee on Appropriations

The Honorable Marcy Kaptur
Ranking Member, Subcommittee on Energy and Water Development, and Related Agencies
House Committee on Appropriations

The Honorable Mike Rogers

Chairman, Subcommittee on Strategic Forces
House Committee on Armed Services

The Honorable Jim Cooper

Ranking Member, Subcommittee on Strategic Forces
House Committee on Armed Services

If you have any questions or need additional information, please contact me or Nora Khalil, Associate Administrator for External Affairs, at (202) 586-7332.

Sincerely,

Lisa E. Gordon-Hagerty

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Message from the Secretary

National security is a fundamental mission of the Department of Energy (DOE). Maintaining a safe, secure, and effective U.S. nuclear stockpile consistent with the President's 2018 *Nuclear Posture Review* is chiefly performed through the work of DOE's National Nuclear Security Administration (NNSA). This mission accounts for more than a third of the Department's discretionary budget. It comprises the developments made at the national security laboratories in science-based stockpile stewardship, advanced manufacturing, laser science and optics, high performance computing, and many other areas of benefit to DOE as well as other departments and agencies throughout the Government and our Nation.

The recently released *Nuclear Posture Review* (DOD 2018) addresses the dynamic nature of today's threat environment and the implications for our Nation's nuclear security mission. A safe, secure, and effective nuclear deterrent remains an essential element of our Nation's defense, both to deter attacks and to protect our interests and those of our allies. DOE/NNSA will work in close partnership with the Department of Defense (DOD) to provide additional diversity in the attributes and flexibility of our deterrence options, as directed in the *Nuclear Posture Review*. This year's *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) outlines the groundwork to support these objectives. Future editions of the SSMP will continue to document plans and progress.

The science-based Stockpile Stewardship Program has allowed DOE and DOD to certify to the President for the 22nd consecutive year that the U.S. nuclear weapons stockpile remains safe, secure, and effective without the use of nuclear explosive testing. This impressive scientific achievement is enabled by DOE/NNSA's most valuable resource, its workforce. DOE/NNSA's ability to recruit, train, and retain the next generation of world-class scientists, engineers, and technicians is a major priority. An additional priority is the revitalization and modernization of the facilities and related infrastructure of the nuclear security enterprise.

With continued congressional support for the program described in this FY 2019 SSMP, we will continue to meet our Nation's evolving nuclear security requirements while keeping the nuclear deterrent safe, secure, and effective.

Sincerely,

Rick Perry

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Executive Summary

This *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) describes the Department of Energy/National Nuclear Security Administration (DOE/NNSA) strategic program for maintaining the safety, security, and effectiveness of the nuclear stockpile over the next 25 years. DOE publishes the SSMP annually, either in full report form or as a summary, in response to statutory requirements, to support the President's Budget for Weapons Activities. This annual plan provides a single, integrated picture of current and future nuclear security enterprise activities and capabilities funded by the Weapons Activities account in support of the Nation's nuclear deterrent and is developed to be consistent with the *Nuclear Weapons Council's Strategic Plan for Fiscal Years (FY) 2017–2042*.

This SSMP lays the foundation for meeting the tenets laid out in the *National Security Strategy* (White House 2017) and the *Nuclear Posture Review* (DOD 2018). Examination of the Weapons Activities capabilities in Chapter 3, "Capabilities That Support the Nuclear Security Enterprise," is the first step in ensuring that these capabilities enable the capacity and flexibility to meet shifting requirements, as well as national security needs over the coming decades. Additionally, an effective, responsive, and resilient nuclear weapons infrastructure staffed by a trained and ready workforce is essential to the United States' capacity to adapt to these shifting requirements. The analysis of the capabilities and the infrastructure that enable them is further detailed in the chapters that follow.

Highlights of near-term and out-year mission objectives include the following:

- Complete production of the W76-1 warheads by FY 2019.
- Deliver the first production unit of the B61-12 by FY 2020 and complete production by FY 2024.
- Deliver the first production unit of the W88 Alteration (Alt) 370 (with refresh of the conventional high explosive) by December 2019 and complete alterations by FY 2024.
- Achieve a first production unit of the W80-4 by FY 2025, with completion of the life extension program (LEP) by 2031, and ensure alignment with the Department of Defense (DOD) Long Range Stand Off program.
- Advance the W78 warhead replacement 1 year to begin in FY 2019 to support fielding on the Ground-Based Strategic Deterrent by FY 2030.
- Sustain the B83-1 until a suitable replacement is identified.
- Explore future ballistic missile warhead requirements.
- Provide the enduring capability and capacity to produce plutonium pits at a rate of no fewer than 80 pits per year in 2030.
- Create an effective, responsive, and resilient nuclear infrastructure that ensures the availability of the strategic materials to meet military requirements.
- Advance the innovative experimental platforms, diagnostic equipment, and computational capabilities necessary to ensure stockpile safety, security, reliability, and responsiveness.
- Phase out mission dependency on Building 9212 at the Y-12 National Security Complex (Y-12) and deliver the Uranium Processing Facility for no more than $6.5 billion by the end of 2025.

- Implement the strategy to achieve the strategic priorities laid out in the *Nuclear Posture Review*, as further defined by the Nuclear Weapons Council.
- Achieve exascale computing and deliver a capable exascale machine by the early 2020s.
- Ensure an enduring trusted supply of strategic radiation-hardened microsystems beyond 2025.
- Develop an operational enhanced capability (advanced radiography and reactivity measurements) for subcritical experiments by the mid-2020s.
- Implement the Stockpile Responsiveness Program that fully exercises the workforce and capabilities of the nuclear security enterprise.

Life Extension and Major Alteration Program Highlights

- As of May 2018, NNSA completed 95 percent of the total production units of the W76-1 LEP, one of the two warheads associated with the Navy's submarine-launched ballistic missile. This LEP will add an additional 30 years of service life to the W76. NNSA has delivered more than 90 percent of the total warheads to the Navy.
- The B61-12 LEP, a nuclear gravity bomb for the Air Force, is currently in production engineering and continues to meet its qualification test schedule; multiple flight tests were completed during the past year. This LEP remains on track for a first production unit in 2020. Once completed, the LEP will add at least 20 years to the life of the system and consolidate four models of the B61 into a single variant.
- The W88 Alt 370 program accelerated activities for the change-out of the high explosive in the W88, the other submarine-launched ballistic missile warhead. The program is currently in the production engineering phase and remains on schedule for a first production unit in December 2019.
- NNSA made significant progress on the W80-4 LEP and entered the design definition and cost study phase in September 2017. The W80-4 is the nuclear warhead planned for incorporation into the Air Force's new Long Range Stand Off weapon system, which will replace its aging air-launched cruise missile.

Infrastructure and Operations Program Highlights

NNSA is long overdue for infrastructure upgrades to create a modern nuclear security enterprise that will reduce risk to the mission and improve staff, public, and environmental safety. More than half of NNSA's facilities are over 40 years old; nearly 30 percent date back to the Manhattan Project era; and 10 percent are currently excess and no longer needed. In 2017, guided by an updated infrastructure roadmap, NNSA leveraged new management tools to prioritize investments across the enterprise. NNSA continued to meet the long-term challenge of modernizing its infrastructure and providing high-quality facilities for its high-quality workforce via progress on the following projects:

- The Uranium Processing Facility at Y-12 achieved the 90-percent design phase, which is required to baseline the cost and schedule of nuclear projects, and completed the Construction Support Building. The completion of the $27.5 million Construction Support Building on time and $5 million under budget marks a major milestone for the project, which will replace an early Cold War plant with a modern, more efficient, and safer facility for conducting highly enriched uranium operations at Y-12.
- NNSA approved Critical Decision 4 (CD-4, Approve Start of Operations or Project Completion) at the High Explosive Pressing Facility at the Pantex Plant (Pantex), signaling the beginning of testing

process equipment and training staff prior to commencing operations. The High Explosive Pressing Facility will improve operational safety and security, thereby enhancing the quality and efficiency of high explosives production at Pantex.

- NNSA relocated many of its Pantex employees into the John C. Drummond Center (formerly known as the Pantex Administrative Support Complex). This facility was built by a private developer using third-party financing and provides a modern, energy-efficient workspace. The relocation of approximately 1,000 employees will allow for disposition of 1950s era buildings and the elimination of roughly $20 million in deferred maintenance at Pantex.
- Two critical subprojects for the Chemistry and Metallurgy Research Replacement (CMRR) project at Los Alamos National Laboratory (LANL) are on track to achieve CD-4 by FY 2022 on budget and schedule. The CMRR project will make it possible for mission-critical technical capabilities, such as analytical chemistry, materials characterization, and metallurgy research and development, to be relocated to modern laboratory facilities that meet or exceed current safety and environmental protection standards.
- Working with the Army Corps of Engineers, NNSA completed the 100-percent design phase for the Albuquerque Complex Project and broke ground on July 2, 2018. This is an important milestone on the path to a modern and efficient facility for over 1,200 DOE and NNSA employees in New Mexico.
- NNSA approved the start of operations at the Transuranic Waste Facility at LANL in September 2017, completing the project $2 million under budget and 4 months ahead of schedule. The facility will safely store transuranic solid waste from LANL in accordance with nuclear facility requirements.
- A groundbreaking was held at the Nevada National Security Site for the Mercury Modernization program. Mercury serves as the "base camp" for the Nevada National Security Site, housing facilities such as the operations command center, a fuel station, office buildings, and other support structures. The modernization effort will consolidate facilities into a smaller footprint, reduce energy costs, and provide a modern, sustainable infrastructure.
- Working with the State of Missouri, NNSA transferred excess Federal property at the Bannister Road Federal Complex in Kansas City to private developers. The transfer will save taxpayers approximately $700 million and will lead to further community development.

Experimental Highlights

- The National Ignition Facility (NIF) at Lawrence Livermore National Laboratory completed its 2,000th experiment in August 2017. NIF broke its own record for neutron yield twice in the past year, achieving a yield of 54 kilojoules and doubling the previous record from 2014. High energy density and inertial confinement fusion experiments support stockpile stewardship, as well as other national security applications and discovery science.
- The Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility at LANL completed seven integrated hydrodynamic experiments that examined the effects of component aging and the changes proposed in the LEPs.
- The Z pulsed power facility (Z) at Sandia National Laboratories (SNL) executed over 140 experiments in FY 2017. As the world's most powerful and efficient laboratory radiation source at several weapon-relevant pulse durations and frequencies, Z is capable of creating

weapon-relevant conditions that enable experiments to further our knowledge of weapon physics.

- The Joint Actinide Shock Physics Experimental Research (JASPER) gas gun at the Nevada National Security Site completed 18 experiments, including two with plutonium. Sixteen experiments on other special nuclear materials readied the platform for advanced diagnostics in support of upcoming plutonium experiments.
- The Microsystems and Engineering Sciences Applications (MESA) Complex at SNL produced integrated circuits for the nuclear security enterprise, including circuits used in state-of-the-art diagnostic detectors.
- The Los Alamos Neutron Science Center (LANSCE) fielded 122 experiments for NNSA and 546 experiments for other users including other government organizations, universities, and industry (under proprietary user agreements). The proton radiography facility and the Lujan Center facility both executed shots in support of the B61-12 LEP and future stockpile options. The Weapons Neutron Research Facility measured nuclear criticality data, as well as radiochemical data from underground tests.

High Performance Computing

The Trinity high performance computing system at LANL began full operations. Trinity is one of the most advanced computers in the world and performs more than 30 times better than the laboratory's former supercomputer, Cielo. With a speed of 41 petaFLOPS,[1] Trinity provides computing resources to support the highly accurate multi-dimensional modeling necessary to understand and predict performance as nuclear weapons age.

Conclusion

While executing the current plan, DOE/NNSA had an outstanding FY 2017. NNSA maintained the existing nuclear weapons stockpile, made impressive progress on a number of LEPs, and continued to advance the science and engineering capabilities that underpin the Nation's Stockpile Stewardship Program.

NNSA continued to extend the life of existing U.S. nuclear warheads by replacing nuclear and non-nuclear components with systems that use modern technologies. Unique, state-of-the-art capabilities for research, development, testing, evaluation, and production enabled this critical effort. Finally, the scopes, budgets, and schedules of the LEPs, infrastructure modernization efforts, and DOE's nuclear delivery systems have been fully integrated and coordinated.

Additional information regarding these and other advances that ensure NNSA's ability to achieve its mission is included in the chapters that follow.

[1] PetaFLOPS = one million billion or 10^{15} floating point operations per second.

Information at a Glance

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Legislative Language

Title 50 of United States Code Section 2523 (50 U.S.C. § 2523), requires that:

> The Administrator, in consultation with the Secretary of Defense and other appropriate officials of the departments and agencies of the Federal Government, shall develop and annually update a plan for sustaining the nuclear weapons stockpile. The plan shall cover, at a minimum, stockpile stewardship, stockpile management, stockpile responsiveness, stockpile surveillance, program direction, infrastructure modernization, human capital, and nuclear test readiness. The plan shall be consistent with the programmatic and technical requirements of the most recent annual Nuclear Weapons Stockpile Memorandum.

Pursuant to previous statutory requirements, the Department of Energy/National Nuclear Security Administration (DOE/NNSA) has submitted reports on the plan to Congress annually since 1998, with the exception of 2012.[1] Starting in 2013, full reports on the plan are to be submitted every odd-numbered year, with summaries of the plan provided in even-numbered years.

The majority of the *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) is a summary of DOE/NNSA's 25-year program of record to maintain the safety, security, and effectiveness of the nuclear stockpile and is captured in this single, unclassified document. A classified Annex to the SSMP contains supporting details concerning the U.S. nuclear stockpile and stockpile management.

[1] In 2012, a *Fiscal Year 2013 Stockpile Stewardship and Management Plan* was not submitted to Congress because analytical work conducted by DOD and NNSA to evaluate the out-year needs for nuclear modernization activities across the nuclear security enterprise had not yet been finalized.

Chapter 1
Overview

The Department of Energy/National Nuclear Security Administration (DOE/NNSA) is tasked with carrying out most of DOE's national security responsibilities. That mission and authority is drawn from the *Atomic Energy Act of 1954* (42 United States Code [U.S.C.] § 2011 *et seq.*) and, more specifically, the *National Nuclear Security Administration Act* (50 U.S.C. § 2401 *et seq*.), from which DOE/NNSA's core mission pillars are derived. These pillars include maintaining a safe, secure, and effective nuclear deterrent; preventing, countering, and responding to the threats of nuclear proliferation and terrorism worldwide; and providing naval nuclear propulsion (see **Figure 1–1**).

Figure 1–1. DOE/NNSA mission pillars and cross-cutting capabilities

Accomplishing these missions requires cross-cutting capabilities that support each mission pillar, including advances in world-class science, technology, and engineering (ST&E); supporting the people and modernizing the infrastructure that make up the DOE/NNSA nuclear security enterprise; and maintaining a management culture that efficiently operates a safe, secure enterprise.[1]

[1] Additional details are available in the *U.S. Department of Energy National Nuclear Security Administration Enterprise Strategic Vision*, August 2015.

Achieving success in the Weapons Activities mission areas that support the Nuclear Weapons Stockpile pillar requires unique capabilities to maintain the stockpile while ensuring the ability to adapt and respond to a dynamic security environment, as well as to geopolitical and technological surprises. The capabilities that enable the critical missions of weapons activities are defined in Appendix C, "Weapons Activities Capabilities," and discussed in detail in Chapter 3. Each capability is complementary and supports multiple elements of the DOE/NNSA nuclear security enterprise and the Nation's nuclear deterrent. Continued investment in these capabilities is necessary to sustain and modernize nuclear weapons, improve understanding of nuclear weapons performance, maintain confidence in the aging and evolving stockpile, and ensure that the nuclear security enterprise remains responsive.

This *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) is DOE/NNSA's 25-year strategic program of record for the nuclear weapons mission and was developed to be fully consistent with the 2018 *Nuclear Posture Review* and the *Nuclear Weapons Council's Strategic Plan for Fiscal Years (FY) 2017–2042*. The annual SSMP has two primary purposes:

- The SSMP documents DOE/NNSA's plans to maintain and extend the life of the nuclear stockpile, enhance understanding of the internal nuclear weapons function through science-based stockpile stewardship, modernize the supporting infrastructure, and sustain DOE/NNSA's highly skilled workforce.
- The SSMP provides DOE/NNSA's formal response to multiple statutory reporting requirements, a full listing of which can be found in Appendix A, "Requirements Mapping."

The FY 2019 SSMP includes budget information for the FY 2019 Future Years Nuclear Security Program (FYNSP), along with life extension program (LEP) schedules, preliminary infrastructure resource planning, and the long-term DOE/NNSA strategy through FY 2043 to ensure the Nation's nuclear deterrent.[2]

1.1 Policy Framework Summary

The *National Nuclear Security Administration Act* (50 U.S.C. § 2401, *(b) (2))* directs DOE/NNSA "To maintain and enhance the safety, reliability, and performance of the United States nuclear weapons stockpile, including the ability to design, produce, and test, to meet national security requirements."

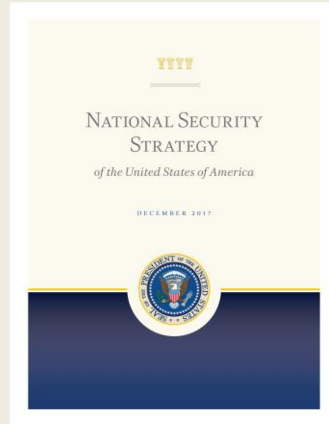
Presidential and DOE policy documents provide additional direction to DOE/NNSA on accomplishing the nuclear weapons mission. The 2017 National Security Presidential Memorandum on Rebuilding the U.S. Armed Forces (NSPM-1) directed that, "The Secretary [of Defense] shall initiate a new Nuclear Posture Review to ensure that the United States nuclear deterrent is modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st-century threats and reassure our allies."[3] The 2018 *Nuclear Posture Review* (DOD 2018) and the 2017 *National Security Strategy* provide guidance for NNSA and influenced the development of the FY 2019 SSMP. The 2018 *Nuclear*

"Recapitalizing the nuclear weapons complex of laboratories and plants is also long past due; it is vital we ensure the capability to design, produce, assess, and maintain these weapons for as long as they are required."

[2] See 50 U.S.C. § 2453, Future-years nuclear security program, for a detailed description of the FYNSP.

[3] See *Presidential Memorandum on Rebuilding the U.S. Armed Forces*, National Security Presidential Memorandum for the Secretary of Defense and the Director of the Office of Management and Budget, Section 3(b), January 27, 2017.

Posture Review reinforced the requirement for a nuclear weapons infrastructure that has the design, engineering, and manufacturing capabilities necessary to be flexible and responsive to meet changing geopolitical challenges. Evaluation of DOE/NNSA's Weapons Activities capabilities, discussed in Chapter 3, "Capabilities That Support the Nuclear Security Enterprise," is the first step in ensuring DOE/NNSA's capacity and flexibility to meet shifting requirements over the coming decades.



"Nuclear weapons…are the foundation of our strategy to preserve peace and stability by deterring aggression against the United States, our allies, and our partners."

The 2018 *Nuclear Posture Review* also provided policy direction, in the near term, to modify a small number of submarine-launched ballistic missile warheads to provide a low-yield option and, in the long term, to pursue a modern nuclear-armed sea-launched cruise missile. Aspects of the 2018 *Nuclear Posture Review* policy direction have been implemented and are included in the FY 2019 budget request. DOE/NNSA's program of record for maintaining the nuclear weapons stockpile will continue to be updated in coordination with the Nuclear Weapons Council and the interagency process that weighs and prioritizes missions and resources. Additional updates will be included in the 2020 SSMP, as appropriate.

1.2 Summary of Strategic Environment for Nuclear Security

The current strategic environment includes an unprecedented range and mix of threats, including major conventional, chemical, biological, nuclear, space, and cyber threats, as well as violence perpetrated by non-state actors. The resulting increased uncertainty and risk requires the United States to maintain a diverse set of nuclear capabilities that can provide flexible, tailored options for deterring threats from across the spectrum of adversaries, threats, and contexts. The U.S. nuclear triad (which includes capabilities via sea, land, or air) and nonstrategic nuclear forces provide the diversity of platforms, weapons, and modes of operation necessary to allow the United States to implement its strategies for deterrence and achieve its objectives should deterrence fail.

The 2018 Nuclear Posture Review found that the current threat environment and an uncertain future necessitate a national commitment to maintain modern and effective nuclear forces, as well as the infrastructure needed to support them. Sustaining and replacing existing nuclear capabilities is critical to preserving our ability to deter threats to the Nation.

1.3 Summary of the DOE/NNSA Nuclear Security Enterprise

The DOE/NNSA nuclear security enterprise (**Figure 1–2**) consists of NNSA Headquarters (located in Washington, DC; Germantown, Maryland; and Albuquerque, New Mexico); the NNSA field offices; the three national security laboratories (two of which have production missions); the four nuclear weapons production sites; and the Nevada National Security Site. NNSA implements the overall nuclear weapons strategy, in collaboration with its management and operating (M&O) partners, and oversees and coordinates activities to ensure they are accomplished in an efficient, fiscally responsible manner.

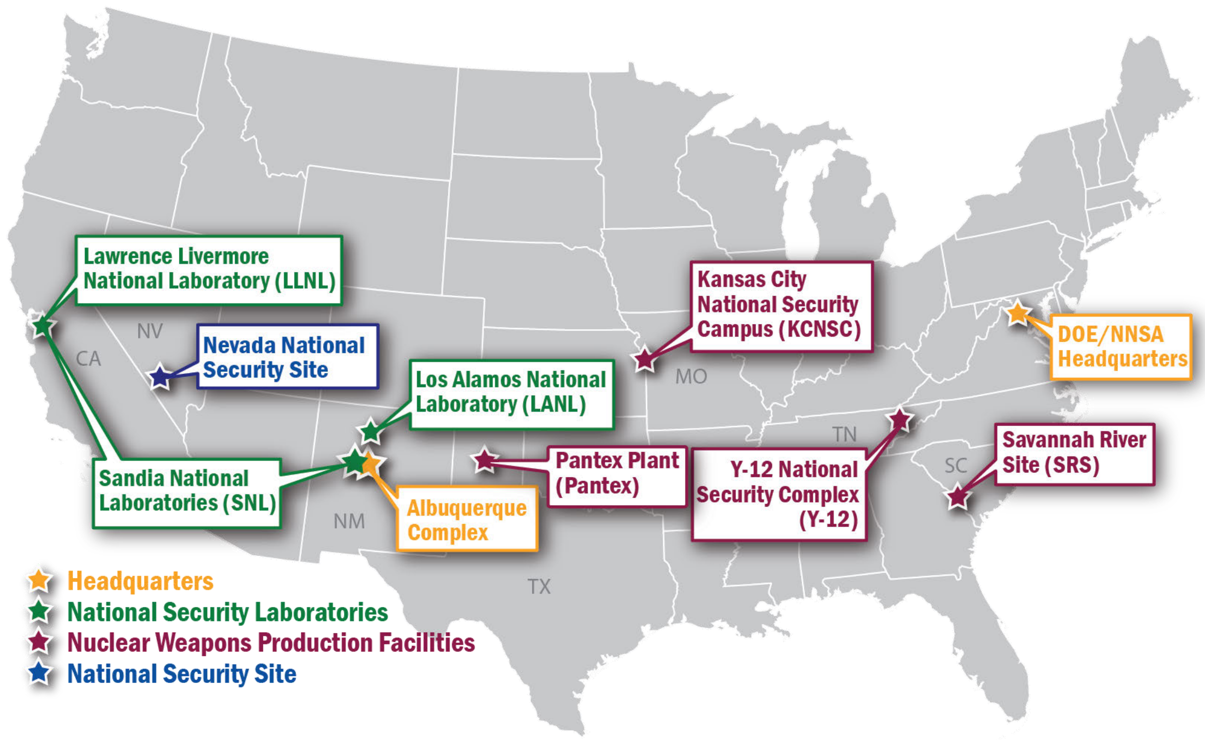


Figure 1–2. The DOE/NNSA nuclear security enterprise

1.3.1 National Security Laboratories

Three national security laboratories are devoted to nuclear weapons design and data interpretation:

- Lawrence Livermore National Laboratory (LLNL) in Livermore, California;
- Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico; and
- Sandia National Laboratories (SNL) in Albuquerque, New Mexico, and Livermore, California.[4]

The primary mission of these national security laboratories is to develop and sustain nuclear weapons design, simulation, modeling, and experimental capabilities and competencies to ensure confidence in the stockpile without nuclear explosive testing. All three laboratories are Federally Funded Research and Development Centers (FFRDCs).[5] The national security laboratories engage in long-term research, development, test, and evaluation (RDT&E) activities for the nuclear weapon missions and apply ST&E to solve other national challenges, such as nuclear threat reduction. Other DOE national laboratories also support the Weapons Activities and Defense Nuclear Nonproliferation programs.

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[4] DOE's Savannah River National Laboratory at the Savannah River Site also conducts research and development in support of tritium processing and gas transfer system design and certification activities.

[5] FFRDCs are unique nonprofit entities sponsored and funded by the U.S. Government to meet special long-term research or development needs that cannot be met as effectively by existing in-house or contractor resources. FFRDCs are operated, managed, and/or administered by either a university or consortium of universities, another not-for-profit or nonprofit organization, or an industrial firm either as an autonomous organization or an identifiable separate operating unit of a parent organization.

1.3.2 Nuclear Weapons Production Sites

The four nuclear weapons production sites conduct a range of stockpile management activities:[6]

- The Kansas City National Security Campus in Kansas City, Missouri, produces non-nuclear components.
- The Pantex Plant (Pantex) in Amarillo, Texas, manufactures and tests high explosive (HE) components and assemblies and disassembles and refurbishes stockpile weapons and components.
- The Y-12 National Security Complex (Y-12) in Oak Ridge, Tennessee, manufactures uranium components and dismantles and stores highly enriched uranium (HEU).
- The Savannah River Site in Aiken, South Carolina, extracts, recycles, and loads tritium into gas transfer systems.

In addition, these facilities process uranium and plutonium to support DOE/NNSA's nonproliferation goals and counterterrorism activities.

1.3.3 Nevada National Security Site

The Nevada National Security Site partners with the national security laboratories to provide facilities, infrastructure, and personnel to conduct unique nuclear and non-nuclear experiments that are essential to maintaining the stockpile. It is the primary location where experiments with radioactive and other high-hazard materials are conducted and the only location where HE-driven plutonium experiments can be conducted at weapon-scale with weapon-relevant amounts of special nuclear material. The Nevada National Security Site also develops and deploys state-of-the-art diagnostics and instrumentation, analyzes data, stores programmatic materials, conducts criticality experiments, and supports other DOE/NNSA activities.

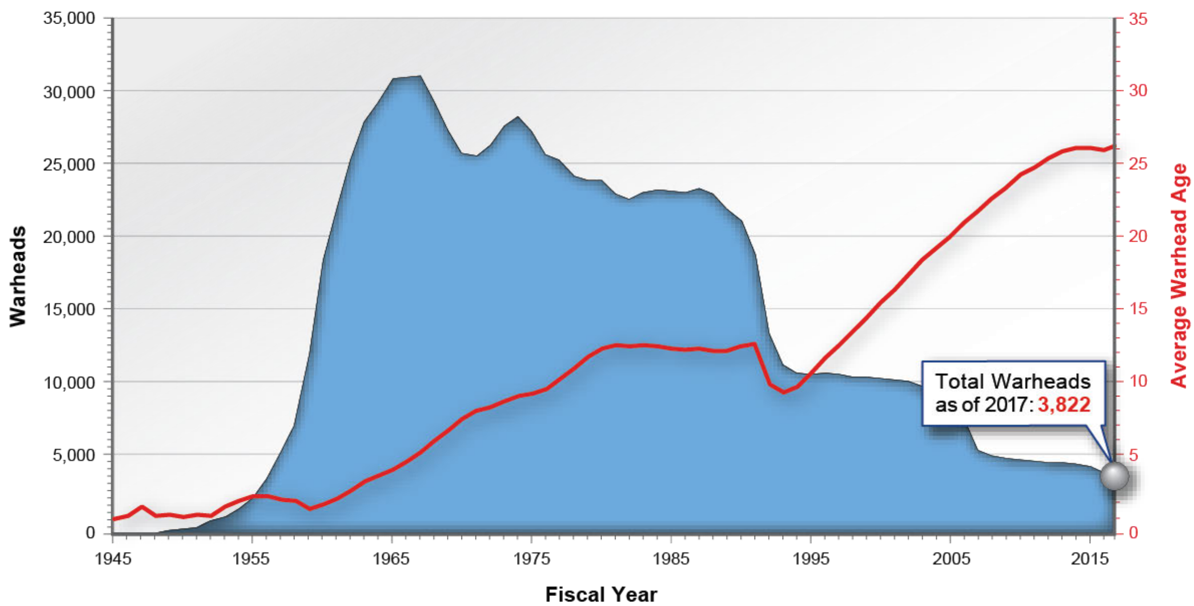
1.4 Summary of the Current Nuclear Weapons Stockpile

The size and composition of the nuclear stockpile has evolved as a consequence of the changing global security environment and U.S. national security need. The average age of weapons in the stockpile remains high. Many weapons are well past their original design life and require stockpile management to assess their condition and perform routine maintenance to ensure operability and extend weapon lifetimes. The evolution in the size and age of the nuclear weapons stockpile is illustrated in **Figure 1–3**.

The current stockpile consists of active weapons, which are maintained to meet military requirements, as well as inactive weapons, which are used to augment or replace warheads in the active stockpile as necessary. Retired weapons are not included in the count of stockpile weapons. **Table 1–1** reflects the major characteristics of the Nation's current stockpile, which is composed of two types of submarine-launched ballistic missile warheads, two types of intercontinental ballistic missile warheads, several types of bombs, and a cruise missile warhead.

The classified Annex includes specific technical details about the stockpile by warhead type.

[6] Some production capabilities also exist at LANL and SNL.



Note: NNSA closely tracks the age of each component within every nuclear weapon in the Nation's stockpile as part of ensuring safety, security, and reliability. The age of each weapon is taken from the day that final assembly at the Pantex Plant is completed. The age of each weapon is reset to "zero" following a major modernization, such as a life extension, after which the weapon is certified by the national security laboratories for an additional 20-30 years, depending on the weapon type and modernization conducted. The database that tracks this information, and the information itself, is classified. It is important to note that, while a life extension does reset the age of a weapon to zero for purposes of tracking (such as this figure depicts), components within that weapon are older than the assigned weapon age. Both weapon age and the age of each component within each weapon are tracked by NNSA.

Figure 1–3. Size and age of the U.S. nuclear weapons stockpile, 1945–2017

Table 1–1. Current U.S. nuclear weapons and associated delivery systems

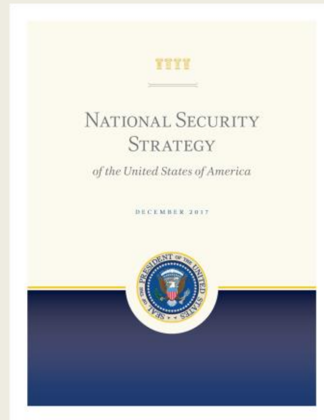
Type [a]	*Description*	*Delivery System*	*Laboratories*	*Mission*	*Military*
Warheads—Strategic Ballistic Missile Platforms					
W78	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LANL/SNL	Surface to surface	Air Force
W87	Reentry vehicle warhead	Minuteman III intercontinental ballistic missile	LLNL/SNL	Surface to surface	Air Force
W76-0/1	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
W88	Reentry body warhead	Trident II D5 submarine-launched ballistic missile	LANL/SNL	Underwater to surface	Navy
Bombs—Aircraft Platforms					
B61-3/4	Non-strategic bomb	F-15, F-16, certified NATO aircraft	LANL/SNL	Air to surface	Air Force/Select NATO forces
B61-7	Strategic bomb	B-52 and B-2 bombers	LANL/SNL	Air to surface	Air Force
B61-11	Strategic bomb	B-2 bomber	LANL/SNL	Air to surface	Air Force
B83-1	Strategic bomb	B-52 and B-2 bombers	LLNL/SNL	Air to surface	Air Force
Warheads—Cruise Missile Platforms					
W80-1	Air-launched cruise missile strategic weapons	B-52 bomber	LLNL/SNL	Air to surface	Air Force

LANL = Los Alamos National Laboratory
LLNL = Lawrence Livermore National Laboratory
NATO = North Atlantic Treaty Organization
SNL = Sandia National Laboratories

[a] The suffix associated with each warhead or bomb type (e.g., "-0/1" for the W76) represents the modification associated with the respective weapon.

1.5 Overall Strategy, Objectives, and Prioritization of Weapons Activities

DOE/NNSA and the Department of Defense (DOD) implement the Nation's objectives to maintain strategic stability with other major nuclear powers, deter potential adversaries, and reassure allies and partners regarding the national security commitments of the United States. DOE/NNSA priorities are to sustain and maintain the stockpile while balancing infrastructure and RDT&E investments to meet technical and national security challenges.



"We will modernize our nuclear enterprise to ensure that we have the scientific, engineering, and manufacturing capabilities necessary to retain an effective and safe nuclear Triad and respond to future national security threats."

There are four major strategies to sustain and maintain the stockpile:

- Extend the life of the stockpile; replace obsolete technology; enhance stockpile safety and security; and meet military requirements, treaties, and other international obligations.
- Assess and certify the stockpile through science-based stockpile stewardship by conducting experiments and direct weapon surveillance, incorporating new knowledge into the models embedded in the design codes, and enhancing the computational capabilities of those codes.
- Address aging infrastructure and equipment obsolescence by improving processes to plan and prioritize investments. Make additional facility and infrastructure investments, target reduction of safety and programmatic risk, and dispose of excess facilities at the eight M&O partner sites.
- Augment the Stockpile Stewardship and Stockpile Management Programs with an effective Stockpile Responsiveness Program[7] to provide a greater breadth of opportunities to exercise key capabilities and skills. Exercising these capabilities also will provide a mechanism to preserve and transfer knowledge across the workforce.

Additional activities to sustain and maintain the stockpile include the following:

- DOE/NNSA is investing in additive manufacturing to reduce development and production costs, improve cycle time, and ensure against product and manufacturing obsolescence. Advanced manufacturing may also enable novel design opportunities and increase in-house production of nuclear weapon components.
- To better assure supply chain protection and viability, DOE/NNSA has implemented several initiatives in the Nuclear Enterprise Assurance program to address threats to critical products and processes. The program focuses on restricting information, enhancing and sustaining designs, establishing robust secure manufacturing and testing processes, and augmenting supply chain management to ensure malicious hardware and software do not enter nuclear security enterprise products.

[7] For additional information, see the DOE/NNSA February 2018 report to Congress, *Stockpile Responsiveness*.

- NNSA and DOE are also investing in the DOE-wide Exascale Computing Initiative to ensure that future high performance computing architectures meet the needs of the nuclear security enterprise.

1.6 Partnership with the Department of Defense

DOE/NNSA and DOD work collaboratively to maintain and modernize the stockpile and delivery systems. DOE/NNSA's role is to ensure that nuclear weapons remain safe, secure, and reliable, and DOD's role is to provide a range of delivery options that can be tailored to meet the desired objectives.

These complementary efforts are coordinated through the congressionally mandated Nuclear Weapons Council. The Council is a joint DOD-DOE activity established by 10 U.S.C. § 179 to facilitate cooperation and coordination, reach consensus, and establish priorities between the two agencies in fulfilling dual responsibilities for stockpile management. The Council is also the focal point for routine interagency activities to maintain the U.S. nuclear weapons stockpile.

Major Goals of Weapons Activities

- *Complete W76-1 production by FY 2019.*
- *Cease programmatic operations at the Chemistry and Metallurgy Research facility at LANL.*
- *Deliver the first production unit of the B61-12 by FY 2020 and complete production by FY 2024.*
- *Deliver the first production unit of the W88 Alt 370 (with refresh of the conventional high explosives) by December 2019 and complete alterations by FY 2024.*
- *Synchronize NNSA's W80-4 life extension with DOD's Long Range Stand Off program and complete the LEP by 2031.*
- *Provide the enduring capability and capacity to produce plutonium pits at a rate of no fewer than 80 pits per year in 2030.*
- *Phase out mission dependency on Building 9212 at Y-12 by the end of 2025.*
- *Provide experimental and computational capabilities to support annual assessment and certification of the stockpile.*
- *Enhance the predictive capability to certify and assess via theory, modeling, and experimental validation using advanced scientific tools.*

1.7 Stockpile Strategy

The Nuclear Weapons Council is reviewing the current strategic plan to align objectives with the 2018 *Nuclear Posture Review*. Given the changes in the global security environment since the 2010 *Nuclear Posture Review*, the 2018 *Nuclear Posture Review* directed a review of the roles of nuclear weapons in the national security of the United States, the strategy for fulfilling these roles, and the capabilities required to implement the strategy.

The 2018 *Nuclear Posture Review* calls for a tailored and flexible approach to provide deterrence across a spectrum of adversaries, threats, and contexts. The increasing need for diversity and flexibility of platforms, weapons, and modes of operation reinforces the necessity to continue sustaining and modernizing the enduring stockpile.

To meet the emerging requirements of U.S. strategy, the United States will enhance the flexibility and range of its tailored deterrence options in a variety of ways, including the following:

- Modifying a small number of existing submarine-launched ballistic missile warheads to provide a low-yield option.
- In the longer term, pursuing a modern, nuclear armed sea-launched cruise missile.
- Retaining the B83-1 and B61-11 gravity bombs in the stockpile until there is sufficient confidence in the B61-12 gravity bomb that will be available in 2020 and a suitable replacement for the B83-1 is identified.

The United States must have the ability to maintain and certify a safe, secure, and effective nuclear arsenal. Synchronized with DOD replacement programs, DOE/NNSA will sustain and deliver on time the warheads needed to support the Nation's strategic and non-strategic nuclear capabilities in six ways:

- Complete the W76-1 LEP by FY 2019.
- Complete the B61-12 LEP by FY 2024.
- Complete the W88 Alteration (Alt) 370 by FY 2024.
- Synchronize NNSA's W80-4 life extension with DOD's Long Range Stand Off program and complete the W80-4 LEP by FY 2031.
- Advance the W78 warhead replacement 1 year to FY 2019 to support fielding on the Ground-Based Strategic Deterrent by 2030 and investigate the feasibility of fielding the nuclear explosive package in a Navy flight vehicle.
- Explore future ballistic missile warhead requirements based on the threats and vulnerabilities of potential adversaries, including the possibility of common reentry systems for Air Force and Navy systems.

The United States will pursue initiatives to ensure the capability, capacity, and responsiveness of the nuclear weapons infrastructure and the skills of the workforce, including the following:

- Pursue a joint DOD and DOE advanced technology development capability to ensure that efforts are appropriately integrated to meet DOD needs.
- Provide the enduring capability and capacity to produce plutonium pits at a rate of no fewer than 80 pits per year in 2030.
- Ensure that current plans to reconstitute the U.S. capability to produce lithium compounds are sufficient to meet military requirements.
- Complete the Uranium Processing Facility to provide sufficient uranium components to meet military requirements.
- Ensure the reactor capacity to produce an adequate supply of tritium to meet military requirements.
- Ensure continuity in the U.S. capability to develop and manufacture secure, trusted strategic radiation-hardened microelectronic systems beyond 2025 to support stockpile modernization.
- Pursue the Stockpile Responsiveness Program established by Congress to expand opportunities for young scientists and engineers to advance warhead design, development, and production skills.
- Develop an NNSA roadmap that sizes production capacity to modernization and hedging requirements.
- Retain confidence in nuclear gravity bombs to meet deterrence needs.
- Maintain and enhance the computational, experimental, and testing capabilities to annually assess nuclear weapons.

1.8 Challenges in Executing the Stockpile Stewardship and Management Plan

> *"Recapitalizing the nuclear weapons complex of laboratories and plants is also long past due; it is vital we ensure the capability to design, produce, assess, and maintain these weapons for as long as they are required."*
>
> *2018 Nuclear Posture Review*

DOE/NNSA has made substantial progress on near-term priorities, including LEPs, to ensure the stockpile remains safe, secure, and effective as long as nuclear weapons exist. DOE/NNSA surpassed the 95 percent mark of the total production units of W76-1 warheads to the Navy as of May 2018, delivered more than 90 percent of the total warheads to the Navy, and authorized the national security laboratories and nuclear weapons production sites to enter Phase 6.4 (Production Engineering) for the B61-12 LEP. In addition, planning activities for the W88 conventional high explosive refresh were accelerated and combined with replacement of the weapon's arming, fuzing, and firing systems, along with safety enhancements. This resulted in a single W88 Alt 370 effort by the time the program received authorization to transition to Phase 6.4 in February 2017. The W80-4, a life-extended version of the existing cruise missile warhead (W80-1), entered Phase 6.2A (Design Definition and Cost Study). Major investments in infrastructure are currently underway to address a number of critical capabilities identified in the 2018 *Nuclear Posture Review*, such as the Uranium Strategy, which includes the Uranium Processing Facility Project, and the Plutonium Strategy, which includes the Chemistry and Metallurgy Research Replacement project.

Notwithstanding these accomplishments, the DOE/NNSA nuclear security enterprise requires major recapitalization, as do all three legs of the nuclear triad, to ensure that the deterrent is modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st-century threats. NNSA's missions depend on specialized facilities, infrastructure, and equipment. DOE/NNSA must build a more modern enterprise to guarantee capabilities to continue to meet the Nation's requirements; keep the nuclear deterrent safe, secure, and effective; and improve worker and public safety. More than half of NNSA's facilities are over 40 years old, and the demands of the LEPs and the Stockpile Stewardship Program have increased the loads on the aging infrastructure. Without infrastructure modernization, the risk to NNSA's missions will increase. Workforce, ST&E, and infrastructure needs are discussed further in Chapter 3, "Capabilities That Support the Nuclear Security Enterprise," and Chapter 4, "Budget and Fiscal Estimates."

There are three key considerations:

- The nuclear weapons stockpile requires updated technologies that will require significant investment in new processes, technologies, and tools to produce, qualify, and certify warheads in accordance with the stringent specifications the stockpile requires.
- The trustworthiness of the nuclear weapon supply chain that provides specialized components (e.g., radiation-hardened electronics) must be sustained to protect against the potential for sabotage, malicious introduction of an unwanted function, or subversion of a function without detection. NNSA's radiation-hardened silicon microelectronics facility, the Microsystems and Engineering Sciences Applications (MESA) Complex at SNL, relies on tools and capabilities that are no longer supported by manufacturers. DOE/NNSA is installing new tooling and planning recapitalization efforts to extend the life of the MESA facilities. DOE/NNSA is also engaging with DOD and the Massachusetts Institute of Technology's Lincoln Laboratory to establish research and development efforts that could also serve as a production capability.
- The DOE/NNSA nuclear security enterprise has many retirement-eligible employees who will be leaving the workforce in the near future (**Figure 1–4**). In order to prepare for this loss of expertise,

aggressive programs are necessary to recruit and retain high-quality individuals and provide new personnel with opportunities to acquire the experience and expert judgment needed to sustain the stockpile.

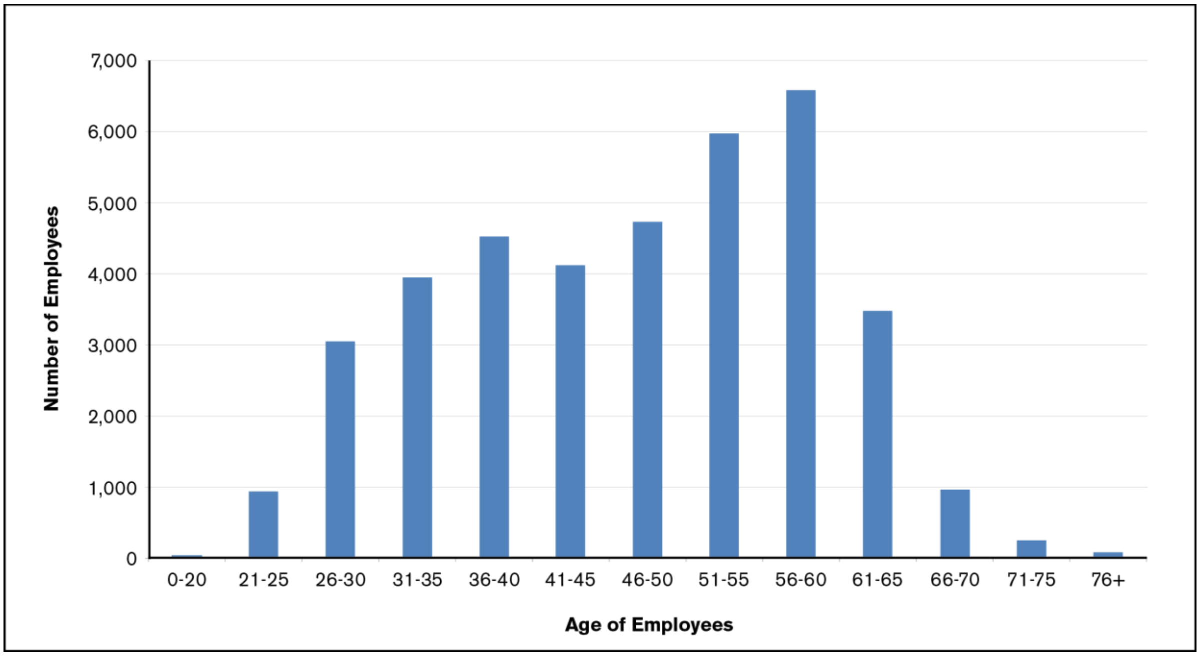


Figure 1–4. Management and operating partners headcount distribution by age

Chapter 2
Status of the Stockpile and Modernization Efforts

This biennial summary plan reflects the current approved program of record, consistent with Presidential direction and congressional authorizations and appropriations. However, due to the release of the *National Security Strategy,* the *Nuclear Posture Review*, and DOD's *National Defense Strategy,* it is anticipated that implementation plans and congressional action may impact ongoing program work.

2.1 Stockpile Management Overview and Nuclear Enterprise Assurance

Stockpile management encompasses annual assessment of the stockpile; certification of a weapon before it enters the stockpile; surveillance and maintenance throughout the weapon's lifetime; significant finding investigations (SFIs); plans for major alterations (Alts), modifications (Mods), or life extension programs (LEPs) as the stockpile ages and as policy changes; dismantlement and disposal of retired weapons; recovery and reuse of material from dismantled weapons; and procurement and production of strategic materials to support the stockpile. As part of these activities, DOE/NNSA also manages limited life component (LLC) exchanges, addresses issues that affect stockpile reliability, and manages nuclear and non-nuclear materials. The Nuclear Enterprise Assurance program focuses on designing, developing, producing, and maintaining weapon components while mitigating the consequences of threats ranging from subversion to counterfeiting attempts.

2.2 Status of the Stockpile

The status of the stockpile is determined annually through multi-layered assessments of the safety, security, and reliability of the weapons, based on surveillance, maintenance, physics and engineering analyses, non-nuclear hydrodynamic tests, computer simulations, material evaluation, and other sources of information. The Directors of the three national security laboratories and the Commander of U.S. Strategic Command (USSTRATCOM) prepare annual assessment letters to document their independent perspectives. These letters are included in the congressionally mandated Report on Stockpile Assessment, which the Secretaries of Energy and Defense sign and deliver to the President.

2.2.1 Weapons Assessment, Reliability, Certification, and Prediction of Performance

The assessment and certification processes determine whether the parts, components, subsystems, and systems meet all required weapon performance characteristics. Both processes are quantitative and rely on assembling and combining data from experiments, physical and environmental tests, destructive and nondestructive evaluations, models, and simulations.

2.2.1.1 Annual Assessment

The overall assessment philosophy and approach involve quantification of weapon characteristics and rigorous reviews of the results and certification basis by teams of weapons scientists and engineers. The teams responsible for assessing each weapon type include individuals with extensive weapon experience and access to both historical and new data. The Annual Assessment Reports are reviewed by independent peers, subject matter experts appointed by program managers, senior laboratory managers, and the Directors of the three national security laboratories.

The Laboratory Directors' letters include the state of each warhead's existing certification, based on information generated by the Stockpile Stewardship Program each year. Assessments may also evaluate the effect of aging on weapon performance and quantify the changes to performance thresholds, uncertainties, and margins.

2.2.1.2 Weapon Reliability

Nuclear weapon reliability is the probability that a designated weapon can deliver the specified nuclear yield at the target. An annual weapon reliability assessment is compiled into the Weapon Reliability Report, which concerns the military effectiveness of the stockpile. This is the principal DOE/NNSA report on reliability that USSTRATCOM uses for overall strategic planning actions and targeting.

2.2.1.3 Certification

Certification is the process whereby all available information on the performance of a weapon system is considered when making the determination that a weapon will meet (with noted exceptions) the prescribed military characteristics within the environments defined by the system's stockpile-to-target sequence. The Laboratory Directors responsible for each system make this certification before the weapon enters the stockpile.

2.2.1.4 Prediction of Weapon Performance

DOE/NNSA relies on a combination of experiments and integrated design codes (IDCs) to predict weapon performance. This is accomplished by developing high-fidelity weapon simulation codes and acquisition of high performance computers, as well as by acquiring detailed data to calibrate and validate the models in the codes. To provide a predictive capability, DOE/NNSA must know how accurately the code simulations can describe real weapon performance because understanding any error in the simulation predictions is critical. To determine that error, LANL and LLNL scientists compare the simulation results with data generated from small-scale laboratory experiments, large-scale experiments, subcritical experiments, and nearly 50 years of U.S. nuclear explosive testing. Predictive capabilities allow weapon designers to extrapolate from legacy nuclear explosive testing, modern non-nuclear experiments, and nuclear subscale or subsystem experiments to regimes that cannot be probed experimentally.

Although DOE/NNSA has made significant progress in eliminating phenomenological models, much computational and experimental research remains to be performed. Stockpile stewardship scientists have broken down the operation of a weapon into a sequence of individual steps, analyzed those steps through models and experiments, and then reintegrated the steps through large-scale IDCs and computational tools. This process can be enhanced by new facilities that support experiments that approach the densities, pressures, velocities, temperatures, and timescales relevant in a nuclear detonation. Improved experimental tools and simulation codes can also be used to qualify nuclear and non-nuclear components for a broader set of environments in which components could be expected to function.

Development of Accurate Models of Weapon Systems and Components

Understanding the full-system behavior of a weapon, based only on knowledge of its component subsystems, is one of the most difficult aspects of modeling a nuclear weapon. The processes that must be modeled include material damage, mixing of fluids, and detonation of high explosives (HE). A full-system simulation depends on accurate, reliable models for material equations of state, material motion, interaction of neutrons with materials, radiation flow, etc. These models are based on data from experiments that represent some, but not all, of the environments experienced by the weapon.

Quantification of Margins and Uncertainties

Using predictive capabilities to assess and certify the performance of a weapon is a tremendous challenge. A methodology for quantifying the margins and uncertainties addresses this challenge. This methodology evaluates the confidence in a prediction in terms of the degree to which the operation of a weapon is judged to be within the bounds of judiciously chosen operating characteristics. Confidence is numerically represented as a confidence factor. This factor is the ratio of the margin (M) over uncertainty (U), or M/U.[1] A confidence factor significantly greater than 1.0 is desirable. A value at or less than 1.0 motivates actions to increase the confidence factor by increasing the margin or decreasing the uncertainty. Increasing the margin might include shortening the interval between LLC replacements. Decreasing the uncertainty can be done by focusing research and development (R&D) resources on areas such as the specific characteristics of the strategic materials to which weapon performance is sensitive (like the uncertainty in cross-sections) or by improving the fidelity of the models used to simulate the operation of the warhead, as validated by experimental results. The research, development, test, and evaluation (RDT&E) programs pursue both approaches.

2.2.2 Surveillance of the Stockpile

DOE/NNSA's surveillance activities provide data to evaluate the condition of the stockpile in support of annual assessments of safety, security, reliability, and performance. In addition, the cumulative body of surveillance data supports decisions regarding weapon life extensions, Alts, Mods, repairs, and rebuilds. The Surveillance program has six goals:

- Identify defects (e.g., from manufacturing, design, and adversary exploitation) that affect safety, security, performance, or reliability.
- Identify and associate possible failure mechanisms to surveillance measurements and then judge the risks to safety, security, and performance based on the surveillance data.
- Calculate the margins between design requirements and performance at the component and material levels.
- Identify age-related changes and trends at the subsystem or component and material levels.
- Further develop capabilities for predictive assessments of stockpile components and materials.
- Provide critical data for the semiannual (May and November) Weapons Reliability Report and the annual Report on Stockpile Assessments.

[1] Margin is measured based on how much "room" is available between the predicted value of a metric and the boundary where that metric becomes unacceptable. Uncertainty is a measure of the ability to predict the metric based on both the measured values (via experiments) and the calculated values (via databases for physical quantities, physical models, and numerical simulations).

The Surveillance program consists of the Stockpile Evaluation program and the Enhanced Surveillance subprogram, which are described below.

- The Stockpile Evaluation program conducts surveillance evaluations of both the existing stockpile (i.e., stockpile returns) and newly refurbished LEP weapons (using Retrofit Evaluation System Test selections).
- The Enhanced Surveillance subprogram provides the diagnostics, processes, and other tools needed by the Stockpile Evaluation program to predict and detect initial or age-related defects, assess reliability, and estimate component and system lifetimes.

These two program elements work closely together to execute the Surveillance program and develop new surveillance capabilities at the system, component, and material levels. System-level flight tests are conducted jointly with the Air Force and Navy. Newly produced weapons or those returned from the stockpile are disassembled, and their non-nuclear components, along with surrogate parts for the nuclear components, are used to build a joint test assembly (JTA), which is delivered to DOD for flight testing. Some JTAs contain extensive telemetry instrumentation, while others contain high-fidelity mock nuclear assemblies to recreate the mass properties of War Reserve weapons as closely as possible. These JTAs are flown on the respective DOD delivery platform to gather information to assess the effectiveness and reliability of both the weapon and the launch or delivery platform, as well as the associated crews and procedures. Stockpile laboratory tests at the subsystem or component level assess major assemblies and components and, ultimately, the materials that compose the components (e.g., metals, polymers, glasses, plastics, ceramics, foams, electronics, optics, and explosives). This surveillance process enables detection and evaluation of aging trends and anomalous changes at the component or material level and prevents introduction of malicious functions by adversaries.

NNSA conducts stockpile evaluation through weapon disassembly and inspection, stockpile flight testing, stockpile laboratory testing, component testing and material evaluation, and test equipment. The number of disassembly and inspections and major component tests completed in FY 2017 and planned for FY 2018 are detailed in **Table 2–1**.

Table 2–1. Fiscal years 2017 actual and 2018 planned Directed Stockpile Work Program stockpile evaluation activities (as of March 5, 2018)

	D&Is		*JTA Flights*		*Test Bed Evals*		*Pit NDE*		*Pit D-Tests*		*CSA NDE*		*CSA D-Tests*		*GTS Tests*		*HE D-Tests*		*DCA Tests*		*Program Totals*	
	Fiscal Year																					
Warheads	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*	*17*	*18*
B61	11	9	5	5	4	4	20	15	0	1	13	9	2	3	17	8	0	0	10	16	82	70
W76-0	4	4	0	2	5	0	4	4	0	2	4	4	1	1	12	9	3	3	9	10	42	39
W76-1	20	29	1	6	24	19	31	29	0	1	24	8	4	3	13	9	3	3	22	21	142	128
W78	8	8	3	4	0	0	22	19	1	2	8	8	3	2	8	6	3	3	0	17	55	69
W80-1	0	19	4	4	8	10	35	40	0	3	0	0	1	1	7	5	4	4	8	28	67	114
B83	2	2	1	1	1	1	11	9	1	2	0	0	1	1	5	2	1	1	6	0	29	19
W84	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	5	3
W87	8	9	3	2	9	8	12	12	0	0	0	0	1	1	4	5	1	1	3	5	41	43
W88	7	7	4	4	12	4	15	25	1	1	0	0	2	2	13	15	1	3	7	7	62	68
Totals	**65**	**88**	**21**	**28**	**63**	**46**	**150**	**153**	**2**	**12**	**49**	**29**	**15**	**14**	**79**	**59**	**16**	**19**	**65**	**105**	**525**	**553**

CSA = canned subassembly
D&I = disassembly and inspection
DCA = detonator cable assembly
D-tests = destructive tests
GTS = gas transfer system
HE = high explosive
JTA = joint test assembly
NDE = nondestructive evaluation

The numbers of major surveillance evaluations completed in FY 2017, planned for FY 2018, and planned within the Future Years Nuclear Security Program (FYNSP) are detailed in **Table 2–2**. The national security laboratories, in conjunction with NNSA and the nuclear weapons production sites, continually refine these planning requirements based on new surveillance information, annual assessment findings, and analysis (or reanalysis) of historical information using modern assessment methodologies and computational tools.

Table 2–2. Major surveillance evaluations completed in fiscal years 2017, planned for fiscal year 2018, and baselined for the Future Years Nuclear Security Program (fiscal years 2019 through 2023) (as of March 5, 2018)

Major Activity	FY 2017 Actual	FY 2018 Planned	FYNSP (FY 2019 through FY 2023)					
			FY 2019 Requirements	FY 2020 Requirements	FY 2021 Requirements	FY 2022 Requirements	FY 2023 Requirements	FYNSP Total [a]
D&Is	65	88	79	92	89	78	82	420
JTA Flights	21	28	20	26	29	23	25	123
Test Bed Evaluations	63	46	47	70	60	60	46	283
Pit NDEs	150	153	187	202	225	217	222	1053
Pit D-Tests	2	12	19	17	17	14	21	88
CSA NDEs	49	29	43	43	75	68	63	292
CSA D-Tests	15	14	19	14	18	22	19	92
GTS Tests	79	59	103	69	63	55	59	349
HE D-Tests	16	19	21	42	37	36	33	169
DCA Tests	65	105	63	82	94	84	92	415
TOTALS	525	553	601	657	707	657	662	3284

CSA = canned subassembly
D&I = disassembly and inspection
DCA = detonator cable assembly
D-tests = destructive tests
FY = fiscal year
FYNSP = Future Years Nuclear Security Program
GTS = gas transfer system
HE = high explosive
JTA = joint test assembly
NDE = nondestructive evaluation

[a] FYNSP-forecasted quantities do not reflect reductions that may result from the lowering of stockpile readiness proposed for certain weapons.
Note: Totals are preliminary counts as of March 5, 2018

2.2.3 Significant Finding Investigations

SFIs are conducted when anomalies arise that have the potential to affect safety, security, reliability, or performance. SFIs are usually triggered during surveillance or are identified during weapons production, DOD operations, reacceptance and rebuild, and dismantlement. The SFI process includes determining the cause; ascertaining the impact on weapon system performance, reliability, security, and safety; and recommending corrective actions, if applicable. A majority of SFIs are closed without significant impact to the stockpile (**Figure 2–1**). If the finding has significant impact, it can result in a change to the reported reliability, issuance of an exception to the Major Assembly Release, or an Alt, Mod, or LEP.

2.2.4 Maintenance of the Stockpile

Weapons contain LLCs (such as gas transfer systems [GTSs], power sources, and neutron generators) that require periodic replacement to sustain system functionality. Many of the age-related changes affecting these components are predictable and well understood. LLC exchanges periodically replace these components throughout the lifetime of the weapon. NNSA produces the LLCs, while NNSA and DOD jointly manage component delivery and installation of replacements before warhead performance or personnel safety are adversely affected. NNSA activities for sustainment of legacy weapons are illustrated in **Figure 2–2**.

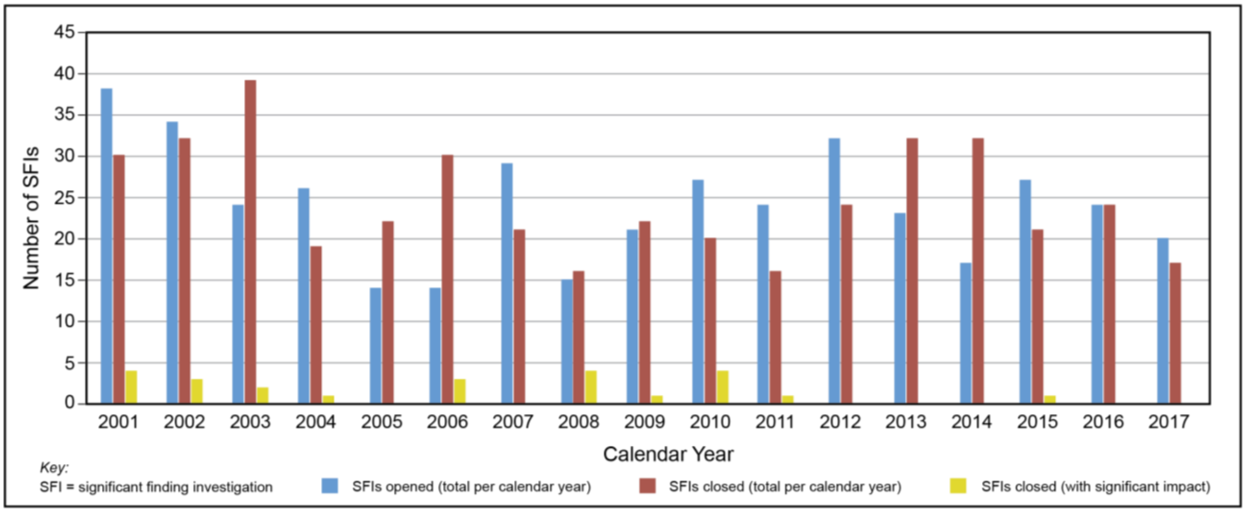


Figure 2–1. Historical number of significant finding investigations opened, closed, and closed with significant impact for calendar years 2001 to 2017

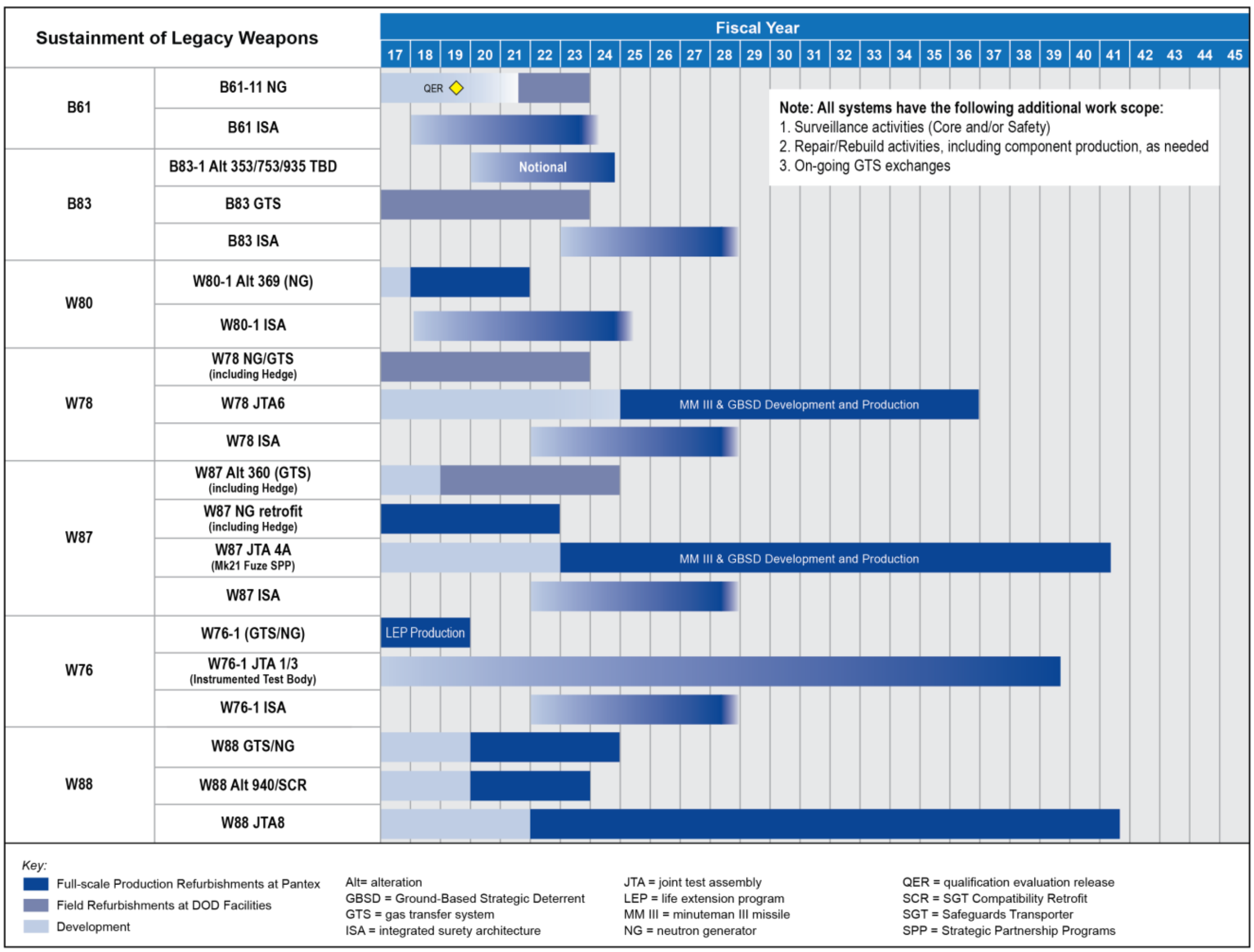


Figure 2–2. Sustainment of legacy weapons

2.2.4.1 Gas Transfer Systems

Status

Tritium-filled GTSs are designed, produced, filled, and delivered to DOD for existing and future weapon systems. SNL and LANL have the design agency role, while the Kansas City National Security Campus (KCNSC) is the manufacturer. Modern GTS designs have extended LLC intervals and have increased the weapon performance margin, thereby improving maintenance efficiency and enhancing weapon safety and reliability. LANL conducts function testing of preproduction development hardware at the Weapons Engineering Tritium Facility to validate the performance characteristics and provide tritium R&D to inform GTS designs supporting the current and future stockpile. The Savannah River National Laboratory at SRS works closely with SNL and LANL to evaluate new GTS designs and verify that the GTSs can be loaded in the production facilities and meet weapons systems performance characteristics. In parallel with R&D efforts, SRS maintains production facilities for tritium-loading operations, GTS surveillance, and tritium recovery from end-of-life GTSs. SRS is the only location in the enterprise for GTS tritium operations and is the primary source for tritium R&D. The supply of tritium to fill reservoirs is discussed further in Section 2.4.5.1, "Tritium Supply, Recovery, and Recycle."

Challenges

Formal risk analyses indicate that deterioration of infrastructure and programmatic equipment is a primary risk to the continuity of SRS' efforts. To meet increasing program schedules and requirements, production and infrastructure capability and capacity at SRS and KCNSC must be increased. Increased volume also requires large increases in technical staffing levels, which is complicated by extended clearance times. DOE/NNSA faces infrastructure challenges in aging facilities, as well as evolving requirements that affect facility modifications.

Long-Term Sustainment Strategy

SRS will maintain both production and R&D capabilities by (1) refurbishing or constructing more capable R&D, (2) recapitalizing the existing process equipment and infrastructure, and (3) fully replacing some production facilities through line-item construction, such as the Tritium Production Capability. To address capacity, SRS will modify the process and infrastructure equipment in multiple facilities by FY 2020 and has requested additional staff for some production and infrastructure areas. For example, in FY 2016, SRS started a project to establish a new capability to unload GTSs more efficiently from currently fielded and future LEPs.

KCNSC is executing a plan to increase capacity by replacing and adding additional multi-axis machines and replacing other machining in key areas.

2.2.4.2 Power Sources

Status

All legacy and planned nuclear weapons, as well as life-extended warheads, require compact, high-powered, highly variable power sources that are reliable for multi-decadal lifetimes. Requirements for size, weight, long life, responsiveness, and output are unique to nuclear weapon applications. In general, such devices are not available via commercial vendors. The capability to produce these devices also supports other national security missions that require advanced power sources with similarly stringent requirements. In addition to prototyping and parts development, this capability includes the full life cycle requirements of power source components through early-stage R&D and modeling, technology maturation, design and development, production, surveillance, and disassembly.

Challenges

SNL has primary production responsibility for power source components. SNL's power sources capability includes research, design, production, and surveillance activities. The facility housing the power sources capability was not originally built for this purpose, is well beyond its design life, and does not meet evolving mission needs and modern building code requirements. Corrective measures and modifications have been employed to convert the facility to meet evolving mission requirements, but the investments are not cost-effective, resulting in the need for an alternative solution. New facilities and infrastructure are required to meet the long-term, full life cycle requirements. Instabilities in the supplier base have also put the primary production capability at risk, and facility inadequacies put SNL's RDT&E and production capabilities at an elevated risk of not meeting the mission.

Long-Term Sustainment Strategy

To address the current, inadequate facility, SNL is working with DOE/NNSA to relocate the power sources capability to a new facility, the cost of which is incorporated within the FYNSP planning period.

2.2.4.3 Neutron Generators

Status

Neutron generators are highly complex LLCs that provide neutrons at specific timing and rates to initiate weapon function. SNL's Neutron Generator Enterprise, which is an integrated national security laboratory and nuclear weapons production facility, manages the entire life cycle of neutron generators to meet NNSA's commitments, including scientific understanding through design, development, qualification, production, surveillance, dismantlement, and disposal.

Challenges

Aging facilities, infrastructure, and equipment are the primary challenges to sustaining neutron generator production. Near-term investments will focus on sustainment through recapitalization of existing facilities, infrastructure, and equipment, while making incremental improvements in process efficiency and cleanliness.

Long-Term Sustainment Strategy

SNL's Neutron Generator Enterprise is conducting formal planning to establish long-term capabilities that will ensure mission deliverables are met while allowing consolidation, increased flexibility, and expanded capabilities. These improvements include clean room enhancements, advanced additive manufacturing, increased use of automation, and streamlined safety and security management.

2.2.5 Weapons Dismantlement and Disposition

The Weapons Dismantlement and Disposition Program takes retired weapons[2] and disassembles them into their major components. Those components are then assigned for reuse, storage, surveillance, or disposal. Dismantlement of retired nuclear weapons is scheduled to provide material and components for the stockpile (including LEPs) and external customers, to maintain the proficiency of technicians, and to balance the work scope at the nuclear weapons production facilities.

Dismantlement rates are affected by many factors, including, logistics, legislation, weapon system complexity, and the availability of qualified personnel, equipment, and facilities. DOE/NNSA's current dismantlement plan balances these constraints while maintaining strict adherence to the funding and schedule limits initiated in the *National Defense Authorization Act* (NDAA) *for Fiscal Year 2017*, and

[2] Retired weapons are no longer part of the stockpile because of changes in military requirements or surveillance evaluations.

continued in the FY 2018 NDAA, which cap Weapon Dismantlement and Disposition funding through FY 2021 and limit the rate of dismantlements to that described in the FY 2016 SSMP. Chapter 3, Section 3.25, "Weapon System Assembly and Disassembly," has more detail on the status of the equipment and facilities required to conduct Weapon Dismantlement and Disposition activities.

2.3 Modernizing and Sustaining the Stockpile

As weapons systems age or issues arise through SFIs or other assessments, sustainment activities may warrant LEPs, Alts, or Mods to address material aging or performance issues, enhance safety features, and improve security. New technologies are typically more modern than those they replace and are developed and matured as part of NNSA's *Phase 6.x Process*.[3] These modernization programs are described below.

- **Life Extension Programs**. An LEP is intended to evaluate an entire weapon system and refurbish, reuse, or replace components to extend the service life of a warhead while increasing safety and improving security. LEPs require routine Selected Acquisition Reports (SARs) to Congress.
- **Alterations**. An Alt is a material change to, or a prescribed inspection of, a nuclear weapon or major assembly that does not alter its operational capability but is sufficiently important to the user regarding assembly, maintenance, storage, or test operations to require controlled application and identification. Minor Alts are less intrusive, less costly changes that are performed on a priority basis; major Alts are governed by the *Phase 6.x Process* and require an SAR to Congress.
- **Modifications**. A Mod is a change to a major assembly that alters the nuclear weapon's operational capabilities. This change involves the user and requires positive control to ensure that an operational capability is clearly defined. A change in operational capability results from a design change that affects delivery (employment or utilization), fuzing, ballistics, or logistics.

NNSA activities for LEPs and major Alts of specific weapons are illustrated in **Figure 2–3**.

2.3.1 W76 LEP

2.3.1.1 W76-1 LEP

The W76-1 LEP extends the original W76-0 warhead service life. The W76-1 first production unit was completed in September 2008, and the first delivery of refurbished warheads to the Navy, using the original W76-0 pits, was in FY 2009. The last production unit is scheduled for delivery no later than the end of FY 2019. The program is making all warhead deliveries to the Navy on schedule and under budget.

Status

According to the current program of record, as of the end of June 2018, NNSA had delivered more than 90 percent of the total production units to the Navy. In FY 2018, Pantex remains on track to meet the cumulative warhead production and delivery requirements.

[3] Since the cessation of nuclear testing, NNSA spends the vast majority of its time and effort in Phase 6 of the life-cycle. The *Phase 6.X Process* provides the framework for modern stockpile sustainment activities and each subphase of the process mirrors the life-cycle phases shown below. The *Phase 6.X Process* activities are for non-routine nuclear weapon Alts at the system, subsystem, or component level; LEPs; and other warhead modernization activities, while the life-cycle phases below are associated with weapon introduction into the stockpile through retirement. The *Phase 6.X Process* is not intended to replace established Phase 6 activities such as routine maintenance, stockpile evaluation, enhanced surveillance, and annual assessment.

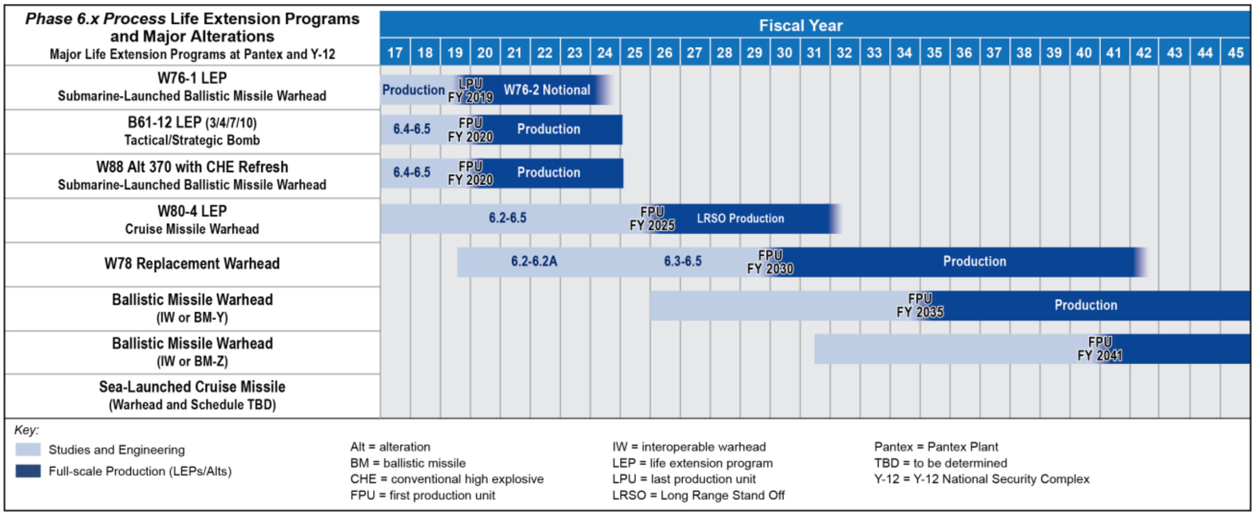


Figure 2–3. National Nuclear Security Administration warhead activities

The deliverables for the W76-1 LEP through the end of full production are as follows:

- Achieve or exceed annual refurbished warhead production rates at Pantex.
- Deliver the refurbished warheads on schedule to the Navy.
- Produce and deliver JTAs for surveillance flight tests.
- Execute retrofit evaluation system test and stockpile surveillance activities to facilitate completion of annual assessment and weapon reliability activities.

Challenges

During FY 2018, the following areas challenged DOE/NNSA's ability to meet its warhead production and delivery commitments to the Navy:

- Technical issues associated with production of various warhead components.
- Failure of aging production equipment and facility infrastructure.

Despite these challenges, DOE/NNSA is meeting its FY 2018 requirements and cumulative warhead production schedule.

Mitigations/Strategies

Multiple strategies and approaches were used to mitigate program risk associated with production and delivery challenges, including the following:

- Strategic acceleration of raw material procurement.
- Increased component production quantities to provide a positive margin for component delivery schedules.
- Procurement of new production equipment to mitigate against aging and single-point failures.
- Use of production efficiencies to reduce program costs and gain a positive schedule margin.

2.3.1.2 W76-2

NNSA will support the Low Yield Ballistic Missile, as stated in the 2018 *Nuclear Posture Review*. While NNSA awaits congressional appropriations to implement the W76-2 program, it has examined notional manufacturing plans to de-conflict with other major weapon modernization programs.

2.3.2 B83-1 Alt 353 and Alt 753 Strategic Bomb

The B83-1 gravity bomb holds at risk a variety of protected targets. The 2018 *Nuclear Posture Review* directs sustaining the B83-1 past its current planned retirement date until a suitable replacement is identified. NNSA is coordinating with DOD to determine the period for sustaining the B83-1 and the schedule for restarting limited Alt 353 and Alt 753 programs if necessary.

2.3.3 B61-12 LEP

The B61 gravity bomb is the oldest nuclear weapon in the stockpile. The B61-12 LEP addresses multiple components that are nearing end of life, as well as military requirements for reliability, service life, field maintenance, safety, and use control. The life extension scope includes refurbishment of both nuclear and non-nuclear components and incorporates component reuse where possible. With the addition of an Air Force-procured tailkit assembly, the B61-12 LEP will consolidate and replace the B61-3, -4, -7, and -10 bomb variants, to reduce the overall number of gravity bombs.

Status

As of March 2018, the program continues in Phase 6.4, which is the final development phase prior to production of War Reserve units. The B61-12 LEP has completed final design reviews of major components to allow the DOE/NNSA nuclear weapons production facilities to begin final Process Prove-In of the production processes. Qualification of component production processes, including certified tooling and testers, is scheduled to continue in FY 2018. This qualification will enable the nuclear weapons production facilities to begin shipment of first production units for components to Pantex in FY 2019. System qualification of the B61-12 continues on schedule with the completion of over 45 system tests since the start of Phase 6.4, including seven qualification flight test releases using F-16 and F-15 aircraft at the Tonopah Test Range. Certification activities that the weapon meets DOD requirements, such as joint qualification activities and testing, will continue to support the program as it moves to the first production unit, Phase 6.5 (expected in March 2020).

The B61-12 LEP is executing within the cost documented in the December 2017 Baseline Cost Report, which estimated program costs at $7.605 billion (then-year dollars). The B61-12 LEP is continuing to leverage other DOE/NNSA programs for multi-system production process improvements. The costs of these related programs are estimated to be $648 million. The overall program cost is $8.253 billion, which is within 1.1 percent of the initial baseline SAR that was provided to Congress in FY 2013.

Challenges

Risks for the B61-12 LEP are similar to those for other LEPs and major Alts; these risks include late component design changes in Phase 6.4, integration risks with Air Force systems, and delayed deliverables from other programs needed for the B61-12.

Mitigations/Strategies

DOE/NNSA closely monitors component development and schedule progress with Air Force partners to manage any design changes and minimize impacts to the schedule. DOE/NNSA also manages all programs closely to understand any impacts to B61-12 deliverables.

2.3.4 W88 Alt 370

The W88 Alt 370 includes a new arming, fuzing, and firing (AF&F) system, conventional high explosive (CHE) refresh to replace the main HE charges, a lightning arrestor connector, trainers, flight test assemblies, and associated handling gear. The late addition of the CHE refresh required acceleration and compression of the design and development activities in the late stages of Phase 6.3. This was required to align with the original Alt 370 scope by Phase 6.4 (Production Engineering). The W88 Alt 370 conversion is scheduled concurrent with LLC exchanges of the GTSs and neutron generators.

Status

The W88 Alt 370 program is now in Phase 6.4 and on schedule for the first production unit by the first quarter of FY 2020. The Follow-on Commander's Evaluation Test-53) flight test and the critical system-level and AF&F tests were completed in 2017. Final development testing (Commander's Evaluation Test-1) is scheduled for FY 2018, with remaining qualification flights planned for FY 2019. The remaining hydrodynamic tests for the program are planned in FY 2018. The last Final Design Reviews were completed early in FY 2018; most components have begun Process Prove-In builds, and Production Readiness Reviews have been conducted.

DOE/NNSA completed a high-fidelity cost estimate (the Baseline Cost Report) in FY 2017. The report estimate is $2,618 million; which is approximately $255 million (or 11 percent) higher than the estimate in the 2015 SAR. The increased costs were primarily caused by increased testing and qualification, as well as planning margins for treating technical risks, accompanied by some offsetting reduction in the scope associated with the nuclear components. This estimate represents the program baseline and is reflected in the FY 2017 SAR.

Challenges

The W88 Alt 370 faces a continued risk of late component design changes in Phase 6.4. As an integrated program with shared technology between the Air Force and Navy, changes or delays to one program may directly impact progress on the other.

Mitigations/Strategies

DOE/NNSA closely aligns efforts on the W88 Alt 370 Program with those of its DOD partners to manage design changes and minimize production impacts. This close collaboration ensures scope, schedule, and cost decisions are aligned with strategic-level priorities.

2.3.5 W80-4 LEP

DOD intends to replace the aging air-launched cruise missile with the Long Range Stand Off (LRSO) missile in order to maintain the bomber force's vital stand-off weapon deterrent capability. In close coordination with DOD, DOE/NNSA is extending the W80 warhead through this LEP for use in the LRSO missile.

Status

The W80-4 LEP is currently in Phase 6.2A (Design Definition and Cost Study), during which the design will continue to be refined and the DOE/NNSA team will continue working closely with the LRSO missile development team and contractors. The primary Phase 6.2A deliverable will be the W80-4 LEP Weapon Design and Cost Report, which will describe a bottom-up planning baseline used to further inform DOE/NNSA and stakeholder decisions and integration with LRSO missile development.

Challenges

The program faces the unique risk of a parallel design with the Air Force LRSO weapon. This is the first effort in more than 30 years to design a warhead and delivery platform on similar timeframes. Changes or delays to either program may directly affect progress on the other. The W80-4 LEP has experienced a loss of $120 million in productivity due to delays associated with Continuing Resolutions since the beginning of FY 2016. As a result, ramp-up of management and operating program staffing was constrained for 3 years across the entire nuclear security enterprise, preventing the program from reaching the required staffing levels and affecting the Federal program office's ability to complete Phases 6.2 and 6.2A on schedule (a 4-month delay).

Mitigations/Strategies

DOE/NNSA closely aligns W80-4 LEP efforts with those of DOD to refine program goals and define the interface scope in detail. This collaboration ensures coordinated cost-informed decisions and inter-departmental schedule alignment. Component product realization teams have completed Component Scope and Requirements Exchange between national security laboratories and nuclear weapons production sites. This early engagement increases the effectiveness of the product realization teams and reduces risks when combined with application of lessons learned from other programs.

2.3.6 W78 Replacement Warhead (Formerly Interoperable Warhead 1)

In FY 2014, the W78 Replacement Warhead program's planned first production unit milestone was delayed from FY 2025 to FY 2030. Phase 6.2 activities were suspended, but are now scheduled to restart in FY 2019. The program objective is to develop and produce W78 Replacement Warheads for use in the Mk21 aeroshell and investigate the feasibility of fielding the nuclear explosive package in a Navy aeroshell.

Challenges

Three main challenges face the W78 Replacement Warhead program:

- Development must be integrated with potentially two service aeroshell acquisition schedules, as well as the Ground-Based Strategic Deterrent delivery platform acquisition program.
- Production is predicated on all newly manufactured components and a nuclear material manufacturing modernization strategy that relies on large, multi-year investments in component and material capabilities.
- Program success is contingent on the development of new technologies to address antiquated design, material obsolescence, and performance expectations. Additionally, the W78 Replacement Warhead program must meet stringent technical requirements, including a greater component life expectancy, as well as expectations such as reduced manufacturing cost and development time, increased safety and security, and improved maintainability.

Mitigations/Strategies

To mitigate these challenges, DOE/NNSA:

- Has established early integration and communication with both the Air Force and Navy to coordinate strategic planning;
- Has actively supported commodity and capability programs that will provide the materials, components, and capabilities in-time for the future stockpile;

- Is working on a technology readiness assessment for the W78 Replacement Warhead that helps identify the technology development elements and processes required to reach proven maturity levels; and,
- Is incorporating lessons learned from previous LEPs and major modernization programs in W78 Replacement Warhead program documents, including the W78 Replacement Program Plan, Requirements Management Plan, Risk Management Plan, Configuration Management Plan, System Engineering Plan, Integrated Phase Gate Plan, Program Protection Plan, and Program Control Plan.

2.3.7 Ballistic Missile Warhead (IW or BM-Y) and Ballistic Missile Warhead (IW or BM-Z)

DOD and NNSA will leverage the interoperability considerations associated with the W78 Replacement Warhead for development of follow-on ballistic missile systems.

2.3.8 Sea-Launched Cruise Missile

NNSA will support the Sea-Launched Cruise Missile Analysis of Alternatives (AoA), as requested by DOD. NNSA will support these efforts through the Nuclear Weapons Council, but will not create a formal program until the AoA is concluded.

2.4 Strategic Materials

Strategic materials are key to ensuring the safety, security, and effectiveness of the Nation's nuclear deterrent, as well as addressing national security concerns such as nuclear proliferation and terrorism. Sustaining the capabilities to store and process these materials requires a highly skilled workforce and significant programmatic infrastructure. Weapons and test components created with these strategic materials generally cannot be produced outside the United States. In addition to managing individual materials, DOE/NNSA is responsible for planning, prioritizing, and supplying the required quantities of materials by recycling, recovering, and storing nuclear and select non-nuclear material for nuclear security missions. DOE/NNSA has long-term plans to maintain the facilities, scientific equipment, production capabilities, and manpower to sustain the supply of strategic materials. A common obstacle is the need to refurbish or replace the aging and obsolete facilities where these materials are handled. The strategies presented below for the individual materials and supporting programs outline solutions to such challenges or offer bridging strategies to manage implementation of capability investments. A detailed look at NNSA's strategic material capabilities is provided in Chapter 3, Sections 3.20 through 3.22.

2.4.1 Plutonium

Status

An agile, reliable, and flexible capability to process and handle plutonium is essential to assess and maintain a credible nuclear weapons stockpile. Plutonium requires proper storage facilities, safe and secure disposal pathways, and unique equipment and facilities. The manufacture and surveillance of pits and other plutonium components, as well as experiments and analysis of plutonium alloys, currently occur at LANL's Plutonium Facility (PF-4). SNL, LLNL, Pantex, and the Nevada National Security Site also provide critical expertise, capabilities, and facilities to support DOE/NNSA's defense-related plutonium missions. DOE/NNSA evaluated its options to achieve long-term sustained production levels of no fewer than 80 pits per year in 2030. On May 10, 2018, the Administrator informed Congress that NNSA's recommended alternative is to repurpose the SRS Mixed Oxide Fuel Fabrication Facility to produce 50 War Reserve plutonium pits per year in 2030, while maximizing pit production at LANL to produce at least 30 pits per year by 2026.

Challenges

DOE/NNSA faces several plutonium challenges. DOE/NNSA must ramp up pit production over the next decade to meet a capacity of 80 pits per year in FY 2030. The current schedule includes a War Reserve first production unit in FY 2023, building to a production capability of 10, 20, and 30 War Reserve pits per year in 2024, 2025, and 2026, respectively. Meeting these deliverables remains a challenge as DOE/NNSA continues to re-optimize existing available space and invest in manufacturing equipment, associated facilities, and staff. DOE/NNSA also faces space challenges caused by the need to store retired pits and the aging Cold War-era infrastructure. A detailed description of DOE/NNSA's plutonium challenges is provided in Chapter 3, Section 3.21.1.

Mitigations/Strategies

DOE/NNSA will continue to invest in PF-4 to establish an enduring 30-pits-per-year production capability at LANL by FY 2026 and will maintain LANL as the Nation's Plutonium Center of Excellence for Research and Development. To evaluate options in meeting the additional high-hazard, high-security space requirements and sustain long-term production levels of no fewer than 80 pits per year in 2030, DOE/NNSA completed a formal AoA in October 2017, as well as an engineering assessment and workforce analyses. These results informed the decision to repurpose the Mixed Oxide Fuel Fabrication Facility for pit production and assess opportunities for LANL to produce more than 30 pits per year. DOE/NNSA is addressing plutonium infrastructure challenges through construction projects such as the Chemistry and Metallurgy Research Replacement Facility and is modernizing waste processing and treatment facilities through recapitalization and line-item projects, including the Technical Area (TA)-55 Reinvestment Project, Radiological Liquid Waste Treatment Facility Project, and Transuranic (TRU) Waste Facility Project.

2.4.2 Uranium

Uranium is a strategic national defense asset with different enrichments (depleted uranium, low-enriched uranium, and highly enriched uranium) used for a wide variety of applications, including weapon components, naval reactors, and commercial power reactors for the production of tritium. The primary production infrastructure to process and store uranium is at Y-12, with R&D capabilities at LANL and LLNL. A detailed discussion of DOE/NNSA's uranium efforts is in Chapter 3, Section 3.21.2.

Status

DOE/NNSA's uranium processing infrastructure faces significant challenges as a result of age. DOE/NNSA is implementing the Building 9212 Exit Strategy to phase out mission dependency on this building. In phasing out mission dependency on Building 9212, DOE/NNSA is enacting a series of enriched uranium capability relocations into other Y-12 facilities, investing in modernization projects, and constructing the Uranium Processing Facility. The facility is slated to achieve Critical Decision 4 (CD-4; Approve Start of Operations or Project Completion) by the end of FY 2025. Existing processes are slated to be simplified or eliminated to increase safety and efficiency, and new technologies will be deployed.

Challenges

DOE/NNSA's uranium challenges primarily involve transition of enriched uranium capabilities into existing and new-build facilities. This transition involves implementing the Building 9212 Exit Strategy to shut down Building 9212's production processes, drain and isolate systems, and facilitate post-operations cleanout of the facility. DOE/NNSA must extend the life of other Y-12 facilities while the Uranium Processing Facility is constructed to contain processes that cannot be transferred to another facility. DOE/NNSA also faces challenges in maintaining subject matter expertise at the national security laboratories in base R&D capabilities and production support, as a result of retirements combined with industry competition for a small pool of highly skilled, technical employees.

Mitigations/Strategies

DOE/NNSA is maintaining direct communications with Y-12, LANL, and LLNL to support accomplishment of the overall mission while closely tracking the progress of construction and relocation activities. DOE/NNSA is continuing to advance technologies currently planned for deployment in the field, as well as technologies required to meet future mission needs.

2.4.3 Depleted Uranium

Depleted uranium is a byproduct of the enrichment process that has a lower ratio of uranium-235 to uranium-238 than naturally occurring uranium. DOE/NNSA has a long-term requirement for high-purity depleted uranium feedstock to meet national security needs.

Status

DOE/NNSA is currently exhausting usable inventories of high-purity depleted uranium metal feedstock. While DOE/NNSA has a large quantity in the form of depleted uranium hexafluoride (DUF_6) gas, there is no capability to convert the gas to the depleted uranium tetrafluoride (DUF_4) that provides feedstock material for conversion to depleted uranium metal. DOE/NNSA will work to re-establish this capability beginning in FY 2019. NNSA published the Depleted Uranium/Binary Strategy in September 2017, outlining the plan to maintain this material, and held a Depleted Uranium Strategy meeting in February 2018 to discuss updates to the depleted uranium supply and demand model, validation of material requirements, technologies to meet future mission needs, and the status of legacy processes at Y-12.

Challenges

DOE/NNSA estimates a shortfall of usable depleted uranium in the 2029 to 2031 timeframe and must adjust accordingly.

Mitigations/Strategies

DOE/NNSA continues to advance technologies currently planned for deployment in the field, as well as technologies that will be required to meet future mission needs. DOE/NNSA is investigating alternative processes and technology improvements to increase the efficiency of traditional manufacturing processes.[4] After evaluating various options for re-establishment of the capability to convert DUF_6, DOE/NNSA plans to begin re-establishment in FY 2019.

2.4.4 Uranium (Domestic Uranium Enrichment)

Enriched uranium contains higher concentrations of the fissile uranium-235 isotope than natural uranium and is required at various levels of enrichment and forms for national security missions. Domestic uranium enrichment provides a reliable supply of enriched uranium.

[4] The majority of this work is funded by the Material Recycle and Recovery Program and Storage Program.

Status

The U.S. Government currently has no uranium enrichment capability. Mission needs for enriched uranium are currently fulfilled via the United States' remaining highly enriched uranium stockpile, which is a finite, currently irreplaceable source. DOE/NNSA is funding two centrifuge R&D programs for potential deployment in an enrichment facility.

Challenges

Construction of an enrichment facility would carry a large budgetary requirement around the same time that DOE/NNSA is engaged in other large-scale construction projects to maintain strategic materials capabilities.

Mitigations/Strategies

DOE/NNSA established CD-0 (Approve Mission Need) in December 2016 and began an AoA in August 2017. DOE/NNSA is on schedule to re-establish a domestic uranium enrichment capability for future national security needs.

2.4.5 Tritium

Tritium, a critical component for the functioning of the pits in the stockpile, reaches the pit through a GTS. Because tritium decays at 5.5 percent per year, GTSs are considered LLCs. Each system must be regularly cycled through SRS's tritium facilities for tritium to be recovered and recycled once the system reaches its end of life. New GTSs are filled and sent back to the military (or Pantex) to meet LLC exchange schedules.

To maintain these LLCs, an inventory of tritium is maintained at SRS's tritium facilities. Outlined below are the two sources of tritium that maintain this inventory: (1) recovery and recycle and (2) production via irradiation of lithium targets. DOE/NNSA's tritium capability is further discussed in Chapter 3, Section 3.22.

2.4.5.1 Tritium Sustainment, Recovery, and Recycle

Status

DOE/NNSA's ability to process tritium and fill reservoirs is sufficient for the current stockpile. However, DOE/NNSA is evaluating future tritium supply to support the complex system designs and concurrent production of multiple weapon systems described in the 2018 *Nuclear Posture Review*. Because of current processing technology, a significant amount of tritium is obligated to maintain production/loading system functionality and is not available for GTS loading. Recapitalization efforts are necessary to sustain processing capabilities and are often competing with other program priorities. Alternative concepts are being evaluated to determine whether the system can be made more efficient to free this obligated tritium without interrupting production. Other aspects of tritium processing (purification and separation of hydrogen isotopes) meet current demand. However, alternative technologies, materials, and equipment may also provide cost benefits and efficiencies for continuous tritium processing and handling in the future.

Challenges

DOE/NNSA faces a number of challenges, such as:

- An aging infrastructure that must be maintained to last year's beyond designed life status.
- Availability of unique equipment and qualified vendors to deal with low molecular weight materials, such as hydrogen isotopes.
- Retention of specialized staff.

Mitigations/Strategies

DOE/NNSA is working to develop appropriate commercial supply chains, assess procurement processes to aid in retaining the tritium supplier base, and the ability to refurbish and replace unique equipment. DOE/NNSA is also working to establish pathways with local educational institutions for training and hiring personnel while exploring and developing new strategies for training and retaining experienced staff.

2.4.5.2 Tritium Production

Status

DOE/NNSA is meeting its production goals. The tritium production goals in the 2015 Baseline Change Proposal were independently certified by the Nuclear Weapons Council, as requested by Congress. The Baseline Change Proposal increased tritium production requirements from approximately 1,700 grams to 2,800 grams per 18-month cycle by 2025, which necessitates the use of two reactors.

Challenges

DOE/NNSA must demonstrate the ability to produce 2,800 grams of tritium per cycle by 2025 and faces challenges in leveraging a declining nuclear industrial base, a result of the decreased status of nuclear power in the U.S. energy market. DOE/NNSA will monitor the nuclear industry as it evolves and will explore its options amid a high degree of uncertainty.

Mitigations/Strategies

DOE/NNSA is working to maximize tritium production as tritium-producing burnable absorber rod production increases and to monitor programmatic risk to ensure the supply chains are sustainable. DOE/NNSA is preparing for the future by considering tritium production alternatives beyond 2040. While there are a range of options, such as building new reactors or extending their licensing of existing reactors, strategies will depend on where the commercial nuclear industry stands at that time.

2.4.6 Lithium

DOE/NNSA uses lithium to manufacture nuclear weapon components and supplies lithium to the Department of Homeland Security, the DOE Office of Science, and others. More detailed information on DOE/NNSA's lithium efforts is contained in Chapter 3, Section 3.20.4.

Status

DOE/NNSA has completed a formal AoA for a new lithium production capability and started work on CD-1 (Approve Alternative Selection and Cost Range). CD-4 (Approve Start of Operations or Project Completion) is slated for 2027. DOE/NNSA has also updated the Lithium Strategy Document and developed the Lithium Technology Maturation Plan. To introduce efficiencies into the current process and prepare for the lithium production capability, DOE/NNSA has completed a Technology Readiness Assessment for lithium purification and production technologies.

Challenges

The United States no longer maintains full lithium purification capabilities and relies on recycling as its primary source of lithium for weapon systems. At 75 years old, the current lithium processing facility at Y-12 is one of the oldest operating facilities in the nuclear security enterprise. Until a new lithium production capability is operational, much of the risk to lithium sustainment is associated with the age of the existing facility.

Mitigations/Strategies

DOE/NNSA will continue using the current lithium processing facility and equipment to meet near-term stockpile needs while implementing a lithium bridging strategy and establishing a new lithium production capability to address long-term capability requirements. DOE/NNSA has identified a number of weapons systems and canned subassembly inventories that can serve as a source for recycled lithium for future LEP use, once certified by LANL and LLNL. DOE/NNSA will also take steps to upgrade the lithium facility and develop and mature new purification and production technologies to make the current process more efficient. These technologies will be used as part of the new lithium production capability when operational.

2.4.7 Material Recycle and Recovery and Storage

The MRR and Storage programs are integral to strategic materials sustainment. With materials recycled from assembly operations, LLCs, and weapons dismantlement, the MRR program provides vital quantities of strategic materials (i.e., plutonium, uranium, lithium, and tritium) to sustain the Nation's nuclear deterrent. Using these recycled materials allows the nuclear security enterprise to forego the expense of producing new quantities of these materials. The MRR and Storage programs interface closely with other programmatic work scopes. These interfaces directly support the Federal managers for sustainment of tritium, uranium, plutonium and for the proposed lithium sustainment, as well as LEPs and weapons dismantlement and disposition. The following important efforts are overseen by the MRR and Storage programs:

- De-inventory of LANL's Chemistry and Metallurgy Research and PF-4 vault facilities.
- Re-establishment of the capability to deliver high-purity depleted uranium feedstock.
- Production of purified lithium metal at Y-12.
- Recycle, recovery, and purification of tritium after LLC unloading to enable loading the gas into GTSs.

The Storage program manages materials storage by providing receipt costs, inventory logistics for nuclear and non-nuclear materials, surveillance, and storage of dismantled warhead components.

Status

The nuclear security enterprise's recent efforts in these areas include the following:

- SRS completed tritium recycle and recovery activities ahead of schedule in support of mission requirements and improved its operational interface with DOE's Office of Science.
- Y-12 demonstrated the ability to increase production of purified enriched uranium metal to meet Defense Programs requirements, replenished the purified metal working inventory, and provided a risk mitigation inventory.
- Y-12 continued to minimize technology risk on the production microwave with the completion of a carbon reduction study report.
- Y-12 reduced the Storage program's operational risk by improving consumables inventory management (e.g., use of a rackable can storage box); by re-containerizing 120 carbon steel cans in support of a Defense Board commitment to remove all such cans from long-term storage in the Highly Enriched Uranium Materials Facility; and by continuing improvements in non-enriched uranium storage areas.

- LANL's first waste shipment to the Waste Isolation Pilot Plant (WIPP) since its reopening occurred on November 16, 2017, using the Mobile Loading Unit at TA-55. The first shipment of four waste drums from TA-55 to the TRU Waste Facility occurred in the week of October 10, 2017. As of March 30, 2018, 28 transuranic drums have been shipped to the TRU Waste Facility. It is expected that the operational tempo will increase to a level sustaining operational needs.
- LANL performed significant work on risk reduction activities and vault material disposition, including the reduction of material-at-risk on the LANL PF-4 main floor and implementing a push inventory management tool for transuranic waste to ensure efficient supply chain management.
- LANL's Storage program installed equipment to better evaluate container performance and support reducing the risk of employee exposure.
- Pantex deployed the Laser Gas Sampling Station II in FY 2017. Completion of full qualification across all active stockpile pits is planned in FY 2018. CoLOSSIS II (Confined Large Optical Scintillator Screen and Imaging System) was installed in FY 2017; qualification and authorization is planned in the fourth quarter of FY 2018. Pantex, in coordination with LLNL, demonstrated significant diagnostic capability sustainment and improvement with the installation of the CoLOSSIS II equipment.
- The Nevada National Security Site's Storage program reduced operational risk through an accelerated effort to characterize legacy items.

Challenges

DOE/NNSA faces storage capacity constraints and competing demands, especially for plutonium and transuranic waste. LANL's recently operational TRU Waste Facility is essential for providing waste staging capacity until WIPP begins accepting full shipments from LANL. DOE/NNSA must also re-establish a capability to produce depleted uranium and depleted uranium-alloyed feedstock and effectively and efficiently execute the recapitalization efforts necessary to sustain its processing and storage capabilities.

Mitigations/Strategies

DOE/NNSA will continue its strategy to repurpose and reconfigure nuclear material bays to stage plutonium pits until a long-term staging facility is available. The proposed Material Staging Facility at Pantex is a potential solution that has recently completed CD-0 (Approve Mission Need). LANL has developed a strategic plan to manage transuranic waste until WIPP is fully operational. LANL's TRU Waste Facility will help maintain storage in the meantime. Initial, critical, high-priority shipments to WIPP have begun, although full shipments will not resume until FY 2023, when a new ventilation system will be installed and operational. The sites have already initiated comprehensive assessments of storage process health, and DOE/NNSA will begin to establish a depleted uranium capability in FY 2019. DOE/NNSA sites are working to develop comprehensive recapitalization plans to sustain their processing and storage facilities, including hydride storage for tritium operations at SRS and reducing the dependence on Building 9212 at Y-12.

Chapter 3
Capabilities That Support the Nuclear Security Enterprise

DOD and DOE/NNSA together deliver the capabilities required to ensure an effective nuclear deterrent that will provide the Nation with the ability to adapt and respond to a dynamic security environment, emerging strategic challenges, and geopolitical and technological surprises. Underpinning this responsibility for the deterrent is the technical expertise resident at DOE/NNSA's national laboratories, production sites, and Nevada National Security Site and the nuclear weapons infrastructure.

Capabilities that address critical elements of the life cycle of U.S. nuclear weapons are depicted in **Figure 3–1**. Each capability is complementary and supports multiple elements of the weapons life cycle. Continued investment is necessary to sustain and modernize nuclear weapons, improve understanding of nuclear weapons performance, maintain confidence in the aging and evolving stockpile, and ensure that the DOE/NNSA nuclear security enterprise remains responsive. Achievement of these capabilities occurs at appropriate levels, as defined by both the Nuclear Weapons Council and the interagency process that weighs and prioritizes missions and resources. Definitions for each of these capabilities can be found in Appendix C, "Weapons Activities Capabilities," while current resource prioritizations can be found in Chapter 4.

- Simulation Codes and Models
- High Performance Computing
- Nuclear Physics and Radiochemistry
- Atomic and Plasma Physics
- High Energy Density Physics
- Laser, Pulsed Power, and Accelerator Technology
- Advanced Experimental Diagnostics and Sensors
- Hydrodynamic and Subcritical Experiments
- Chemistry
- High Explosives Science and Engineering
- Materials Science and Engineering
- Weapon Physics Design and Analysis
- Weapons Engineering Design, Analysis, and Integration
- Environmental Effects Analysis, Testing, and Engineering Sciences
- Weapons Surety Design, Testing, Analysis, and Manufacturing
- Radiation-Hardened Microelectronics Design and Manufacturing
- Weapon Component and System Prototyping
- Advanced Manufacturing
- Weapon Component and Material Process Development
- Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Material
- Handling, Packaging, Processing, and Manufacturing of Special Nuclear Material
- Tritium Production, Handling, and Processing
- Metal and Organic Material Fabrication, Processing, and Manufacturing
- Non-Nuclear Weapon Component Manufacturing and Assembly
- Weapon System Assembly and Disassembly
- Testing Equipment Design and Fabrication
- Weapon Component and System Surveillance and Assessment
- Secure Transportation
- Physical Security
- Information Technology and Cybersecurity

Crosscuts: People, Infrastructure, and Management and Operations

Figure 3–1. Weapons Activities capabilities

From 1945 to 1991, U.S. nuclear warheads were designed, developed, produced, and deployed in the stockpile (usually for a period of 15 to 20 years) and then retired and dismantled to be replaced by new, more modern weapons that generally offered unique military capabilities and improved safety and security features. This continuous replacement cycle was used to ensure U.S. nuclear weapons exploited technological advances and optimized military performance.

In 1991, President George H. W. Bush announced the end of additional production of nuclear weapons consistent with the shutdown of the Rocky Flats Plant and a moratorium on nuclear explosive testing, which began in 1992 and has continued ever since. As a result, the nuclear weapons acquisition model was eventually supplanted by indefinite retention of the weapons in the legacy stockpile. To fulfill this mandate, stockpile life cycle strategies evolved to maintain an established stockpile of aging weapons through stockpile refurbishment life extension programs (LEPs). This evolution resulted in an increased focus (more than 90 percent of current weapons activities) on the Maintain, Assess, and Repair/Refurbish portions of the life cycle. Innovative science and engineering approaches to diagnose and analyze both the current state of nuclear weapons in the stockpile and the trajectory of weapons and components as they age have increased in importance. Since 2015, NNSA has worked to establish the congressionally mandated Stockpile Responsiveness Program to ensure that NNSA exercises and maintains the necessary capabilities to complete the full weapons life cycle illustrated in **Figure 3–2**.[1]

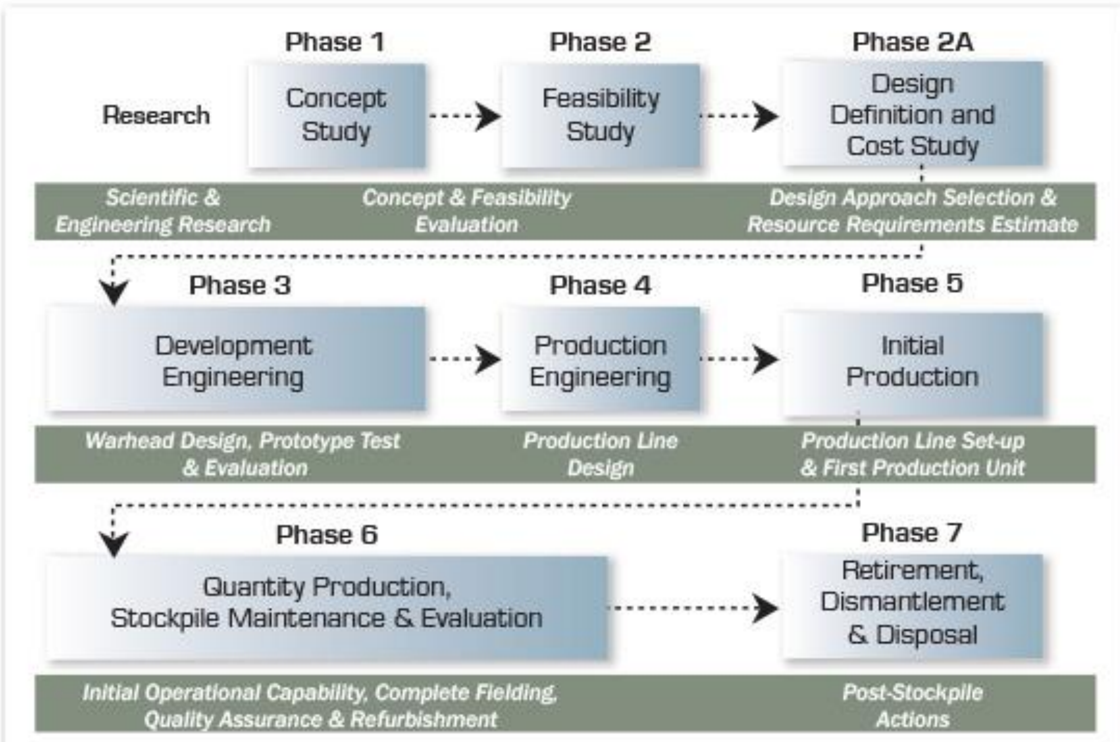


Figure 3–2. Joint DOD–DOE/NNSA nuclear weapons life-cycle phases

Figure 3–3 depicts the importance of each Weapon Activities capability for each phase of the nuclear weapon life cycle. Dark green signifies that a given capability is required to successfully complete that life cycle phase. Medium green signifies that a capability is important to the success of a life cycle phase. Light green signifies that a capability contributes less directly to a phase. Each capability is required for at least one phase. Some cross-cutting capabilities are required throughout the full life cycle, such as Physical Security, Information Technology and Cybersecurity, and Environmental Management. The level of importance of a capability in a particular phase may vary slightly depending on the scope of the work necessary for a given weapon system or situation, and the timing or preparation for work supporting a particular phase may occur in tandem with earlier design and implementation phases.

[1] Please refer to the *Nuclear Matters Handbook* for more information.

Capability	Phase 1 Concept Study	Phases 2 and 2A Feasibility Study, Design Definition & Cost Study	Phase 3 Development Engineering	Phases 4, 5, and Part of 6 Production Engineering, Initial Production, & Quantity Production	Part of Phase 6 Stockpile Maintenance & Evaluation (Certify & Assess)	Phase 7 Retire, Dismantle, Dispose
	Joint Nuclear Weapon Life Cycle Phases					
Simulation Codes and Models	Required	Required	Required	Important	Required	Contributes
High Performance Computing	Required	Required	Required	Important	Required	Contributes
Nuclear Physics and Radiochemistry	Contributes	Important	Important	Contributes	Required	Contributes
Atomic and Plasma Physics	Contributes	Important	Important	Contributes	Required	Contributes
High Energy Density Physics	Contributes	Important	Important	Contributes	Required	Contributes
Laser, Pulsed Power, and Accelerator Technology	Contributes	Important	Important	Contributes	Required	Contributes
Advanced Experimental Diagnostics and Sensors	Contributes	Important	Important	Important	Required	Contributes
Hydrodynamic and Subcritical Experiments	Contributes	Important	Required	Important	Required	Contributes
Chemistry	Contributes	Important	Required	Important	Required	Important
High Explosives Science and Engineering	Important	Important	Required	Important	Required	Important
Materials Science and Engineering	Important	Important	Required	Important	Required	Important
Weapon Physics Design and Analysis	Required	Required	Required	Important	Required	Contributes
Weapons Engineering Design, Analysis, and Integration	Required	Required	Required	Important	Required	Contributes
Environmental Effects Analysis, Testing, and Engineering Sciences	Important	Important	Required	Required	Required	Contributes
Weapons Surety Design, Testing, Analysis, and Manufacturing	Required	Required	Required	Required	Required	Important
Radiation-Hardened Microelectronics Design and Manufacturing	Contributes	Important	Required	Required	Important	Contributes
Weapon Component and System Prototyping	Important	Important	Required	Important	Contributes	Contributes
Advanced Manufacturing	Important	Important	Required	Important	Contributes	Contributes
Weapon Component and Material Process Development	Contributes	Important	Required	Important	Contributes	Contributes
Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Material	Contributes	Important	Required	Required	Important	Required
Handling, Packaging, Processing, and Manufacturing of Special Nuclear Material	Contributes	Important	Required	Required	Important	Required
Tritium Production, Handling, and Processing	Contributes	Important	Required	Required	Important	Required
Metal and Organic Material Fabrication, Processing, and Manufacturing	Contributes	Important	Required	Required	Contributes	Contributes
Non-Nuclear Weapon Component Manufacturing and Assembly	Contributes	Important	Required	Required	Contributes	Contributes
Weapon System Assembly and Disassembly	Contributes	Important	Required	Required	Important	Required
Testing Equipment Design and Fabrication	Contributes	Contributes	Required	Required	Required	Important
Weapon Component and System Surveillance and Assessment	Contributes	Contributes	Required	Contributes	Required	Important
Secure Transportation	Contributes	Contributes	Required	Required	Required	Required
Physical Security	Required	Required	Required	Required	Required	Required
Information Technology and Cybersecurity	Required	Required	Required	Required	Required	Required

Importance of Capability to the Process Step

Required for successful execution (Required) | Important for success (Important) | Contributes to success (Contributes)

Figure 3–3. Weapons Activities capabilities

People and Infrastructure

Providing the necessary capabilities to support all phases of the nuclear weapon life cycle depends on a workforce with specialized skills in a broad array of technical fields. Recruiting, retaining, and training the current and future workforce in essential areas of expertise are critical to mission delivery. Closely related to attracting and retaining the workforce is providing the specialized facilities and equipment needed to enable this workforce to deliver world-class work products using unique tools, platforms, and processes.

The workforce with the requisite skills (e.g., scientists, engineers, production personnel) and the associated facilities and equipment help to accomplish the following mission objectives:

- Sustain today's nuclear stockpile and ensure continued safety, security, and effectiveness.
- Extend the life of a select sub-set of nuclear warheads and design, develop, and produce nuclear weapons as needed for today and into the future.
- Assess and report annually whether the safety and reliability of the future nuclear stockpile can be assured in the absence of underground nuclear testing, and, as a safeguard, maintain a nuclear test capability.
- Maintain the capability to design, develop, certify, and produce nuclear warheads with new or different military capabilities if required in the future.
- Provide an effective response to technical problems with a warhead or to adverse geopolitical developments that call for force augmentation.

> *"There is now no margin for further delay in recapitalizing the physical infrastructure needed to produce strategic materials and components for U.S. nuclear weapons."*
>
> *Nuclear Posture Review, 2018*

Over the past several decades, the U.S. nuclear weapons infrastructure has suffered the effects of aging and underfunding. Previous Nuclear Posture Reviews highlighted the need to maintain a modern nuclear weapons infrastructure. To achieve this goal, DOE/NNSA developed a list of major programmatic facilities and major capital acquisition project proposals through the following efforts: the Master Asset Plan (MAP) Deep Dives, the Construction Working Group, and the Integrated Planning Group, which includes representatives from all of the sites and responsible Federal offices across DOE/NNSA. In 2018, there are almost 300 major programmatic facilities[2] with an average age of 44 years in operations. The current Weapons Activities program of record and program-vetted project proposals are the basis for NNSA's cost estimates for the addition of new capabilities and the sustainment of existing major facilities. NNSA will track the average age of major programmatic facilities from the FY 2019 SSMP onwards to judge the adequacy of the long-term infrastructure modernization plan. **Table 3–1** contains low- and high-estimate projections in then-year dollars for Weapon Activities major capital acquisition projects for the 25 years between FY 2019 and FY 2043. Several of these projects contain a high degree of scope and cost uncertainty, resulting in a wide cost range. Each capability will be evaluated for future need, and capabilities will be examined as resourcing decisions are made. Once NNSA conducts analyses of alternatives, some planned acquisitions may convert to alternate strategies to meet mission needs. These decisions could change projections. This year's SSMP "High" estimate benefits from three improvements to prior SSMP projection methodology:

[2] Major facilities are defined as those whose recapitalization, including equipment, will require line-item project(s) as cost estimates are greater than $20 million.

- Expanding the planning process to include collecting and validating capital acquisition requirements over the full 25-year SSMP timeframe.[3]
- Performing a cost estimate for every validated project proposal (either a Defense Programs' independent cost estimate [ICE] or site estimates for refurbishment projects),[4, 5] in addition to conducting ICEs or reviews prior to each critical decision (CD).
- Updating the "High" estimate to represent the 85th percentile of the estimated confidence level range for each project.[6]

Table 3–1. Weapons Activities major capital acquisition estimated costs, fiscal years 2019–2043

Then-Year Dollars, in Billions	*Low* [a]	*High* [b]
Weapons Activities major capital acquisition estimated costs	61.1	90.7

[a] "Low" reflects the Infrastructure and Operations Construction portfolio's FY 2023 amount in Chapter 4, Figure 4–21, escalated at 2.1 percent inflationary rate.

[b] "High" reflects the program-provided Infrastructure and Operations Construction portfolio with the 85th percentile of the Defense Programs independent cost estimates confidence level range, which is based on the underlying scope and cost uncertainties.

DOE/NNSA continues to analyze this portfolio's long-term needs, and the next SSMP will include further changes to align DOE/NNSA's needs with the 2018 *Nuclear Posture Review*.

For each of the 30 Weapons Activities capabilities, this chapter discusses the contributions the capabilities provide to the DOE/NNSA nuclear security enterprise goals, current status, and challenges, as well as the long-term vision and strategy to address those challenges.

3.1 Simulation Codes and Models

Maintaining and enhancing the necessary simulation and modeling capabilities involves developing and using computer programs (i.e., codes) that simulate the physical behavior of nuclear weapons and components and address production. To enable analysis of a variety of weapons systems' needs, DOE/NNSA codes operate on computers ranging in capacity from desktop machines to the world's largest high-performance supercomputers. Modifying a computer code for use on more than one high performance computing (HPC) platform often requires significant refactoring of the code to ensure optimal performance. Simulation codes are categorized as integrated design codes (IDCs) and weapon science codes. IDCs perform large-scale, physics-rich simulations, while weapon science codes model detail phenomena and inform the models in the IDCs where experimental results are lacking.

The Simulation Codes and Models capability allows the nuclear security enterprise to model the extraordinary complexity of nuclear weapons systems and is essential to maintaining confidence in the performance of the aging stockpile without underground testing.

[3] Table 3–1 reflects only the 20-year post-Future Years Nuclear Security Program planning horizon in last year's SSMP.
[4] It was assumed that KCNSC will not require a line-item project to maintain forecast capabilities during the planning period.
[5] The provisional $15 billion "High" estimate for domestic uranium enrichment capability in last year's SSMP remains unchanged.
[6] Use of the 85th percentile is consistent with DOE Order 413.3B guidance to select an acceptable point estimate selection.

Discrepancies between experimental data and simulations often shed light on needed improvements in algorithms and models in the codes, as well as the physical data used by the codes. Once validated against experimental data, the simulation codes provide insight into the physics at play in the experiments by providing information far beyond what is obtained through diagnostic measurements. Simulation codes are heavily used in preparation for experiments to provide information on, for example, optimal placement and timing of diagnostics, containment of materials and blast, and to ensure that a subcritical experiment remains subcritical. Simulation codes are also used to analyze the safety of assembly and disassembly procedures at the plants.

DOE/NNSA's simulation codes have proven to be invaluable in predicting weapons performance and analyzing the results of weapons-related experiments, including historical nuclear tests.

The Simulation Codes and Models capability depends on HPC to provide the necessary platforms and is regularly used by all other Weapon Activities capabilities.

Codes, Computers, and Component Development

Scientists determined that a certain class of weapons physics simulations of the B61 nuclear explosive package (NEP) required computing exceeding the capability of Cielo, NNSA's most capable computing platform at that time. The Trinity computer, at 41 petaFLOPS, is sized to perform those simulations. The Trinity acquisition project began in 2013, technology demonstrations and transitioning of codes began in 2014, and the complete system was accepted in late 2016. In 2017, these B61 simulations were completed on Trinity, resulting in a validated NEP model for this class of operation.

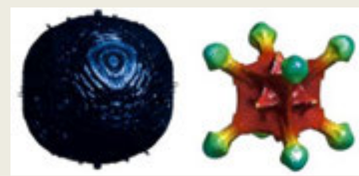


Image from a 3D simulation of an ICF capsule implosion showing density (left) and temperature (right) isocontours

3.1.1 Contributions to Nuclear Security Enterprise Goals

Current simulation capabilities and computer platforms, coupled with advanced model development and focused experiments, have enabled weapons designers to continue certifying the stockpile to date. This includes resolution of all significant finding investigations (SFIs), aging and safety assessments, and certification of changes due to LEPs (notably, weapon response to hostile environments, for which physical testing is limited). The improved fidelity of simulations has allowed the nuclear security enterprise to resolve many of the remaining questions related to underground tests that were first raised when the tests were performed.

3.1.2 Status of Simulation Codes and Models

The Simulation Codes and Models capability is supported by several funding sources and, in turn, supports many weapon systems and capabilities within the nuclear security enterprise. The investment in this capability has adequately supported the necessary enhancements identified a decade ago. Current changes in the nuclear security landscape, including evolving hostile requirements and data on material aging, may force reprioritizations in the annual budget process to sustain the capability for the future. DOE/NNSA must be able to anticipate the effects of aging and proactively act before those effects become issues for the stockpile. Better understanding of fundamental material property changes that occur with age as well as in weapons science simulations requires additional investments in model and database development.

3.1.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
The ongoing shift in computer architectures continues to degrade efficiency and portability of current IDCs and weapons science codes.	Short-term: Optimize current codes for advanced technology hardware. Longer term: Develop next-generation simulation tools with algorithms and data structures designed for exascale architectures.
The migration to new computing platforms diminishes the rate at which new physics capabilities are provided to the Stockpile Stewardship Program.	Develop and implement a broader range of tools to enable more rapid design, evaluation, and qualification of new materials for a range of mission applications while keeping costs manageable.
The ability to simulate the effects of aging and manufacturing changes is limited.	Collaborate with the Experimental Sciences Program to develop the experiments, models, and databases needed to simulate the effects of aging and manufacturing changes.
Develop a higher-fidelity simulation capability to model effects of adversarial threats on weapons systems. Develop computational resources to evaluate fully the multitude of inherently three-dimensional scenarios of threat encounters.	Continue ongoing efforts to develop systems of simulation codes that work together to solve the multiple physics aspects and timescales of adversarial threats. Validate capabilities with results from the experimental efforts in other capabilities areas, such as high energy density physics.
Quickly evolve the ability to perform rapid evaluations of new materials and model additive manufacturing techniques.	Continue current efforts to model additive manufacturing processes and couple these more closely with molecular dynamics and mesoscale modeling to enhance the utility of these models.

3.2 High Performance Computing

The HPC capability includes developing, deploying, and operating very high-capacity computers (along with the requisite software, hardware, facilities, and underpinning infrastructure) to achieve the resolution, dimensionality, and complexity required of the simulation codes used to model performance of weapon systems, components, and relevant experiments.

As the key enabler of simulation codes and modeling, HPC directly or indirectly supports both simulation capabilities and many Weapons Activities capabilities related to validation of models or qualification of weapon components and systems.

3.2.1 Contributions to Nuclear Security Enterprise Goals

The HPC capability is the linchpin enabler for multi-dimensional computer simulation and modeling. While this capability has garnered accomplishments related to approaching exascale computational speeds, its principal contribution to the nuclear security enterprise is supporting the modeling and simulation codes that allow qualification of weapon components and systems without nuclear testing. In particular, two important contributions are assessing the performance and safety of the nuclear explosive package (NEP), as well as of the full warhead system in the stockpile-to-target sequence (STS) environments.

3.2.2 Status of High Performance Computing

HPC technologies are evolving to ever-increasing numbers of computing cores and more heterogeneous architectures. The current generation of IDCs was not originally developed for this technology evolution, resulting in degraded efficiency on recent HPC platforms. Since this degradation will further worsen on future HPC platforms, a next generation of IDCs (requiring new capabilities in numerical methods, software design, and development) will help optimize the use of new HPC technologies.

Current HPC technologies are the foundation for a future exascale supercomputer capability. These capabilities include HPC computation, storage and analysis technologies, large-scale power and cooling infrastructure, and staff drawn toward designing and operating HPC platforms at the very largest scale. Software and computer engineering and science activities support long-term simulation and computing goals relevant to both exascale computing and DOE/NNSA's national security missions.

The Advanced Simulation and Computing (ASC) Program has three major interdependent components (**Figure 3–4**) that must evolve together to contribute to DOE/NNSA missions: codes, computing platforms, and facilities. These three components work together to enable the Stockpile Stewardship Program mission by employing simulation in lieu of nuclear testing.

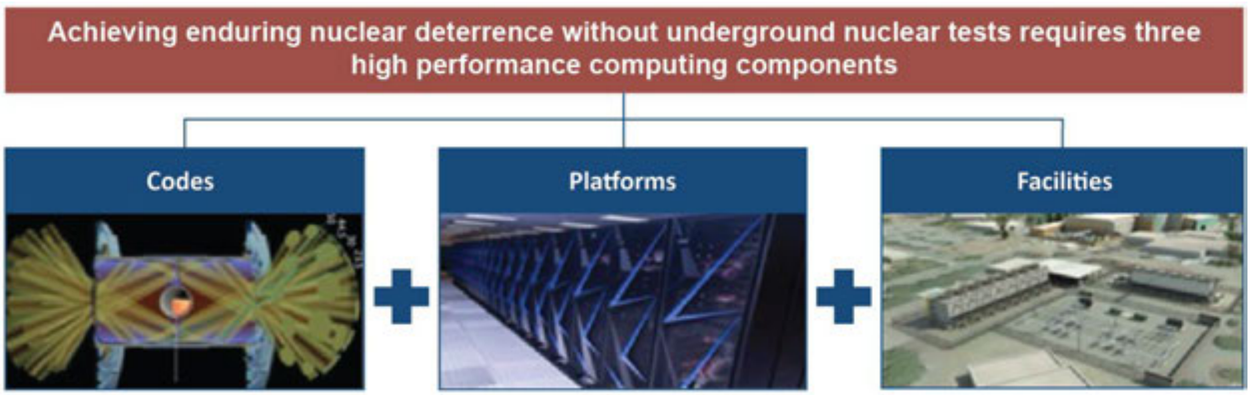


Figure 3–4. Coordinated high performance computing components

As computer architectures have evolved, demands on supporting infrastructure to provide adequate power and cooling have grown dramatically. In addition, computer vendor offerings are evolving and requiring more sophisticated programming models, software designs, and algorithms in the codes that run on these advanced systems. If DOE/NNSA is to meet the requirement for significant advances in modeling capabilities in the future, all three HPC components must be addressed in an integrated and consistent manner over the next decade.

In response to these challenges, the ASC Program's system acquisition strategy incorporates three key objectives:

- Meet the mission needs of the Stockpile Stewardship Program
- Actively engage the U.S. HPC technology sector
- Manage the timing and impact of technological disruptions

This capability will require significant investment in the future to keep pace with the nuclear security enterprise's continually increasing simulation demands. Another challenge, over which the ASC Program has dwindling influence, is the very rapid technological disruption taking place. The ASC Program has a clearly defined strategy of siting HPC platforms at regular intervals to meet mission need. The ASC Program carefully manages and coordinates code development and facility upgrades with advanced platform acquisitions to assure the effective use of HPC for DOE/NNSA.

3.2.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
HPC architectures have evolved from what is used in the nuclear security enterprise, resulting in IDCs that are not effectively using the advances in computational capabilities.	Evolve HPC tools for a next generation of IDCs to achieve new levels of capability through sophisticated programming models, software designs, and numerical algorithms.
Provide appropriately sized facilities and supporting infrastructure (power and cooling) to house exascale platforms.	Plan and secure capital investment funding for next-generation computing facilities and infrastructure. Coordinate system procurements with the Office of Science. Aggressively pursue power and cooling efficiencies, and build on recent programmatic planning and execution successes to deliver large-scale power and cooling infrastructure.

3.3 Nuclear Physics and Radiochemistry

Nuclear physics is the study of atomic nuclei and interactions, especially fission and fusion. Knowledge of the probabilities of interactions of neutrons with fissile material, as well as interactions of light nuclei that can result in fusion, is necessary to understand the physics of nuclear detonations and inform the design of the NEP. Actinide chemistry is a branch of nuclear chemistry that studies the actinide series of elements, which are especially applicable to DOE/NNSA activities. Actinide chemistry capabilities include synthesis, purification, and characterization in support of the stockpile.

Radiochemistry is the chemistry of radioactive materials. This capability is important in evaluating data from legacy underground tests, as well as data from experiments that explore the nature of nuclear material behavior. These tests and experiments are performed at major NNSA facilities such as the Los Alamos Neutron Science Center, the Device Assembly Facility/National Criticality Experiments Research Center, National Ignition Facility (NIF), Omega Laser Facility (Omega), and Z pulsed power facility (Z).

Nuclear Physics and Radiochemistry capabilities provide data and interpretations from nuclear explosion debris. Such data enable simulations and decisions about nuclear explosions associated with the current and future stockpile. In addition, these capabilities provide information that is directly integrated into computer simulations used by the design community and generate the data against which calculated results are compared for accuracy. These data are the most accurate information against which integral performance calculations can be compared. Nuclear Physics and Radiochemistry capabilities are also essential for development of new experimental capabilities, such as neutron diagnosed subcritical experiments, and will be key to the interpretation of neutron diagnosed subcritical experiment data.

Nuclear Physics and Radiochemistry capabilities particularly support Weapon Physics Design and Analysis, which depends on Advanced Experimental Diagnostics and Sensors to collect data, as well as HPC and Simulation Codes and Models to interpret the data. These capabilities are tightly coupled with many other science capabilities, such as Atomic and Plasma Physics and Materials Science and Engineering.

3.3.1 Contributions to Nuclear Security Enterprise Goals

Measurements made at DOE/NNSA facilities that serve Nuclear Physics and Radiochemistry capabilities are used to study key aspects of the fission and fusion processes that are relevant to stockpile stewardship programs, as well as to underwrite analysis of historical test data. As such, Nuclear Physics and Radiochemistry are critical to the sustainment and future viability of the stockpile.

3.3.2 Status of Nuclear Physics and Radiochemistry

In addition to the major facilities, there are many smaller, supporting laboratory facilities across the DOE/NNSA complex that provide specific complementary capabilities. These key facilities are in high demand, putting a strain on the operations of the facilities and the experimental machines housed. Progress has been made on addressing infrastructure gaps, including approvals for establishing new facilities to make some needed improvements.

3.3.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Data generated from nuclear tests last held over 25 years ago have not been preserved in an easily accessed format.	In FY 2017, NNSA began a multi-year weapons research, development, test, and evaluation program to preserve radiochemical data, including digitizing historic media (e.g., paper, microfiche, etc.).
Many DOE/NNSA facilities central to nuclear physics and radiochemistry efforts are aging and in need of upgrades.	Current efforts to address laboratory facility deficiencies are supported by DOE/NNSA infrastructure programs using a serial approach. Plans to clean and refurbish laboratories extend to approximately 2021. Additional proposals will be submitted to address the remaining deficiencies.
Much of DOE/NNSA's experimental science equipment will reach its end of life within the SSMP planning period. Much of this equipment will require a step up to the next generation to sustain Nuclear Physics and Radiochemistry capabilities.	DOE/NNSA is working on long-term strategic visions for improving several next-generation experimental science equipment that will sustain Nuclear Physics and Radiochemistry capabilities into the future.

3.4 Atomic and Plasma Physics

Atomic physics is the study of atoms and the interactions of electrons with x-rays. Plasma physics is the study of the fourth state of matter, in which energy added to a material splits into ionized atoms and unbound electrons. The extremely high temperatures and densities created in nuclear weapons detonations generate plasma and x-rays; involve these states of matter interacting and evolving over short timescales; and are rich in complex phenomena.

The Atomic and Plasma Physics capability produces fundamental results that are used in radiation-hydrodynamic codes that are essential to the Simulation Codes and Models capability. These results include opacities (describing material absorption of radiation), equations of state (EOS) (material responses to pressure), and transport properties of materials (the ways heat and radiation propagate). These results are challenging to acquire due to the extreme temperatures and pressures involved.

3.4.1 Contributions to Nuclear Security Enterprise Goals

Experiments to validate our opacity, EOS, and transport models, as well as the physics simulations used to understand these experiments, continue to improve. Detailed experiments to better understand EOS are extending the range of pressure conditions (1 to ~800 megabars [Mbar]) and the atomic numbers of the materials studied. Opacity measurements are executed on multiple platforms to validate and improve confidence in DOE/NNSA's model to ensure understanding of the complexity of the plasma environment and its interplay with the radiating plasma atoms, as well as the regimes over which model approximations remain valid. Simulations of stockpile and non-stockpile systems have been performed to assess the sensitivity of results to variants in opacity tables, leading to a fundamental understanding of opacity effects on performance and the identification of focus areas for future theory and experimental efforts.

3.4.2 Status of Atomic and Plasma Physics

To model, design, and interpret stockpile-related experiments, simulation tools require validated opacity, EOS, and transport data. Depending on the pressure, density, and temperature regime, such data can be provided through measurements or a combination of theoretical calculations.

The vast range of regimes and extreme conditions achieved by nuclear devices provides challenges for complete experimental validation of data tables. However, reproducible measurements achievable at aboveground experimental facilities provide confidence in DOE/NNSA models. These measurements provide the necessary data to allow examination of the fundamental physical processes and inherent assumptions. Experimental platforms have recently been developed at NIF, Z, and Omega, as well as the Jupiter laser facility, to provide measurements of EOS and opacity in specific physical regimes. Several platforms have been developed to measure the EOS of both low atomic number (low-Z) and high atomic number (high-Z) materials that are relevant to programmatic needs. For low-Z materials (Z less than 10) such as carbon, DOE/NNSA is able to measure pressures above 100 Mbar, but is currently limited to pressures up to several tens of Mbar in higher-Z materials. The absorption opacity of mid-Z materials at densities near 1 percent of solid density can also be measured.

Computational methods now routinely provide the ability to compute EOS from first principles over a wide range of phase space, particularly for low-Z materials. Higher-Z materials still present a challenge for most theoretical techniques due to both the higher computational expense and the need for novel approaches to the physics that is relevant to these materials.

3.4.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
DOE/NNSA needs an EOS platform that can measure data for high-atomic number materials at high pressures (above 100 Mbar), particularly in a broad range of density and pressure conditions. The ability to measure data at these pressures is needed to extend current data sets to additional stockpile conditions.	Develop and test new experimental platforms, such as targets with well-controlled porosity or multi-shock, as well as ramp-drive platforms to provide results in these environments. Develop both equilibrium and non-equilibrium opacity platforms to directly benchmark models.
New and improved diagnostics are needed to more accurately determine the experimental conditions of temperature and density.	Develop a national diagnostic plan identifying transformational diagnostics to provide the required data.
Techniques for computing opacities are limited by how efficiently the tools can compute, store, and analyze the simulation results.	Mature and validate a new computational technique for calculating opacities for high atomic number materials.
The capability to produce EOS results is limited to idealized materials and does not include more complex materials, such as foams or additive manufacturing lattice structures. High-Z materials typically present a challenge for first-principles theoretical methods.	Develop and mature first-principles EOS modeling tools and techniques for non-equilibrium conditions and complex materials. HPC platforms advancements will be needed to efficiently execute computationally intensive methods.

3.5 High Energy Density Physics

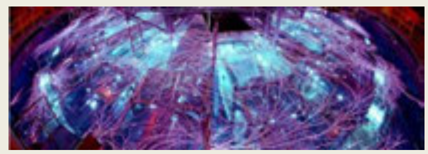
High Energy Density (HED) Physics is the study of matter and radiation under extreme conditions, typically defined as material at energy densities greater than 100 kilojoules per cubic centimeter, which is equivalent to pressures greater than approximately 1 million times the Earth's atmosphere (1 Mbar). The overwhelming majority of the yield of the Nation's nuclear weapons is generated when the conditions within the NEP are in the HED state. HED science proficiency is required to maintain core technical competency and ensure adequate understanding of the complex nature of these systems.

DOE/NNSA has three cutting-edge experimental HED facilities that were developed and are maintained by the Inertial Confinement Fusion (ICF) Program to enable access to HED regimes that are relevant to nuclear weapons: NIF at LLNL, Z at SNL, and Omega at the University of Rochester Laboratory for Laser Energetics. High-energy and high-power laser and pulsed power drivers are key to generating HED environments of interest. These investments have already enabled critical contributions to the sustainment of the Nation's nuclear stockpile.

HED experiments underpin the validation of the computer models used to qualify nuclear weapon components and systems in the absence of nuclear testing. These HED experiments support capabilities such as Simulation Codes and Models; Radiation Effects Analysis, Testing and Engineering Sciences; Weapon Physics Design and Analysis; and Weapon Engineering Design, Analysis, and Integration activities, as well as scientific inquiry into the fundamental nature of matter found throughout the universe (astrophysics and planetary science). The Advanced Diagnostics and Sensors capability ensures collection of data for these environments.

High Energy Density Plutonium Experiments

In 2006, experiments at the Z pulsed power facility measured the properties of plutonium under extreme pressures for the first time. Executing follow-on experiments required reconfiguring Z to improve safety. In 2010, this was completed and plutonium experiments resumed. Through April 2017, 21 plutonium experiments were performed at Z and the material property results were used to validate, test, and improve simulation codes and models. The latest experiment evaluated one of the oldest (51.5 years) plutonium samples taken from the stockpile, and the results were used in the annual stockpile assessment.



3.5.1 Contributions to Nuclear Security Enterprise Goals

Experiments performed in the HED regime provide the scientific understanding and data required to validate the physics models upon which DOE/NNSA's nuclear weapon simulation capabilities are built. The HED regime includes the study of dynamic material properties in extreme conditions, radiation transport, radiation hydrodynamics, thermonuclear burn, low-energy nuclear physics, hydrodynamic instability-induced mix, boost physics, and radiation opacities. In addition, the radiation and neutrons produced by HED platforms are routinely applied to testing and validating models for outputs, environments, and radiation effects geared toward improving our understanding of vulnerability, hardness, and survivability.

One of the primary research interest areas within the HED capability is generating high fusion energy yields through ICF experiments on the NIF and Z. The value of ICF to the Stockpile Stewardship Program supports the following areas:

- Acquisition of material properties data.
- Testing and validation of opacity, radiation transport, and radiation-hydrodynamic computational algorithms that are important to integrated weapon design codes.
- Testing and validation of radiation effects sciences design codes.
- Experimental examination of models associated with boost, vulnerability, and hardness.
- Capability to measure outputs from a modest gain ICF capsule to uniformly heat and measure the properties of samples at relevant conditions.
- Large fusion yield experimental platforms to provide direct access to the weapons-performance-relevant regimes that reduce the need for physical scaling or extrapolation in all key HED areas.

3.5.2 Status of High Energy Density Physics

Across all three major HED facilities, the experimental platforms have produced data that are relevant to the performance of nuclear weapons. These environments include neutron and x-ray bursts, fusion stagnation pressures, complex radiation hydrodynamics, and material and plasma behaviors at high pressure and density regimes that were previously inaccessible. These advances provided immediate mission impact in predictive nuclear weapon performance and survivability and are crucial for advancing predictive capabilities in energy densities of interest. The ICF Program is committed to achieving a robust burning-plasma platform and eventually a high fusion energy yield (greater than 200 megajoules) in support of the Stockpile Stewardship Program. Again, progress continues to be excellent, as evidenced by record-breaking experimental outputs from all three major HED facilities in 2017.

These breakthroughs were enabled in part by increased operational tempos at the facilities. However, these increased tempos have increased wear and tear on the major experimental facilities, equipment, and diagnostics supporting HED, thus increasing the potential for disruption of experimental schedules (with potential effects to mission partners) and unplanned repair costs. More diligent operational monitoring and a focus on consistent capital reinvestment are required to address this issue.

3.5.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Confidently predicting performance of ICF targets used in HED physics facilities to achieve fusion ignition, followed by developing a high-yield platform.	Execute a program of experiments at the HED facilities to characterize fusion phenomena; then use results to build a predictive modeling capability.
Reducing test costs for HED environments across nuclear weapons applications.	Improve predictive capability of science and engineering models in HED environments to reduce test needs.
Sustaining current and expected operational tempos at major HED facilities.	Sustain maintenance and capital investments in major HED facilities.
Using HED experimental data to better understand evolving hostile environments.	Develop high-fidelity diagnostics, advanced experimental platforms, and predictive capabilities and simulations.
Developing and fielding new technologies for HED experiments and diagnostics at major facilities; developing the next generation of HED scientists.	Expand intermediate-scale HED capability for prove-in of new technologies and training of future HED scientists.
Maintaining the complementary and leading-edge capabilities at NIF, Omega, and Z to support exploration of the HED regime for near- and long-term Stockpile Stewardship Program applications.	Prioritize the near-term Stockpile work and facility allocations that support that immediate scope; reduce – but strive to not eliminate – longer-term scientific Stockpile Stewardship Program work.

3.6 Laser, Pulsed Power, and Accelerator Technology

This capability is a collection of advanced technologies that safely create and probe conditions at pressure, temperature, and/or radiation conditions that are relevant to those present in a nuclear weapon during detonation. This capability includes research and development (R&D) to provide experiment driver technologies that extend the range of accessible laboratory environments ever closer to those in nuclear weapons.

Several complex, high-profile facilities are the backbone of this capability, including (but not limited to) NIF, the Dual-Axis Hydrodynamic Test Facility (DARHT), and Z. More information on the major facilities that contribute to this capability may be found in the FY 2018 SSMP.

Laser, Pulsed Power, and Accelerator technologies underpin the fundamental capabilities that support and strengthen many areas of the stockpile, notably Weapon Physics Design and Analysis; Materials Science and Engineering; Atomic and Plasma Physics; Hydrodynamic and Subcritical Experiments; HED

Physics; Simulation Codes and Modeling; Weapon Engineering Design, Analysis and Integration; and Environmental Effects Analysis, Testing, and Engineering Sciences.

3.6.1 Contributions to Nuclear Security Enterprise Goals

Many stockpile stewardship activities require emulating and probing conditions close to those present in a nuclear weapon detonation. The machines and facilities that provide laser, pulsed power, and accelerator capabilities are used to generate nuclear weapon-relevant experimental data for the Stockpile Stewardship Program in the areas of hydrodynamics, material properties under extreme dynamic conditions, radiation transport, nuclear physics, radiation effects, and thermonuclear fusion and burn physics. These results then contribute to three goals:

- Annual assessment of the nuclear stockpile in the face of increasing challenges due to aging or remanufacture
- Resolving SFIs and stockpile issues
- Exploring and enabling options for future stockpile life extensions and approaches to certification

Improved and extended facilities extend the range of accessible conditions so that further investments in this driver technology capability can increase confidence in our assessment models in more extreme conditions.

3.6.2 Status of Laser, Pulsed Power, and Accelerator Technology

DOE/NNSA sponsors or conducts thousands of experiments annually at the laser, pulsed power, and accelerator facilities across the Nation. This operational tempo has increased wear and tear on machines, components, equipment, diagnostics, and supporting infrastructure, necessitating constant replacement of equipment to prevent single-point failures that would disrupt a full test schedule.

While current experimental facilities continue to achieve required scientific results and modest progression to higher pressures, temperatures, and radiation environments, investments in upgrades or new facilities will likely be required for future leaps forward in plasma temperature, radiation environments, and driving pressures.

What is Pulsed Power?

In the early days, this technology was often called "pulse power" instead of pulsed power. In a pulsed power machine, low-power electrical energy from a wall plug is stored in a bank of capacitors and leaves them as a compressed pulse of power. The duration of the pulse is increasingly shortened until it is only billionths of a second long. With each shortening of the pulse, the power increases. The final result is a very short pulse with enormous power, whose energy can be released in several ways. The original intent of this technology was to use the pulse to simulate the bursts of radiation from exploding nuclear weapons. Now, these bursts are used to drive creative sources to generate a variety of tailored radiation and neutron outputs.

3.6.3 Challenges and Strategies

Challenge	Strategy to Address Challenge
The current laser, pulsed power, and accelerator facilities have yet to generate environments for certain types of experiments that are necessary to validate modeling and simulation capabilities for the full nuclear weapon life cycle.	Sustain driver technology R&D and apply technology advances to extend the capability of existing or new machines and facilities to produce higher-fidelity, more extreme nuclear weapons-relevant environments.
Reliability, availability, and experimental tempo activities, as well as maintaining older equipment, use up significant resources.	Modernize facilities and equipment and increase operational resources where identified.
The increased capability of peer nations threatens U.S. pre-eminence in HED science, ICF, and other relevant science and technologies.	Use the technology sustainment area of interest as a means to train personnel and advance the state of the art in technologies to cost-effectively extend the ranges of current facilities.

3.7 Advanced Experimental Diagnostics and Sensors

Measuring phenomena in experiments and tests relevant to nuclear weapons presents challenges due to the extreme environments created and the stringent requirements for precision and accuracy. The Advanced Experimental Diagnostics and Sensors capability is used to develop, deploy, use, and analyze data from advanced diagnostics and sensors to provide such measurements and to advance the technology and techniques to capture the behaviors unfolding in these experiments. Examples of advanced diagnostics currently in development include dynamic radiography (i.e., several flash x-ray images taken over the course of an explosion), time-resolved x-ray diffraction (measures material crystal structure), and multi-dimensional tomography of microstructures (reconstructing the interior features of a component from x-rays taken from many angles).

Many experimental and test capabilities depend on advanced diagnostics and sensors. These include Nuclear Physics and Radiochemistry; Atomic and Plasma Physics; High Energy Density Physics; Hydrodynamic and Subcritical Experiments; and Laser, Pulsed Power, and Accelerator Technology. Environmental effects testing and analysis capabilities also depend on advanced diagnostics and sensors to help certify weapon systems and components, as does the Weapon Component and System Surveillance and Acceptance capability to support annual assessments.

Diagnostics for Hydrotests

Hydrotests performed at the DARHT facility mimic the implosion of a warhead primary in order to gather data to validate computational models. Diagnostic technologies developed for these hydrotests include stop-motion x-ray imaging capturing five images per test, as well as velocity measurements capturing millions of data points during the implosion. Development of DARHT's accelerator and pulsed power technology started in the mid-1990s; the facility was completed in 2008. Through FY 2017, 62 hydrotests were performed at DARHT.

3.7.1 Contributions to Nuclear Security Enterprise Goals

Developing, deploying, and analyzing data from advanced diagnostics and sensors is a key capability used for the experimental and surveillance elements of stockpile stewardship. Developing experimental capabilities to measure nuclear weapon-relevant results is accomplished with coordinated development of driver technology, e.g., accelerators, the diagnostic techniques and instruments provided by this capability, and experimental methods. The Advanced Experimental Diagnostics and Sensors capability, which is closely tied with simulation and analysis, addresses new and emerging issues that arise from the continually advancing scientific understanding of the stockpile to ensure the safety, reliability, and performance of the stockpile.

Efforts in this capability to develop and deploy diagnostics that function in intense environments also provide the opportunity to develop and exercise the nuclear security enterprise's ability to design, build, and operate devices that are similar to those used in nuclear testing. This is essential to preserving DOE/NNSA's responsiveness and ability to return to nuclear testing, if ever required.

3.7.2 Status of Advanced Experimental Diagnostics and Sensors

The Advanced Experimental Diagnostics and Sensors capability is heavily used to collect the data needed to assess NEP aging effects, to study and map hydrodynamic processes that occur in a weapon implosion, and to improve understanding of the thermonuclear burn and boost processes. Sustainment of DOE/NNSA's ability to certify weapons without nuclear testing is highly dependent on continued improvements in advanced diagnostics and sensors, which will correspond with continued improvements and confidence in our Simulation Codes and Models capability. DOE/NNSA's advanced diagnostic capabilities include, but are not limited to, the following:

- The Cygnus Dual Beam Radiographic Facility at the Nevada National Security Site U1a Complex (U1a) provides flash radiography to measure the behavior of materials during subcritical experiments.
- High-resolution, high-speed x-ray imaging is used to measure fusing regions in NIF, Z, and Omega experiments.
- High-speed velocimetry measurements are used to measure combustion in high explosives (HE).
- Advanced neutron imaging and energy measurements are used measure nuclear reactions.

There is currently no DOE/NNSA facility that can adequately diagnose the high-density stages of plutonium in subcritical experiments. DOE/NNSA is executing the Enhanced Capabilities for Subcritical Experiments (ECSE) program at the Nevada National Security Site to address this capability gap.

3.7.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
There is a gap in the ability to measure state of plutonium in high density, high pressure conditions.	Develop and deploy enhanced (short, multi-pulse) radiographic imaging capabilities through ECSE, HED physics experimental efforts, and other planned capital investments.
Additional capability is needed to increase the quantity and quality of data returned on each experiment. Capability gaps exist to: – Verify survivability in currently inaccessible test environments; – Increase amount of data that can be captured from a single experiment; and – Improve fidelity of radiography data from experiments.	Strategies vary depending on testing site, but include: – Develop high-fluence, burst neutron sources to enable enhanced diagnostic capabilities for survivability and radiography. – Deploy Multiplexed Photon Doppler Velocimetry and laser optical ranging in multiple test and experiment facilities. – Expand use of thick scintillator-based imaging of flash x-ray systems to image hydrodynamic tests. – Execute National Diagnostics Plan for ICF to develop and deploy transformational diagnostics needed for HED experiments
Deliver higher fidelity experimental data for development and subsequent calibration and validation of materials models, for weapons materials under extreme conditions.	Develop improved diagnostics capabilities to better capture temperature, phase, microstructure, and chemistry data for materials under extreme conditions.

3.8 Hydrodynamic and Subcritical Experiments

This hydrodynamic and subcritical experiment capability is used to understand the behavior of imploding primaries without creating nuclear yield. Hydrodynamic experiments involve weapon-like geometries, but use surrogate, rather than fissile, material. The surrogate material replicates the behavior of the fissile material and provides data on implosion dynamics. Subcritical experiments involve fissile material driven by HE in a variety of configurations, some of which approximate those of a weapon. Because of the configurations and quantities of the fissile material and explosives present, these experiments never create self-sustaining nuclear chain reactions. It is this explicit combination of hydrodynamic testing with surrogate materials and subcritical experiments with plutonium that provides the breadth of validation data and the material properties required to build nuclear weapon design and safety simulation capabilities. These experiments, in turn, require advanced accelerators and diagnostics to fully execute and capture these data, which enable the use of modeling to certify weapons reliability and safety, rather than nuclear testing.

This capability depends on a broad swath of other enterprise capabilities, including HPC; Simulation Codes and Models; Advanced Experimental Diagnostics and Sensors; Handling, Packaging, Processing and Manufacturing of Special Nuclear Materials; and a variety of specialized facilities for experimental execution, some of which include pulsed power and accelerator facilities. The most notable of these are U1a at the Nevada National Security Site (for subcritical experiments), DARHT at LANL, the Contained Firing Facility at LLNL, and several outdoor firing sites at LANL, LLNL, and the Nevada National Security Site.

3.8.1 Contributions to Nuclear Security Enterprise Goals

DOE/NNSA's Hydrodynamic and Subcritical Experiments capability supplies data to weapon physicists and engineers, allowing assessment of potential impacts of design changes, material substitutions, or component changes associated with LEPs, alterations (Alts), or modifications (Mods) on weapon performance, safety and surety. Experiments are also used to assess the effects of component aging or defects identified during stockpile surveillances. The data obtained are used for the annual assessment process and certification decisions, as well as to advance nuclear weapon science, refine weapon computational models, develop emergency response tools, assess foreign and terrorist designs, gauge technological surprise, and develop the skills and experience of weapon designers and engineers.

The Hydrodynamic and Subcritical Experiments capability was used in FY 2017 to inform direct stockpile work, weapon science, subcritical campaigns, and other national security needs. Experiments directly supporting the B61-12 LEP, W88 Alt 370 with conventional high explosive (CHE) refresh, W80-4 LEP certification activities, and annual assessment improved the models underpinning DOE/NNSA's understanding of pit reuse and weapon safety.

3.8.2 Status of Hydrodynamic and Subcritical Experiments

The Hydrodynamic and Subcritical Experiments capability is supported by several funding sources. The National Hydrodynamic Testing Complex supports base operations at the various facilities conducting experiments for the National Hydrodynamic Test Plan, while the sponsors of the individual experiments (Experimental Science, Directed Stockpile Work [DSW], Nuclear Counterterrorism, or the like) provide experiment-specific support. As the facilities age, additional investments are required to maintain this capability, and the demand for higher cadence is stressing the workforce and specialized facilities that are operating at near capacity.

3.8.3 Challenges and Strategies

The programs supported by the Hydrodynamic and Subcritical Experiments capability require more testing opportunities. Many future experiments will require enhanced or novel diagnostic measurements to provide the data necessary to adequately characterize and constrain computational models. These programmatic demands come with the imperative of ensuring that the capability manages the risks inherent in explosive testing to protect DOE/NNSA's staff, the environment, and the public.

Challenge	*Strategy to Address Challenge*
Existing subcritical experiments capabilities lack the ability to perform multi-frame penetrating radiographs on hydrodynamic experiments with plutonium pits.	Enhanced Capabilities for Subcritical Experiments program will close capability gaps in the mid-2020s.
Existing subcritical experiments capability cannot measure reactivity of subcritical assemblies.	
The high-energy flash x-ray systems on DARHT Axis 1 and at the Contained Firing Facility are increasingly expensive to operate due to age and underlying technologies.	Investigate replacing DARHT Axis 1 with an enhanced capability that will include a multi-frame capability.
Throughput of experiments at DARHT depends on weather conditions. The original firing point was configured for outdoor testing and has not been modified to take full advantage of testing in vessels. Downtime affects staff safety, data quality, and the efficiency of facility operations, as well as the throughput of experiments.	A weather enclosure for the DARHT firing point has been designed and is planned for construction in FY 2019-2020. In conjunction, the firing point will be reconfigured to improve staff safety and the operational efficiency of the facility, as well as to enhance data quality.
Aging infrastructure at firing sites, as well as the upstream and downstream facilities that support shots at the firing sites limits the potential cadence.	Baseline capability investment is being developed to sustain and enhance hydrodynamic capabilities at firing sites.
Design, procurement and long-term acquisition and support of confinement vessels used for the Hydrodynamic and Subcritical Experiments capability at all firing facilities is a challenge because vessels are approaching lifetime limits.	DOE/NNSA is establishing an enduring vessel procurement funding strategy with the intention to re-establish domestic fabrication and manufacturing capability for vessels.

3.9 Chemistry

Chemistry is the study of the fundamental (or elemental) composition, structure, bonding, and properties of matter. Chemistry is essential for purifying, synthesizing, processing, and fabricating materials. The stability of these materials and how properties and reactivity of materials change with time must be understood to ensure the quality, performance, and safety of the stockpile.

This capability depends on the Materials Science and Engineering capability to address complex issues, such as corrosion, that involve chemistry at a material's surface and can have a significant effect on performance.

3.9.1 Contributions to Nuclear Security Enterprise Goals

The Chemistry capability, within the context of the Stockpile Stewardship Program, synthesizes and formulates new or replacement materials, characterizes the composition and structure of stockpile materials, and connects chemical signatures to service requirements. Chemistry capabilities cover all materials currently fielded or proposed for near-term LEPs, including organics, explosives, composites, plutonium, and uranium.

3.9.2 Status of Chemistry

DOE/NNSA maintains the experimental and computational capabilities needed to inform the selection of materials for system design (LEPs) and modernization and to develop chemistry and physics-based models that describe and predict the behaviors of weapon materials over time. These capabilities provide the experimental data and essential chemistry knowledge required for annual assessments, certification of the stockpile, and future sustainment options. Capabilities are distributed across design and production facilities within the complex and include chemical synthesis, analytical chemistry, and surface science. R&D is ongoing to support qualification of weapons, develop new materials, understand aging-related chemical changes, and control chemical environments over time.

3.9.3 Challenges and Strategies

Chemistry capability challenges are focused on developing simulation tools and maturing this capability.

Challenge	*Strategy to Address Challenge*
Chemistry models of aging materials do not include mesoscale phenomena, degradation of organics and energetics, and corrosion of metals.	Develop experiments, models, and databases needed to simulate effects of aging and manufacturing changes.
New material formulations have not adequately matured to enable transfer to industry so commercial material sources can provide required materials.	Improve automated synthesis, analytical chemistry, and characterization processes to successfully transfer production of material sources to industry
A comprehensive suite of radiological facilities that can address the varied needs of the mission is lacking.	Develop and execute a sustainment plan to maintain required synthesis, analytical chemistry, and characterization facilities and expertise for the purpose of preserving applied chemistry and materials capabilities with a sustainable infrastructure.

3.10 High Explosives Science and Engineering

This capability conducts experiments and modeling activities to qualify and predict the behavior of explosives under a wide range of nuclear weapons operating conditions. These activities directly support stockpile stewardship of energetic materials through weapons assessments, stockpile maintenance, sustainment through LEPs, weapons surveillance, SFIs, and technical guidance for weapon dismantlement, as well as disposition activities. The work also involves a range of activities to understand the properties, engineering, and physics performance of the energetic materials, explosive components, and warhead-level assemblies.

The HE Science and Engineering capability incorporates a variety of physics, chemistry, materials science, and other disciplines to study the behavior of HE or more generally energetic materials through a comprehensive suite of experimental, theoretical, and computational research skills and highly trained personnel.

3.10.1 Contributions to Nuclear Security Enterprise Goals

The HE Science and Engineering capability contributes to the nuclear security enterprise by delivering HE materials that are used both in the NEP and in non-nuclear components for stockpile sustainment and modernization.

3.10.2 Status of High Explosives Science and Engineering

DOE/NNSA has a broad legacy infrastructure that is used to formulate, process, and test both CHE and insensitive high explosive (IHE) materials. This infrastructure includes synthesis and characterization laboratories, fabrication operations, and an indoor and outdoor firing site capability. DOE/NNSA maintains these capabilities to support novel explosive material development, understand the effects of novel and traditional processing operations, and advance physics-based HE models. These models are used to predict explosive performance over a wide range of conditions to provide the essential knowledge required for annual assessment, certification of the stockpile, LEPs, and future sustainment options. Experiments related to this capability are conducted at laboratory facilities across the DOE/NNSA complex.

3.10.3 Challenges and Strategies

Challenge	Strategy to Address Challenge
Aging HE facilities across the complex require recapitalization, consolidation, and modernization to support LEP activities and emerging weapon program needs.	Develop and execute plans to ensure modernization of HE/energetic materials design and production infrastructure to meet immediate programmatic needs, while maintaining the technological capacity to support the long-term HE mission.
Maintain production and processing capability for all CHE and IHE materials when critical ingredients associated with these materials are no longer commercially produced.	Re-establish capability to manufacture and qualify IHE for LEPs. Working groups will be formed to address specific materials.
Stringent specifications and diversity of non-nuclear energetic materials do not provide economic incentives necessary for commercial vendors to improve existing processes. In addition, the number of commercial vendors has decreased.	Collaborate with DOD and industrial partners to produce HE and preserve in-house production authority, such as for War Reserve detonator powder production.
Acceptance of new HE materials and components for use in nuclear weapons lacks a uniform approach for accelerated certification.	Maintain timely delivery of HE materials and technologies to meet weapon program requirements and priorities by ensuring a ready science and engineering capability to develop and qualify materials.

3.11 Materials Science and Engineering

In the context of the nuclear security enterprise, materials science is the characterization and understanding of how all the materials in a nuclear weapon system perform throughout the entire life cycle. Materials engineering involves evaluation and selection of materials for performance in diverse and extreme environments. Strength, aging, compatibility, viability, and damage mechanisms are among the material characteristics to be understood. The Materials Science and Engineering capability plays a key role in resolving stockpile and production issues, validating computational models, and developing new materials (e.g., materials produced through additive manufacturing).

This capability within the nuclear security enterprise encompasses a broad array of Research, Development, Test, and Evaluation (RDT&E) activities that include, but are not limited to, the following:

- Achieving fundamental understanding of the properties and structure of materials.
- Behavior and performance of materials when processed or exposed to a range of conditions.
- Synthesis of new materials.
- Exploration of new materials for use in current and new applications to improve the cost and performance characteristics of products and systems in which they are used.

The Materials Science and Engineering capability is integral to all aspects of nuclear weapon research, design, development, test, processing, and manufacture, resulting in a strong interdependence with other Weapons Activities capabilities.

3.11.1 Contributions to Nuclear Security Enterprise Goals

Materials Science and Engineering capability activities are key to the entire weapon life cycle, including such activities as basic characterization of material properties and the behaviors of properties under extreme conditions; model validation; selection of suitable materials to meet specifications; examining the effects of aging; and safe transport and disposal. This capability is important for both the NEP itself and for the non-nuclear components and systems that ensure the weapon will function as expected.

3.11.2 Status of Material Science and Engineering

Materials science efforts across the nuclear security enterprise have yielded important results in the characterization of current stockpile materials under extreme conditions. This capability must now address the performance of the stockpile as material properties change due to aging of materials and modernized processes to produce those materials. This capability will require expanded experimental and computational investigations and strengthened partnerships between DOE/NNSA production and design agencies. To achieve these goals, efforts will focus on three aspects of this capability:

- Conducting R&D into innovative new materials for future insertion in weapons.
- Conducting R&D to characterize material behavior under extreme conditions for certification of weapons.
- Providing consistent, reliable support for early- and mid-career staff to develop the unique skills and understanding of materials uniquely required by the weapons program.

3.11.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Assess stockpile impacts of material changes due to aging, obsolescence, replacement for hazard mitigation, high cost and production modernization for NEP and non-NEP materials.	Expand experimental and computational abilities to study these material changes through design-production agency partnerships, as well as to rapidly identify and deliver solutions to emerging materials issues.
Aging equipment and facilities pose risk to the development of new materials, as well as to advanced evaluation and assessment of materials behavior, to support development, design, production, and surveillance activities.	Execute capital reinvestment in key facilities and equipment for materials science and engineering capabilities to support nuclear weapons throughout their lifecycle.

3.12 Weapons Physics Design and Analysis

Design and analysis of the NEP is required to maintain existing U.S. nuclear weapons, modernize the stockpile, evaluate possible proliferant nuclear weapon designs, and respond to emerging threats, technological innovations, or surprises. Elements of this capability include concept exploration, satisfaction of specifications, conceptual design, detailed design and development, production process development, qualification and certification against requirements, as well as evaluation of weapons effects.

This capability uses scientific and technological advances from capabilities such as Simulation Codes and Models, Material Science and Engineering, Hydrodynamic and Subcritical Experiments, HPC, HED Physics, and HE Science and Engineering in order to: (1) understand the impacts of materials behavior, including aging and remanufacture on weapon performance; (2) evaluate LEP design options; (3) enhance the weapons certification process; (4) refine computational tools and methods; (5) advance the physical understanding of surety mechanisms; (6) understand failure modes; (7) assess new manufacturing processes; (8) deliver design options to support future LEPs; and (9) provide rapid support to stockpile needs. This competency underpins DOE/NNSA's capabilities in Weapons Engineering Design, Analysis, and Integration; Environmental Effects Analysis; and Weapons Surety.

3.12.1 Contributions to Nuclear Security Enterprise Goals

The Weapons Physics Design and Analysis capability is a key tool in the annual assessment of the U.S. nuclear weapons stockpile and the certification of warheads without resorting to nuclear testing. Several physics issues that are relevant to understanding the performance, safety, and reliability of the stockpile have been resolved in the past decade, including the Energy Balance, Primary Certification, and Secondary

Certification milestones. The continued execution of current LEPs is enabled by this capability, which is being extended to address evaluation of alternative materials and reuse of legacy components for current and future LEPs for the purpose of enabling a more rapid establishment of processes to produce materials and components.

3.12.2 Status of Weapons Physics Design and Analysis

The Weapons Physics Design and Analysis capability currently has the tools and methods to design and analyze NEPs, as well as certify future stockpile options with new safety and security features. The capability is sufficient to meet the present nuclear stockpile annual assessment process and the programs of record for modernization.

DOE/NNSA's present assessment capability is satisfactory for evaluating the current state of materials and components. However, it has not reached the state where entirely new issues can be analyzed responsively or with confidence. This is concerning because the complex's ability to rebuild large numbers of stockpile units requires at least a decade to accomplish according to the planned LEP schedule. This slow response time could leave large holes in the enterprise's deterrent capabilities if the enterprise does not become more flexible and agile in both assessment and production capabilities, as well as system capacity.

Similarly, should the requirements for DOE/NNSA's current systems change in the future (in response to the changing threat environment or an inability to manufacture current materials going forward), the nuclear security enterprise's design physics and analysis tools may require expanded predictive capabilities to certify systems that were never demonstrated through underground nuclear testing.

A non-nuclear approach to integrated certification testing could become essential for future systems. Such approaches are being investigated through the Science Program by developing potential non-nuclear experimental capabilities and boost physics metrics that can quantify performance without an underground nuclear test.

Recapitalization of existing scientific, technical, and engineering facilities and capabilities is needed in the near future so that execution of the LEP program of record can continue. Facilities and equipment throughout the complex are wearing out, failing, and increasingly delaying execution of the program. This results in increased and unplanned costs.

3.12.3 Challenges and Strategies

Challenge	***Strategy to Address Challenge***
Developing and exercising design (rather than assessment) skills in physics, engineering, and chemistry and materials science personnel.	Short-term: Certification Readiness Exercises, Capabilities for Nuclear Intelligence Practicums, and other design studies. Longer-term: Experience through the 2018 *Nuclear Posture Review*-tasked design studies and Stockpile Responsiveness Program exercises.
Developing and exercising certification methodologies using recently developed physics performance metrics on device designs that do not have underground test data.	Short-term: Development of metrics and the methodologies for applying them. Longer-term: Execution of subcritical and HED experiments from which metrics can be extracted or validated.
Reuse design capability should new component production be unable to meet LEP requirements. The ability to simulate the effects of aging and manufacturing changes is limited.	Short-term: Reliance on current simulation capabilities (validated by AGEX) to model reuse design options. Longer-term: Development of certification methodologies for reuse and replacement designs.
Agile and responsive design capabilities will be needed to mitigate emerging adversary threats to deterrence.	Short-term: Reliance on current simulation capabilities (validated by experiments). Longer-term: Development of design skills to take advantage of advanced manufacturing and testing capabilities.

3.13 Weapons Engineering Design, Analysis, and Integration

The Weapons Engineering Design, Analysis, and Integration capability relies heavily on weapon science and engineering capabilities, systems engineering tools (e.g., model-based design), and approaches to derive, analyze, and validate system requirements and perform system trades. Elements of this capability span the following life cycle phases: concept exploration, consideration of requirements, conceptual design, detailed design and development, production, qualification, and certification. This capability also includes understanding and developing the interfaces among the non-nuclear subsystems, between the non-nuclear components and the NEPs, and between the warhead and DOD delivery systems.

This capability is supported by and leverages other capabilities such as HE science and engineering; weapons surety design and analysis for use in control component applications; weapon component and system prototyping to qualify new configurations and designs; simulation codes and modeling to quickly realize designs and promote innovation through rapid feedback; environmental effects analysis, testing, and integration to support design and qualify weapon components and systems; and HPC.

3.13.1 Contributions to Nuclear Security Enterprise Goals

The Weapons Engineering Design, Analysis, and Integration capability underpins DOE/NNSA's ability to develop, test, qualify, and certify designs to support a responsive deterrent. This capability employs science, technology, and engineering (ST&E) methods to ensure that the integrated solution meets all performance, safety, security, and reliability requirements in the most effective manner. It is foundational to all aspects of nuclear weapon research, design, development, test, and manufacture.

3.13.2 Status of Weapons Engineering Design, Analysis, and Integration

Much of the Weapons Engineering Design, Analysis, and Integration capability is being exercised by the multiple concurrent LEPs and Alts, on top of the base workload, to sustain the existing stockpile. Because of the focus of these modernization activities is on extending the life of current stockpile weapons, there has been a decline in capabilities to develop new concepts that address military requirements that differ significantly from those addressed by current stockpile systems. This is expected to be addressed through the Stockpile Responsiveness Program to work on new concepts in concert with DOD, which will provide relevant work to recruit, retain, and train the next generation of weapon designers.

3.13.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Traditional weapon development cycles are long, limiting the ability to respond in a timely manner to emerging threats. Rapid development and incorporation of emerging technologies into weapon systems presents both opportunities and risk in a stockpile that must be certified without nuclear testing and meet extended lifetime requirements.	Seek ways to accelerate the development cycle, respond more quickly to emerging threats, and invest in technology development and process improvements to increase the speed that weapon systems are updated and recertified.
Weapon design, engineering, and production requires use of new processes or materials (due to manufacturing availability). New processes or materials present certification and qualification challenges, especially as weapons design moves further away from the underground tested design.	Engage material science capability early in design process to inform process development and material choices. Perform system trade analyses to develop new materials that can support weapon life extensions.
Cold War-era facilities need to be refurbished and/or replaced to ensure a responsive and resilient capability.	Pursue facility recapitalization, as well as needed equipment replacements, through a carefully planned, prioritized, and executed investment program.

3.14 Environmental Effects Analysis, Testing, and Engineering Sciences

The Environmental Effects Analysis, Testing, and Engineering Sciences capability encompasses analyzing and testing the effects of different environments on weapon systems and components using an array of engineering science test equipment, tools, and techniques. Examples of environments (normal, abnormal, and hostile) include shock, vibration, radiation, acceleration, thermal, electromagnetic, and pressure. Examples of engineering sciences that support this analysis include radiation effects, thermal and fluid sciences, structural mechanics, dynamics, and aerodynamics.

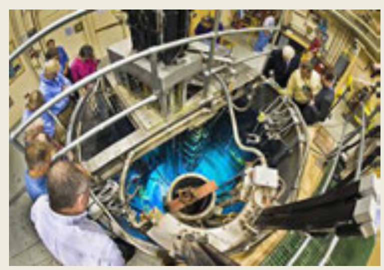
Engineering sciences drive understanding and innovation by integrating theory, computational simulation, and experimental discovery and validation across length and timescales to understand and predict the behavior of complex physical phenomena and systems to meet national security missions.

This capability also requires a broad range of facilities and equipment to reproduce relevant environments (shock, vibration, temperature, g-loading, radiation, electro-magnetic pulse, aging), as well as the tools to conduct the tests and capture data that determines the response to those environments. This work is performed in specialized environmental chambers, blast tubes, centrifuges, wind tunnels, accelerators, reactors, and many specialized laboratory-scale facilities.

Nuclear and non-nuclear component and system design, qualification, and certification depend on the Environmental Effects Analysis, Testing, and Engineering Sciences capability. Environmental tests supported by the HED Physics; Laser, Pulsed Power, and Accelerator Technology; Advanced Diagnostics and Sensors; Simulation Codes and Models; and HPC capabilities are foundational for every element of the nuclear weapons mission.

Environmental Effects on Electronics

Radiation-hardened microelectronics used in warheads employ specialized designs and fabrication techniques developed by DOE/NNSA scientists and engineers. Researchers recently measured the impact of intense radiation on the W88 Alt 370 electronics at DOE/NNSA radiation-effects test facilities. The tests provided data, gathered using advanced diagnostics and sensors, for validation of the models used to calculate the performance margins and uncertainties for the most sensitive circuit features. The calculations serve as an element in the qualification of the W88 Alt 370.



The Annular Core Research Reactor radiation-effects test facility.

3.14.1 Contributions to Nuclear Security Enterprise Goals

The Weapons Effects Analysis, Testing, and Engineering Sciences capability provides the fundamental, sustained engineering R&D for nuclear weapon design, qualification, certification, and assessment, as well as the ability to predict the response of weapon components and subsystems to aging and normal, abnormal, and hostile environments in several ways:

- Integrating theory development, experimental discovery and diagnostics, modeling, and underlying computational approaches to improve the ability to account for and predict complex behavior in engineered systems.
- Providing fundamental understanding of aging phenomena to support component lifetime assessments.
- Supporting development of advanced component and materials testing processes to ensure high-level weapon reliability and certification.

- Providing experimental capabilities, diagnostics, and data needed to discover physics for understanding component, subsystem, and weapon performance when subjected to STS environment regimes.
- Providing tools and testing technologies necessary to ensure components and systems meet requirements in hostile environments.

3.14.2 Status of Environmental Effects Analysis, Testing, and Engineering Sciences

The major environmental test facilities are meeting current test needs for qualification and assessment. However, many are aging and beyond their design lives and are in need of major refurbishment over the next decade, especially considering the heavy demand imposed by multiple LEPs. The same is true for the programmatic equipment supporting the environmental test and engineering sciences facilities. Assuming the availability of investment funding, plans are in place to address these needs within the SSMP planning period. In addition, there is a need to enhance environmental testing capabilities in multiple combined environments such as combined radiation environments, combined radiation and mechanical/thermal environments, and combined thermal and mechanical (aerodynamic) environments without radiation. These additional capabilities in combined environments are driven by the emerging requirements of flight scenarios and associated adverse environments, which are either man-made or natural.

3.14.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Emerging and future requirements for certification of weapon systems are driving the need to provide more testing of components and systems in the combined radiation environments experienced by nuclear weapons during their anticipated life cycle.	Plan facility and equipment investments to ensure continuity of this capability. Priority needs include a new capability for experiments and tests in combined nuclear environments.
Ability to perform in situ experiments in combined mechanical, thermal, radiation and electromagnetic radiation environments.	Pursue enhanced combined hostile, normal, abnormal environment testing capabilities to meet evolving and future mission requirements.
Aging facilities, equipment, structures, and infrastructure that support this capability across the DOE/NNSA nuclear security enterprise are being degrading faster than anticipated. Risk of single-point failure due to breakdown of programmatic equipment is increasing due to deferred maintenance and replacement of key equipment.	Plan for systematic recapitalization of programmatic capital equipment, test facilities, and infrastructure will reduce the risk of the unavailability of test capabilities that could delay qualification and physics experiments.

3.15 Weapons Surety Design, Testing, Analysis, and Manufacturing

The Weapons Surety Design, Testing, Analysis, and Manufacturing capability includes the development, analysis, integration, and manufacture of safety and use control systems to prevent accidental nuclear detonation and unauthorized use of nuclear weapons, all of which are necessary to ensure a safe and secure stockpile. All aspects of this capability require strict classification control, as well as secure facilities and equipment to perform surety activities.

The Weapons Surety Design, Testing, Analysis, and Manufacturing capability is integral to all aspects of nuclear weapon research, design, development, testing, processing and manufacture, resulting in a strong interdependence with other Weapons Activities capabilities.

3.15.1 Contributions to Nuclear Security Enterprise Goals

The Weapons Surety Design, Testing, Analysis, and Manufacturing capability integrates ST&E to create surety components and system architectures that ensure the safety and security of nuclear weapons throughout their lifecycle. For example:

- Consolidating multiple science and engineering disciplines and ensuring that emerging technologies (e.g., future safety mechanisms and next-generation use control technologies) meet specified design requirements. These activities are focused on development of future safety mechanisms and next-generation use control technologies.
- Performing the Joint Integrated Lifecycle Surety (JILS) Assessment, a joint DOE/NNSA/DOD activity to examine the relative benefits of proposed surety technologies. JILS provides specific input to the Use Control Program Officers Group on the impact of proposed policy changes from a security perspective.
- Focusing Integrated Surety Architectures activities on improving DOE/NNSA transportation surety by integrating nuclear weapon shipping configurations with physical security elements.

3.15.2 Status of Weapons Surety Design, Testing, Analysis, and Manufacturing

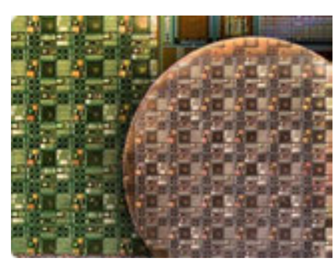
A variety of surety technologies and approaches have been or are currently under development to improve the safety and security of nuclear weapons. Technologies that improve performance margins and reliability have recently been applied to stockpiled weapons. Additional technologies are under development to improve intrinsic surety and enable more optimally designed warheads for improved robustness, reliability, and performance.

3.15.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Sustaining technology maturation activities of advanced and exploratory technology development in the area of surety.	Weapons surety can leverage planned investments in the Weapon Engineering Design, Analysis, and Integration capability to ensure the ST&E base needed for maturing advanced technologies to increase weapons surety and reduce the risk associated with insertion of advanced technologies remains strong.
Continuously creating and evolving highly advanced surety technologies that are independent of specific weapon types or insertion opportunities and can result in major surety improvements.	Establish a balanced program for weapon surety within DOE/NNSA for creating and evolving highly advanced surety technologies that are independent of specific weapon types.

3.16 Radiation-Hardened Microelectronics Design and Manufacturing

The Radiation-Hardened Microelectronics Design and Manufacturing capability provides collocated research, development, and production to support the design, manufacturing, and testing of radiation-hardened microsystems that will function properly when exposed to intense radiation environments. The design of radiation-hardened components depends on environmental analysis, testing, and engineering sciences for validation.



The Radiation-Hard electronics technology is designed to survive strategic levels of radiation.

3.16.1 Contributions to Nuclear Security Enterprise Goals

Microsystems perform critical sensing, arming, fuzing, and firing (AF&F) functions to meet safety, security, and reliability requirements. A strategic radiation-hardened capability is critical to providing an effective, credible deterrent and to DOE/NNSA's ability to build and certify weapons that can survive the hostile environments they might encounter during the STS.

3.16.2 Status of Radiation-Hardened Microelectronics Design and Manufacturing

The Microsystems, Engineering, Science and Applications (MESA) facilities at SNL are DOE/NNSA's only source of trusted, strategic radiation-hardened microsystems for the nuclear security enterprise. MESA has supported every LEP and major Alt since 2005. Over 27,000 War Reserve, diamond-stamped parts have been delivered to date for the current programs, with a total of over 179,000 parts scheduled to be delivered through FY 2026, of which more than 13,000 parts are to be delivered for the W80-4 LEP. MESA continues to produce radiation-hardened microelectronics for stockpile modernization. MESA's Silicon Fabrication facility (SiFab) was commissioned in 1988 and is currently 5 years beyond the intended 25-year design life. In FY 2019, SiFab will complete its Sandia Silicon Fabrication Revitalization program, which provides the needed tools and infrastructure updates necessary for delivery of War Reserve-qualified parts for the B61-12 LEP. However, ongoing investments in infrastructure and tools to support the MESA complex (SiFab, the Microsystem Fabrication facility [MicroFab], and utility buildings) and supporting capabilities (packaging and test, validation and failure analysis, and quality) are required. These investments must be sustained to ensure this capability is well positioned to continue to provide key technologies to meet planned LEPs and evolving national security needs for strategic radiation-hardened microsystems beyond 2025. Without sustained investment and eventual large-scale recapitalization, the MESA complex will experience failures due to aging and will become obsolete. Planning is underway for a long-term sustainment of MESA.

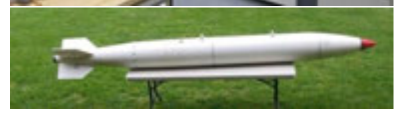
To ensure SiFab sustainability for the near term, MESA will convert existing wafer processing tools from a 6-inch wafer capability to a more widely supported 8-inch wafer capability. This conversion addresses risks to the supply chain (e.g., where a majority of SiFab tools have either marginal support or no 6-inch parts are available). MESA's 8-inch conversion schedule supports the nuclear deterrent program schedule.

3.16.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Research, develop and deliver advanced radiation-hardened microsystem technologies that meet current and emerging requirements to ensure an effective nuclear deterrent.	Complete MESA's SiFab conversion of wafer processing tools from 6-inch to more supportable 8-inch per plan. Develop a long-term executable plan that identifies annual investments required for the following: • Targeted R&D and technology maturation programs for producing future radiation-hardened microelectronics. • Infrastructure, tools, and supporting capabilities (SiFab, MicroFab, utility buildings, packaging and testing).
Replace unsupportable or obsolete tools with more modern, sophisticated, and capable tooling that cannot be supported by the current infrastructure.	Assess critical tool replacement requirements against existing infrastructure over a planning period. Pursue a flexible facility solution for housing future-generation tools and capabilities.
Continue to maintain a stable and competent workforce during low production demands due to conversion efforts as new processes are certified.	Execute to a resource loaded schedule, while monitoring identified risk areas.

3.17 Weapon Component and System Prototyping

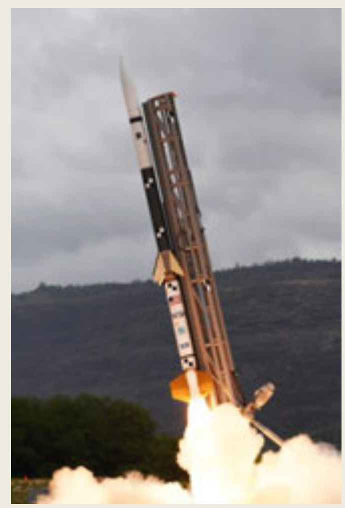
The Weapon Component and System Prototyping capability develops, qualifies, and manufactures high-fidelity, full-scale prototype weapon components and systems to reduce the cost and cycle times required to develop modern designs and technologies prior to producing a component. This capability includes the ability to design, manufacture, and employ mock-ups with sensors to support laboratory and flight tests that will provide evidence that a component can function with DOD delivery systems in realistic environments. Identifying, developing and sustaining process expertise and prototyping is crucial to scientific understanding, production agility, responsiveness, and efficiency in the ever-changing threat environment.



Additive manufacturing room and full-scale B61 mock-up

Prototyping capabilities are used to develop, fabricate, produce, and qualify designs and are interdependent with several other Weapon Activities capabilities, most notably Radiation-Hardened Microelectronics Design and Manufacture, Simulation Codes and Models, and Advanced Manufacturing, to achieve efficient, cost-effective final design hardware. This capability is also interdependent with the Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Material; Metal and Organic Material Fabrication; Non-Nuclear Weapon Component Manufacturing and Assembly; Handling, Packaging, Processing, and Manufacturing of Special Nuclear Material; and HE Science and Engineering capabilities.

The High Operational Tempo Sounding Rocket Flight Test (HOT SHOT) program will provide a lower-cost alternative to conventional flight tests, with the ability to duplicate many of the integrated reentry vehicle environments needed to qualify components, technologies, and subsystems. HOT SHOT activities are focused on maturing the next generation of innovative concepts and technologies through a series of tests and analyses to significantly increase data supporting future stockpile insertions.



High Operational Tempo Sounding Rocket Flight Test (HOT SHOT) Launch

The first HOT SHOT from the Kauai Test Facility in Hawaii in May 2018 supported seven experiments on component technologies, additive manufacturing processes, model validation, and data communications. The HOT SHOT program provides an agile, risk-tolerant technology maturation platform to deepen scientific understanding by testing in relevant environments at a lower cost than operational system flight tests.

3.17.1 Contributions to Nuclear Security Enterprise Goals

To qualify components and systems, DOE/NNSA requires capabilities to provide rapid development cycles enabled by modular systems, rapid prototyping, and integrated simulation. The ability to realize designs quickly will promote innovation as risks and barriers to participation are lowered through rapid feedback.

3.17.2 Status of Weapon Component and System Prototyping

Many weapon components in today's systems use legacy technologies that are decades old and have not been commercially supported for many years. Future LEPs must address new safety, security, and performance requirements that are not achievable or provided in many older designs because of technology limitations and/or component size and weight restrictions. These issues drive the need to refresh designs continuously to address technology obsolescence, end-of-life or aging concerns, and changing requirements.

3.17.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
New capabilities, such as modularity, foundation bus connectivity, and rapid product realization, have not been evaluated in relevant environments. This poses a risk to insertion into future systems.	Provide a high-tempo flight test capability to drive innovative design practices and allow new technologies to gain the necessary flight pedigree to ensure low risk in a systems context.
Current processes and capabilities are inadequate for fast design, production, testing, and qualification of new equipment and technologies.	Pursue advanced manufacturing technologies that enable cost-effective, rapid-prototype iteration and faster transition from design to production, as well as understanding and assuring the properties and performance of additive manufacturing materials and components.
Aging infrastructure and legacy processes increase risk to meeting the mission due to inability to be economically and rapidly modified for new technologies.	Develop a business model that includes proactive maintenance and upgrades for sustaining facilities and infrastructure, to include an approach for managing substandard facilities that house critical functions or operations.
Resources required to meet stockpile modernization commitments have driven significant investment reductions in equipment, infrastructure, and facilities. This has reduced the ability to innovate for the future.	Establish joint projects and milestones between multiple sites, programs, and agencies to enable early prototyping and technology development and maturation. This approach will facilitate a collaborative scope, joint priorities, and combining of resources.

3.18 Advanced Manufacturing

The Advanced Manufacturing capability develops, demonstrates, and transitions improved production processes (including tools, fixtures, parts, and materials) to ensure the safety, security, and performance of the nuclear weapons stockpile. This capability enables the nuclear security enterprise to respond to emerging issues with the current stockpile and adapt new processes for follow-on use to gain production efficiencies. The term advanced manufacturing can encompass a broad range of technologies, such as robotics, artificial intelligence, HPC, etc. Within DOE/NNSA, the predominant focus is currently on additive manufacturing, which is sometimes called three-dimensional (3D) printing. All future non-nuclear component production activities will depend on this emerging capability to achieve efficiencies of time and cost, while also enabling greater agility across the nuclear security enterprise.

The Advanced Manufacturing capability relates most closely to the Non-Nuclear Weapon Component Manufacturing and Assembly, Weapon Component and System Prototyping, and Weapon Component and Material Process Development capabilities.

3.18.1 Contributions to Nuclear Security Enterprise Goals

Additive manufacturing is required for DOE/NNSA's ability to support current and long-term stockpile stewardship needs due to the obsolescence of certain manufacturing technologies and materials that are used to produce nuclear weapons. Additive manufacturing is also essential to reducing the long development times and high costs that are currently associated with stockpile systems (times and costs that are unlikely to be acceptable in the future).

Additive manufacturing is already being used to reduce time and costs for non-stockpile applications, such as development hardware, tooling, models, mock-ups, training aids, etc. Estimated savings are already on the order of millions of dollars per year. As use of additive manufacturing increases, this capability will significantly reduce cost and schedule risks by providing a more versatile and agile manufacturing capability for both development and production builds. This capability will substantially reduce the time and costs for small-lot development builds, as well as enable rapid cycles of learning to reduce risk and create more optimized final designs. As experience and confidence in this emerging technology increase, much greater savings will be realized for stockpile production hardware.

Additive manufacturing will also provide exceptional control during production by keeping a greater portion of the production process in-house, thereby reducing the risks associated with reliance on unduly inefficient or intermittently unavailable suppliers. This control enables DOE/NNSA to meet DOD requirements while enhancing safety and security and remaining responsive to evolving national security requirements.

Additive manufacturing enables new design possibilities that may be used to great advantage in future systems (e.g., shapes that are impossible or impractical to manufacture with traditional methods) or smooth transitions (graded material interfaces between dissimilar materials) to address issues such as thermal expansion mismatch. 3D printing of electrical and electronic components, such as sensors, power sources, etc., may also create new design alternatives for future systems, especially modular and self-aware systems.

3.18.2 Status of Advanced Manufacturing

All of the DOE/NNSA sites are working collectively to rapidly advance additive manufacturing technology for nuclear deterrence applications. DOE/NNSA has established a multi-site Additive Manufacturing Coordinating Team to assure coordination of activities across the enterprise. However, additive manufacturing is still an emerging technology that urgently requires additional scientific understanding and development to achieve the high level of rigor required for many stockpile applications. There are a few low-risk additive manufacturing parts under strong consideration for current LEPs; however, additional work will be needed to gain the confidence required to apply additive manufacturing to more critical weapon applications.

Continued investments in process and materials R&D, equipment, and infrastructure are essential if additive manufacturing is to be advanced as a capability and broadly implemented for nuclear weapon development and production. The resulting benefits in agility, cost, and time savings will pay strong dividends on the investments to mature this critical technology.

3.18.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
There is currently no reliable, cost effective, means to certify additive manufacturing production parts.	DOE/NNSA will task the Additive Manufacturing Coordination Team to develop a qualification and certification framework that can be applied to multiple additive manufacturing processes. Advance the development of next generation additive manufacturing technology for weapon production.
The swiftly changing nature of the capability causes a rapid rate of obsolescence of equipment.	Develop an acquisition strategy to regularly procure equipment for this emerging capability.
There is insufficient dedicated space for additive manufacturing development activities. New additive manufacturing technologies will compete for floor space now being occupied by equipment sustaining older, sunset technologies.	Complete setup of an Advanced Manufacturing Facility at KCNSC. Pursue space options at other sites as needs arise and capability needs increase.
The current lead time to assess new manufacturing technologies for the stockpile is 7–10 years.	Apply principles of accelerated cycles of learning to emerging additive manufacturing processes and materials to reduce lead times.

3.19 Weapon Component and Material Process Development

The Weapon Component and Material Process Development capability is focused on research, development, engineering, and integration of technologies into production operations to improve cycle time, cost, safety, security, reliability, and performance. This process entails improving required manufacturing, scientific, and engineering capabilities while providing DOE/NNSA with cost-effective production processes that reduce risks for future weapons systems. Development of these technologies is subject to a technology readiness level and manufacturing readiness level assessment process.

The Weapon Component and Material Process Development capability is integral to all aspects of nuclear weapon research, design, development, testing, processing and manufacture, resulting in a strong interdependence with other Weapons Activities capabilities.

3.19.1 Contributions to Nuclear Security Enterprise Goals

The Weapon Component and Material Process Development capability develops innovative manufacturing processes necessary to replace sunset technologies, upgrade existing technologies, and introduce future technologies to support maintaining the safety, security, and effectiveness of the stockpile. It also provides improvements in technology and new manufacturing techniques to lessen schedule and cost risks in future applications.

Finding Better Processes

DOE/NNSA engineers and developers are constantly seeking better manufacturing processes to meet national security mission demands. For example, cellular silicone is used in stockpile applications, but the peroxide used to cure cellular silicone has not been commercially available since 2001 due to significant safety concerns associated with the traditional production process. DOE/NNSA engineers recently developed a method to safely manufacture this silicone material using microreactor technology. Because the peroxide curing agent is produced on-demand and in small quantities, it is inherently safe. This new process was rapidly transferred from R&D to full-scale production. The process is being used to produce development parts and will be used to produce W80-4 parts. This microreactor silicon manufacturing process mitigates a critical material supply risk and is expected to save over $1 million.

Micromixer chip for rapid mixing in the microreactor.

3.19.2 Status of Weapon Component and Material Process Development

Programs associated with the Weapon Component and Material Process Development capability continue to develop and improve multi-system component and manufacturing processes to avoid costs and reduce schedule risk for the nuclear security enterprise. Work scopes focus on the following areas:

- Replacing aging and obsolete manufacturing and inspection processes by incorporating digital and advanced manufacturing on the production line.
- Advancing the development of hardware, materials, equipment, and development processes, as well as demonstrating that technology or manufacturing readiness levels are sufficient to transition to a program of record.
- Conducting studies that identify options for advanced capabilities and replacement of sunset technologies affecting the enduring and future stockpile.
- Investigating options for limited life components (LLCs) and other replacement components.

3.19.3 Challenges and Strategies

Challenge	Strategy to Address Challenge
Limited opportunities to insert refurbished and new parts into the stockpile due to the 7-10 years of development before the start of Alts and LEPs.	Develop more opportunities to insert refurbished and new parts prior to the start of Alts and LEPs.
The supply chain for current materials, such as magnesium oxide for thermal batteries or polymers, is becoming obsolete.	Develop in-house capabilities to produce the needed materials.
Aging facilities are beyond expected life. Facilities are degrading faster than anticipated due to multiple LEP and Alt workloads.	Develop new and improved manufacturing processes that have smaller footprints, reduce cost and cycle time, and increase throughput and capacity.

3.20 Handling, Packaging, Processing and Manufacturing of Energetic and Hazardous Materials

The Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Materials capability includes the means to safely and securely handle, package, process, manufacture, and inspect products made from energetic and hazardous materials. Hazardous materials (e.g., lithium, beryllium, mercury) have the potential to harm humans, animals, or the environment. Energetic materials (e.g., explosives and propellants) and hazardous materials require special conduct of operations, containment equipment, and facilities to handle, process, or manufacture products from these materials. Across the nuclear security enterprise, DOE/NNSA laboratories and production sites handle energetic and hazardous material as a part of the nuclear weapon sustainment and LEP missions.

Replacing 1940s-Era Facilities at Pantex

Many buildings across the complex date back to the Manhattan Project. Two major proposed projects at Pantex, the High Explosive Formulation facility and Laboratory Replacement facility, would replace buildings that have served the complex since before the successful Trinity test in 1945. Requirements are being formulated for the proposed High Explosive Formulation facility and it could replace up to eight buildings with original construction dates ranging from 1942 to 1966.

The Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Materials capability is required to support Defense Programs' goals of executing DOE/NNSA's weapon component life extension, dismantlement, and surveillance (including core surveillance and joint test assembly [JTA] production) missions.

3.20.1 Contributions to Nuclear Security Enterprise Goals

Hazardous and energetic materials are used both in the processes to produce weapon systems and in the weapon systems themselves. Across the complex, the Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Material capability expands capacity through recapitalizing space and equipment, increases efficiency through process refinement, and addresses an increasing workload by taking advantage of advanced manufacturing initiatives, consolidating activities into modern facilities, and recapitalizing where facility upgrades are not immediately anticipated. Recapitalization of facilities and equipment reduces maintenance downtime and repeated work, increases staging capacity, and allows better management of the workload.

3.20.2 Status of Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Materials

The equipment used to support this capability has many single points of failure due to the unique and complex nature of the equipment. Energetic and hazardous material equipment is maintained through rigorous corrective maintenance, preventive maintenance, and calibrations. Programmatic supporting equipment and infrastructure need upgrades. Replacements and upgrades are ongoing to address the most critical needs to continue supporting mission deliverables.

Handling of hazardous components requires personnel with extensive training and a focus on safe operations. Rates of retirement, retention, and the length of the clearance process for employees create risks to this capability across the nuclear security enterprise. Due to increased workload demands and staff attrition, some activities within this capability have a workforce that is relatively new to the job.

3.20.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Maintaining aging equipment until upgrades or replacements can be executed.	Maintenance, Operations, and Stockpile Services funding helps keep aging equipment available for LEPs and current stockpile systems. In cases where manufacturers cannot support activities (due to part or manufacturer obsolescence), creative methods for procurement have involved using the additive manufacturing capability to manufacture parts, etc.
Avoiding loss of subject matter experts in key areas.	National security laboratories and nuclear weapons production sites, anticipating multi-year training and clearance requirements, have increased hiring and are working to pass on knowledge from subject matter experts near retirement age. Knowledge from subject matter experts is also being captured through documentation programs targeting critical knowledge areas.
Vended components are impacting mission schedules due to difficulty in maintaining qualified vendors for quality and Nuclear Enterprise Assurance complexities.	DOE/NNSA is working toward establishing clear requirements for Nuclear Enterprise Assurance and, when necessary, looking to bring capabilities that are putting mission schedules at risk back into the core complex.
Continuing operations in aging facilities with increasing safety, security, and environmental requirements and maintaining them until their transition to newly deployed facilities.	Sites and programs are working together to make short-to medium-term recapitalization investments where reasonable and to find creative solutions to maintain facilities past their useful life.

3.20.4 Lithium

3.20.4.1 Contributions to Nuclear Security Enterprise Goals

DOE/NNSA uses lithium to manufacture nuclear weapon components. DOE/NNSA also supplies lithium materials to the Tritium Sustainment Program (for the production of tritium-producing burnable absorber rods [TPBARs]), Department of Homeland Security (DHS), and DOE's Office of Science.

3.20.4.2 Status of Lithium

DOE/NNSA's lithium work is performed at Y-12 in a Manhattan Project-era facility that has experienced accelerated degradation due to the use of hazardous chemical production process equipment that is often at its end of life. The process equipment is well past its end of life. Most of the operating equipment was installed in the 1980s, and the purification equipment was shuttered in 2013 due to increased maintenance costs and decreased reliability. The program currently relies on a material recycle process that includes surface cleaning of qualified material prior to its use in the production process.

DOE/NNSA will maintain and restart required lithium capabilities to support Defense Programs requirements until the new lithium production capability is online. This includes recapitalization of needed infrastructure and process equipment, continuous management of the supply and demand signal, and maturation of technologies to make lithium processing safer and more efficient.

3.20.4.3 Challenges and Strategies

A Lithium Bridging Strategy has been developed to identify how major challenges will be addressed. Implementation plans are being developed to determine more specific actions necessary.

Challenge	*Strategy to Address Challenge*
The Lithium Bridging Strategy depends on lithium technology development work in Building 9202.	DOE/NNSA will develop and mature lithium production technologies to introduce efficiencies into the current process and prepare for insertion of these new technologies into the lithium production capability.
The Lithium Bridging Strategy also depends on the ability of Weapons Dismantlement and Disposition to dismantle weapons systems to provide needed lithium materials for LEPs.	A few processes will be restarted in the existing lithium processing facility in the near term to provide additional feedstock material. In addition, a new material recycle cleaning station is being deployed to provide additional recycling capacity.

3.21 Handling, Packaging, Processing, and Manufacturing of Special Nuclear Materials

Special nuclear material (SNM) is defined in the *Atomic Energy Act of 1954* as all isotopes of plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. Plutonium and enriched uranium operations are central to supporting the DOE/NNSA mission pillars of maintaining a safe, secure, and effective nuclear deterrent and providing operational support for the naval nuclear propulsion plants. Accomplishing these missions requires the ability to handle, package, process, manufacture, and inspect SNM-based products. This capability spans a number facilities and programs across the nuclear security enterprise. A common obstacle is the need to refurbish or replace the aging and obsolete facilities in which these and other strategic materials are handled. The strategies presented below for the overall capability are organized by the individual materials and supporting programs. The following sections also outline solutions or bridging strategies to address and manage implementation of capability investments for each type of SNM.

3.21.1 Plutonium

3.21.1.1 Contributions to Nuclear Security Enterprise Goals

Manufacture and surveillance of pits and other plutonium components, as well as experiments and analysis of plutonium alloys, occur primarily at LANL's Plutonium Facility (PF-4). SNL, LLNL, Pantex, and the Nevada National Security Site also provide the necessary expertise, capabilities, and facilities to support DOE/NNSA's defense-related plutonium missions.

3.21.1.2 Status of Plutonium

The use of plutonium requires proper storage facilities, safe and secure disposal pathways, unique equipment and facilities for R&D activities, and modern plutonium pit production capabilities. Almost all plutonium processing for the nuclear weapons program (i.e., recovery, characterization, component fabrication, nondestructive analysis, and surveillance), as well as basic applied research on plutonium, is conducted in LANL's TA-55. PF-4 within TA-55 is a Hazard Category 2 nuclear facility and is the only DOE/NNSA facility that is currently authorized to produce pits for the enduring stockpile. DOE/NNSA continues to invest in PF-4 to establish an enduring 30-pits-per-year production capability by FY 2026, and to maintain LANL as the Nation's Plutonium Center of Excellence for Research and Development. Meeting future production requirements requires an additional high-hazard, high-security footprint to produce an additional 50 pits per year, for an ultimate long-term sustained production level of at least 80 pits per year in 2030.

An Analysis of Alternatives (AoA) completed in September 2017 identified LANL and SRS as two alternative locations to accomplish this enduring mission. To further inform the identification of a preferred alternative, NNSA completed an engineering assessment and workforce analysis in May 2018. The engineering assessment and AoA provided analysis related to cost, schedule, risk, and feasibility for the alternatives. The workforce analysis examined workforce and staffing environments at SRS and LANL and found that both localities demonstrate the ability to meet future staffing requirements for plutonium pit production.

On May 10, 2018, the Administrator informed Congress that NNSA's recommended alternative is to repurpose the Mixed Oxide Fuel Fabrication Facility (MFFF) at SRS for production of 50 War Reserve plutonium pits per year in 2030, while maximizing pit production at LANL to produce at least 30 pits per year by 2026. This alternative is the optimal path forward to meet pit production requirements while managing the risks and costs associated with increasing production rates and maintaining existing plutonium operations at LANL. A conceptual design for repurposing MFFF will be used to develop CD-1 for the Deputy Secretary's final review and decision.

DOE/NNSA continues to invest in facilities and equipment (i.e., acquire, install, configure and authorize equipment for operation) to replace an aging base capability to manufacture and certify pits. Through a series of TA-55 Reinvestment Projects (TRP I, TRP II, and TRP III), DOE/NNSA has addressed PF-4's aging infrastructure and systems. Additionally, the Chemistry and Metallurgy Research Replacement project maintains continuity in analytical chemistry and materials characterization capabilities by transitioning these activities from the Cold War-era Chemistry and Metallurgy Research facility to newer facilities. The first two subprojects have approved baselines and are on schedule to be completed in 2022.

The largest portion of the U.S. weapons-usable plutonium inventory is in the form of retired pits. DOE/NNSA continues to execute a strategy to repurpose and reconfigure nuclear material bays to stage the pits recovered from dismantlement, surveillance, and disassembly for LEP weapons to address pit staging capacity at Pantex until a long-term staging facility is available. Additionally, the LANL and LLNL national security laboratories continue to direct pit surveillance to be conducted annually at LANL, Pantex, the Nevada National Security Site, and LLNL. DOE/NNSA continues to invest in additional pit nondestructive evaluation throughput capacity (e.g., the Confined Large Optical Scintillator Screen and Imaging System [CoLOSSIS] II and the Laser Gas Sampling Station II) to collect sufficient pit surveillance data to support the laboratories' annual assessment report.

3.21.1.3 Challenges and Strategies

Challenge	Strategy to Address Challenge
Additional Hazard Category 2 nuclear facility space will be required to manufacture at least 80 pits per year. Acquiring the necessary facility and transitioning and operating at full capacity will pose several integration and schedule challenges.	NNSA's recommended alternative is to repurpose the SRS's Mixed Oxide Fuel Fabrication Facility to produce 50 War Reserve plutonium pits per year in 2030. Concurrently, NNSA will continue to invest in LANL to produce an enduring 30 War Reserve pits per year in 2026.
The staging capacity at Pantex is projected to become inadequate within the next decade as more weapons are dismantled, creating additional operational inefficiencies involving required movements of these items.	To address long-term pit staging capacity at Pantex, a new Material Staging Facility at Pantex is being planned. CD-0 (Mission Need) for the facility was completed in FY 2015.
Continued management of transuranic (TRU) waste generated from de-inventory of the PF-4 vault and Chemistry and Metallurgy Research directly, is critical to avoid imposing an operational constraint on plutonium programs throughout the nuclear security enterprise. Startup of LANL's TRU Waste Facility is essential to provide waste staging capacity until the Waste Isolation Pilot Plant (WIPP) begins accepting full shipments from LANL.	LANL continues to manage TRU waste, which reduces the operational risk to plutonium programs. LANL has developed a strategic plan for the management of newly generated TRU waste until WIPP is fully operational. Additionally, startup of and continued shipments to LANL's TRU Waste Facility will help maintain adequate TRU waste storage at LANL for nuclear mission work until WIPP shipments fully resume.
The only pit production workforce capability in the Nation currently exists at LANL.	LANL has developed a plan to acquire, train, and retain staff to support the 30-pits-per-year production mission. Training of the initial SRS personnel to support 50 pits per year will be accomplished during production at PF-4 with LANL personnel.
The long-term supply of plutonium-238 will be insufficient to meet the Nation's needs for use by Defense Programs, the National Aeronautics and Space Administration, and other Government agencies.	NNSA is investigating preliminary options to establish a domestic capability to produce new plutonium-238.

3.21.2 Uranium

3.21.2.1 Highly Enriched Uranium

Highly enriched uranium (HEU) is uranium in which the concentration of the fissile isotope uranium-235 is increased to 20 percent or greater.

Contributions to Nuclear Security Enterprise Goals

Uranium is a strategic national defense asset with different assays and enrichments (depleted uranium, low-enriched uranium, and HEU) being used in a wide variety of applications, including weapon components, naval reactors, and fuel in commercial power reactors for the production of tritium.

Status of Highly Enriched Uranium

The primary production infrastructure to process and store uranium is at Y-12; R&D capabilities are located at LANL and LLNL. Y-12's Building 9212 is over 70 years old, contains the most hazardous enriched uranium operations, and does not meet modern nuclear safety and security standards. DOE/NNSA is phasing out mission dependency on Building 9212 through a series of enriched uranium capability relocations into existing facilities at Y-12, as well as the Uranium Processing Facility when completed. To successfully execute this transition, new technologies will be deployed, and existing processes will be simplified or eliminated to increase the overall safety and efficiency of enriched uranium operations. During this transition period, material risk reduction efforts will continue.

Infrastructure investment in Buildings 9215 and 9204-2E is integral to the overall strategy. These two buildings were constructed in the 1950s and late 1960s, respectively, and their construction predates many of the modern safety standards applicable to nuclear facilities. The infrastructures and programmatic equipment in both buildings are degrading due to age and condition, and replacement facilities are not planned for several decades. Both the machining operations provided in Building 9215 and the assembly and disassembly operations occurring in Building 9204-2E must safely continue with high reliability through the 2040s. The Plant Laboratory, Building 9995, was built in the 1950s to support operations in Building 9212. This facility provides chemical analysis for the entire site. The infrastructure and analytical chemistry capabilities in Building 9995 also require additional investments to continue to support the mission.

The Uranium Processing Facility will provide new floor space for the high-hazard, high-security operations in Building 9212 that are not suitable to relocate to existing facilities. Completion and startup of the Uranium Processing Facility will enable DOE/NNSA to fully phase out mission dependency on Building 9212.

3.21.3 Challenges and Strategies

A Uranium Mission Strategy has been developed to identify how challenges will be addressed. Implementation plans are being developed to determine specific actions necessary.

Challenge	*Strategy to Address Challenge*
Transition enriched uranium capabilities into existing and new-build facilities to phase out mission dependency on Building 9212.	Implement the Building 9212 Exit Strategy, which entails complex activities to shut down Building 9212 production processes, drain and isolate systems, and facilitate post-operations clean-out of the facility.
Extend the operational lifetime of existing enriched uranium processing facilities (Buildings 9215, and 9204-2E and the Plant Laboratory in Building 9995).	Sustain existing enriched uranium capabilities through enhanced equipment maintenance and the purchase of critical spare parts to improve the availability and reliability of production systems. Current extended life programs investments focus on electrical modernization in 9204-2E and 9215.
Construct the Uranium Processing Facility to house processes currently performed in Building 9212 that cannot be transferred to another operating facility.	Capability relocations into existing facilities are executed through the Process Technology Development projects (i.e., Electro Refining, Calciner, Chip Processing/Direct Chip Melt, and 2MeV Radiography). The Uranium Processing Facility will provide new floor space for the high-hazard, high-security operations in Building 9212 that are not suitable to relocate to existing facilities.
Maintain subject matter expertise at the national laboratories in base R&D capabilities to support HEU production.	Continue two-way communications between the nuclear weapon production facilities and the national security laboratories. The laboratories will determine a path forward to provide the expertise necessary to meet production needs and recommend improvements that can be applied to HEU production.

3.21.3.1 Domestic Uranium Enrichment

Enriched uranium contains higher concentrations of the fissile uranium-235 isotope than natural uranium. Enriched uranium is required at various levels of enrichment and forms for national security and nonproliferation missions, including, but not limited to nuclear weapon components, Naval Reactors, power reactor fuel for tritium production, research reactors, and medical isotope production. NNSA is currently conducting an AoA to determine how best to meet the mission need for enriched uranium.

Contributions to Nuclear Security Enterprise Goals

A domestic uranium enrichment capability provides a reliable supply of enriched uranium to support the tritium production, nonproliferation, and Naval Reactors missions.

Status of Domestic Uranium Enrichment

The United States currently has no domestic uranium enrichment capability. Mission needs for enriched uranium are currently fulfilled using the United States' remaining HEU stockpile, which is a finite source. DOE/NNSA is funding a down-blending campaign to extend the need date for low-enriched uranium fuel for tritium production to 2038-2041. Current HEU inventories are anticipated to supply Naval Reactors through the 2050s. In support of the domestic uranium enrichment program, DOE/NNSA is funding two separate centrifuge R&D programs at Oak Ridge National Laboratory. The first is the continued development of Centrus Energy Corporation's AC100 centrifuge; the second is a smaller alternative designed by Oak Ridge National Laboratory. The Domestic Uranium Enrichment program established CD-0 (Mission Need), for re-establishment of a domestic uranium enrichment capability and has initiated an AoA. The capability will be established in time to meet the 2038 need for tritium production.

Challenges and Strategies to Address Them

The capability to enrich uranium faces manageable challenges. The table below captures some of the major challenges and the activities to address them.

Challenge	***Strategy to Address Challenge***
Only one down-blender is operational for national security purposes, and that operation will be closed down if DOE/NNSA stops providing material. DOE/NNSA needs to decide in the early to mid-2020s whether the down-blending capability should be maintained. Additional down-blending would require reallocating material from other programs and further diminishing a currently irreplaceable resource.	DOE/NNSA plans to re-establish a domestic uranium enrichment capability in time for the tritium need date and does not anticipate requiring additional down-blending beyond currently planned campaigns.

3.21.3.2 Depleted Uranium

DOE/NNSA has a long-term requirement for high-purity depleted uranium metal feedstock to meet national security mission needs.

Contributions to Nuclear Security Enterprise Goals

The capability to produce, process, and handle depleted uranium supports a number of key missions within the nuclear security enterprise, from providing parts for LEPs to the down-blending of HEU to low-enriched uranium.

Status of Depleted Uranium

Inventories of high-purity depleted uranium metal feedstock are being exhausted. DOE has a large quantity of depleted uranium in the form of depleted uranium hexafluoride (DUF_6) gas, a byproduct of enriching uranium, stored in cylinders at its sites in Portsmouth, Ohio, and Paducah, Kentucky. Currently, DOE/NNSA does not have the capability to convert it to depleted uranium tetrafluoride (DUF_4). DOE/NNSA has evaluated various options for re-establishment of the capability to convert DUF_6 to DUF_4 and has made a decision regarding the path forward. Re-establishment efforts will begin in FY 2019.

Challenges and Strategies

Challenge	Strategy to Address Challenge
Commercial capabilities do not exist to convert DUF_6 to DUF_4. DOE/NNSA projects a shortfall of depleted uranium between FY 2029 and FY 2031.	Continue advancing those technologies that are currently planned for deployment in the field as well as technologies that will be required to meet future mission needs. Investigate alternate processes and technology improvements that can increase the efficiency of traditional manufacturing processes. DOE/NNSA has evaluated various options for re-establishment of the capability to convert DUF_6 to DUF_4 and has made a decision regarding the path forward. Re-establishment efforts will begin in FY 2019.

3.22 Tritium Production, Handling, and Processing

Tritium is a material used to increase weapon system margins to ensure the weapon system meets required military characteristics. The creation, handling, and processing of tritium includes the recovery, extraction, refinement, storage, filling, and inspection of gas transfer systems (GTSs). Tritium has a 12-year half-life and must be periodically replenished in GTSs. The Tritium Production, Handling, and Processing capability is vital to the Non-Nuclear Weapon Component Manufacturing and Assembly capability.

3.22.1 Contributions to Nuclear Security Enterprise Goals

Tritium is a key material for the proper functioning of nuclear weapons. DOE/NNSA delivers tritium-filled GTSs (which are LLCs) to DOD as part of the nuclear weapon stockpile. GTSs are designed, produced, filled, and delivered for existing and future weapon systems. The Savannah River National Laboratory partners with the national security laboratories to conduct GTS R&D.

3.22.2 Status of Tritium

Tritium Recycle and Recovery

DOE/NNSA's ability to maintain the tritium capability is sufficient to meet the current stockpile and other national security needs. The capability requires continual processing of tritium and other isotopes to maintain the purity requirements specified by the design agencies, as well as the ability to handle and store large quantities of tritium.

Tritium Production

Production of tritium is increasing, as planned, to meet the goal of producing 2,800 grams per reactor cycle by 2024. The production of tritium is one element necessary for NNSA to supply limited life components to the military. This year, 1,104 TPBARs are being irradiated in the Watts Bar Unit 1 reactor. The goal is to insert at least 1,792 TPBARs in each of the two Watts Bar reactors in FY 2023. Three consecutive cycles of tritium extraction from irradiated TPBARs have been completed using recently upgraded extraction processing equipment and infrastructure. Completing three cycles of tritium extraction demonstrates that tritium production and extraction have been reconstituted, adding to the tritium inventory used to fill GTS reservoirs for the stockpile and to meet national security requirements.

Tritium Production

DOE/NNSA is meeting its production goals defined in FY 2015 baseline change proposal. Tritium production rates will increase from approximately 1,700 grams to 2,800 grams per cycle by 2025 through a stepwise increase of irradiating TPBARs to meet tritium requirements, as certified by the Nuclear Weapons Council. This capability uses very unique and specialized equipment that often has single source suppliers. Ensuring capable vendors and/or development capabilities is necessary to maintain this capability.

3.22.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
The Watts Bar Nuclear Plan Unit 1 and 2 licenses will be at the 60- and 40-year renewal points, respectively, in 2055. NNSA must monitor the nuclear energy industry during this time and its impact on the approaches being evaluated.	Studies over the next several years will look at various approaches to meeting long-term tritium production needs and will explore ways to mitigate such risks.
The gas transfer system loading capacity is insufficient to support the 2018 *Nuclear Posture Review* strategy because of the complex system designs and concurrent production of multiple weapon systems.	Modifications to the loading process equipment in multiple SRS facilities will be implemented by FY 2020 to support the mission and avert this issue.
Recapitalization efforts are necessary to sustain processing capabilities and are often competing with other program priorities.	Capabilities to recover and recycle tritium will be maintained and technology investments will be reviewed to determine the best investments to efficiently operate and maintain this infrastructure. A comprehensive recapitalization plan is being developed to ensure continuity of GTS operations, such as the isotope separation column and storage bed replacement.

3.23 Metal and Organic Material Fabrication, Processing, and Manufacturing

Beyond plutonium, uranium, and HE, a large array of weapon components and materials must be produced within the nuclear security enterprise, either because they have unique requirements, they are classified, the raw materials have limited to no other use, or all three. Production of these components requires the enterprise to synthesize materials and process, manufacture, and inspect the resulting components using our knowledge of material behavior, compatibility, and aging.

3.23.1 Contributions to Nuclear Security Enterprise Goals

The Metal and Organic Material Fabrication, Processing, and Manufacturing capability to synthesize, fabricate, or manufacture organic, inorganic, and non-SNM metallic components has enabled the development, certification, and production of all legacy systems, as well as the corresponding LEPs and Alts, and has been central to performing the science experiments that build confidence in the ongoing reliability of the nuclear deterrent. This capability has provided test and War Reserve components, as well as a wealth of data on the static and dynamic materials properties of materials that are critical for design and certification of weapons.

3.23.2 Status of Metal and Organic Material Fabrication, Processing, and Manufacturing

The nuclear security enterprise maintains a broad and specialized capability to fabricate, process, prototype, and manufacture all organic and metallic materials and components for weapon systems. This enterprise-wide capability also plays a critical role in the focused and integrated experiments that, when coupled with HPC capabilities, enable continued certification in the absence of testing. This capability plays a critical and indispensable role in all LEPs. While many of the enterprise's relevant legacy facilities and equipment are adequate to meet today's needs, these facilities continue to age. The capability is also increasingly at risk due to changes in the availability of raw materials (feedstocks) and the evolving health and safety concerns that are increasingly associated with legacy processes. New, digital advanced manufacturing methods (including additive) are being developed and matured across the complex for metal, organic, and inorganic materials. Coupled with advances in computational design and machine learning-enabled defect detection and correction, these capabilities should enable a more responsive enterprise.

3.23.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Aging infrastructure: Complex-wide, major building systems, as well as synthesis, processing, manufacturing, and characterization capabilities are sized for a Cold War complex and are increasingly beyond designed service life or are out of date regarding modern environment, safety, and health standards.	Develop more responsive and efficient capabilities through reinvestment in capital and adoption of modern technical approaches. Continue support for a rational transition to advanced manufacturing processes and digital manufacturing paradigms. Some examples include: • Create new additive production facilities at KCNSC. • Continue reinvestment in the Beryllium Technology Facility and the SIGMA facility replacement (LANL). • Modernize facilities across the complex to support new manufacturing processes.
Qualification and certification: Almost all materials and components within future systems will need to be replaced due to changes in feedstocks, manufacturing methods, and/or component designs. These changes can be necessitated by supply chain disruptions; evolving environment, safety, and health requirements; process obsolescence; or evolving design requirements. Development of efficient approaches to qualification and certification is required.	Close integration with the material science, system and component engineering, and design physics communities and adoption of advanced and digital manufacturing approaches will be critical to providing a responsive route to qualification and certification. The use of advanced data informatics and machine learning should be developed and exploited to accelerate qualification of new processes or updates to old processes. Improved capabilities in nondestructive evaluation and in-situ characterization tools will also facilitate science-based understanding of material and component process linkages to performance and thus enable more efficient qualification.
Workforce Sustainment: Strategies are needed for workforce sustainment, particularly in areas dominated by legacy manufacturing processes.	Adoption of modern and cutting-edge manufacturing approaches will provide a draw for the next generation of nuclear security enterprise staff, including additive manufacturing and computational design of materials and components.

3.24 Non-Nuclear Weapon Component Manufacturing and Assembly

The Non-Nuclear Weapon Component Manufacturing and Assembly capability includes the manufacture, assembly, and inspection of all non-nuclear weapon components. Many non-nuclear weapon components require special manufacturing and inspection protocols. Non-nuclear weapon components include power sources, radiation-hardened microelectronics, neutron generators, GTSs, AF&F assemblies, environmental sensing devices, structural parts, cushions, pads, spacers, engineered polymeric components, and other specialized electro-mechanical components. During the construction of the weapon, this capability validates the following:

- Parts are manufactured within acceptable tolerances.
- Materials meet design specifications.
- Assemblies fit together precisely.
- Connectors connect firmly and fit perfectly into allotted spaces.

To provide high-quality products, this capability depends on the Weapon Engineering Design, Analysis, and Integration capability, as well as that Weapon Component and System Prototyping capabilities are exercised with precision. The Advanced Manufacturing capability is also strongly tied to this capability.

3.24.1 Contributions to Nuclear Security Enterprise Goals

The Non-Nuclear Weapon Component Manufacturing and Assembly capability results in the delivery of all non-nuclear weapon subcomponents and component assemblies in nuclear warheads. Much progress has been made in rapid prototyping and the Advanced Manufacturing capability, which has accelerated production, reduced production issues, and delivered better overall products at lower costs.

3.24.2 Status of Non-Nuclear Weapon Component Manufacturing and Assembly

Most of the production of non-nuclear components occurs at KCNSC. While the leased KCNSC facility is relatively new and is well configured with appropriate flexibility for manufacturing, many pieces of existing programmatic equipment were moved from the old Bannister facility. As a result, the continuity of operations is at risk as that equipment ages and approaches end of life or becomes obsolete.

DOE/NNSA is becoming more dependent on internal suppliers because it is becoming more difficult to find trusted sources for non-nuclear weapon components such as power sources and radiation-hardened microsystems. As this occurs, more investment in facilities, equipment, and infrastructure is needed for certain product lines.

The Neutron Generator Enterprise at SNL has production lines and programmatic equipment that require sustained investments over time to keep the production capability responsive. The same is true for the radiation-hardened microsystems capability. Prudent asset management and monitoring of equipment has kept the neutron generator enterprise robust. In the long term, capital reinvestment will be crucial to maintaining the suite of DOE/NNSA’s manufacturing capabilities.

3.24.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Aging and inadequate specialized facilities and equipment for manufacturing non-nuclear weapon components put sufficient mission capacities and reliability at risk.	The Capability-Based Investments program is providing interim relief for some of the critical equipment needs related to these key product lines. Leverage industrial best management practices to apply across key component production areas. Long-term, DOE/NNSA must plan and execute major investments in facilities, infrastructure, and equipment for key production sites.
Weapon program schedules and requirements are driving the need for increased production capacity across all areas. As a result, more manufacturing floor space and associated support space.	DOE/NNSA will develop options for additional space or more efficient use of existing space. The most prudent option will be implemented.

3.25 Weapon System Assembly and Disassembly

The Weapon System Assembly and Disassembly capability involves assembly, disassembly, and inspection of nuclear weapons systems. Weapons system assembly involves final assembly of the nuclear and non-nuclear components. Lower-level assembly operations are required for both nuclear and non-nuclear components.

This capability is integral to surveillance, production, and prototyping of systems for DOD; DOE/NNSA activities associated with the Weapon Component and System Surveillance and the Assessment and Testing Equipment Design and Fabrication capabilities; and weapon dismantlement and disposition.

3.25.1 Contributions to Nuclear Security Enterprise Goals

The Weapon System Assembly and Disassembly capability provides disassembly, inspection, and storage or disposal of the components of a nuclear weapon through special conduct of operations, quality control, equipment, and facilities throughout the nuclear security enterprise.

3.25.2 Status of Weapon System Assembly and Disassembly

The Weapon System Assembly and Disassembly capability includes performing hazards analysis and weapons response studies for authorization bases, as well as providing engineering evaluations in support of weapon disassembly for surveillance activities.

Equipment support is a large part of this capability and is maintained through rigorous corrective maintenance, preventative maintenance, and calibrations. Examples of equipment supporting this capability include gloveboxes, ovens of many types, lathes of varying sizes, environmental chambers and rooms, nondestructive laser gas sampling devices, coordinate measurement machines, radiography machines, etc.

3.25.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Aging equipment and facilities that support this capability are worn out and/or have not been replaced.	DOE/NNSA continues to execute a strategy for major facilities, infrastructure, and equipment projects that includes refurbishments and replacements to support weapon assembly and disassembly operations.
The largest portion of the U.S. weapons-usable plutonium inventory is in the form of retired pits. As more weapons are dismantled, the staging capacity is projected to become inadequate within the next decade.	DOE/NNSA is working on a strategy to address staging capacity issues for the future.

3.26 Testing Equipment Design and Fabrication

The Testing Equipment Design and Fabrication capability includes design and fabrication of special test equipment to simulate environmental and functional conditions and collect performance and diagnostic data to evaluate against requirements. Data from the test equipment provide evidence for process qualification, weapon certification, reliability, surety, product acceptance, and stockpile evaluation and are used to evaluate performance at all levels of assembly.

This capability is integral to several other DOE/NNSA Weapon Activities capabilities in aspects of nuclear weapon research, design, development, testing, processing, and manufacture, resulting in a strong interdependence with other Weapons Activities capabilities.

3.26.1 Contributions to Nuclear Security Enterprise Goals

The Testing Equipment Design and Fabrication capability designs and produces testing equipment to provide the ability to test, surveil, assess, and certify weapon components in the stockpile. Test equipment provides mechanical, electrical, and radio-frequency stimuli to the system in a specified sequence to simulate a weapon employment scenario and collects data on performance of components, subsystems, and systems.

This capability also performs design and fabrication of test-specific hardware (e.g., test-specific cables/connectors and containment structures), centrifuges, environmental chambers, telemetry systems, radar/tracking systems, and similar equipment necessary to enable mission simulation and data collection.

Testing Equipment Architecture That Saves Time and Money

A common tester architecture (CTA) consisting of standardized hardware and software is used to reduce costs and development time for production testers. In 2017, use of the CTA saved more than 55,000 engineering hours and provided cost avoidance of $6.8 million for testers being built for B61-12 LEP and W88 Alt 370. CTA development began in 2008, and was qualified for production use in 2013. CTA has been implemented in more than 100 testers to date. The majority of W80-4 testers will be CTA-based.

CTA tester used to develop new CTA based capabilities

3.26.2 Status of Testing Equipment Design and Fabrication

The Testing Equipment Design and Fabrication capability underpins design and stockpile evaluation activities through advanced system and component test equipment that has been developed to diagnose margins and robustness at the system and component level.

3.26.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Replacement parts, software upgrades, maintenance for test equipment, and test-specific hardware, are often hard to acquire.	Develop a modular approach to system testers that will enable more commonality and flexibility across systems to provide more cost-effective spares management, upgrade or repair frequencies, and operations, as well as a reduced footprint.
Testing hardware performance under more realistic environmental conditions, such as combinations of stimuli.	Obtain a design and fabricating test capability that will stress components and systems under multiple concurrent environments. This capability will qualify and assess designs under more realistic conditions and emerging threat scenarios.
Recapitalizing one-of-a-kind testing equipment that is nearing or beyond end of life and subject to single-point failures (e.g., system-level acceptance testers, unique centrifuges).	Develop and execute a strategy to replace or modernize existing facilities and recapitalize programmatic equipment to prevent technical obsolescence.
Modern weapon systems require testers to collect and save large volumes of data for acceptance and surveillance. Handling, storage, transport, retrieval, and searching this data set are challenging.	DOE/NNSA is working with a larger consortium on developing solutions for handling, storage, transport, retrieval, and searching large amounts of data.
Testers are often viewed as a commodity that should be procured from industry. However, given that test equipment directly interacts with nuclear weapon hardware, maintenance of an in-house design and manufacturing capability needs to be balanced with industry engagement and procurement.	Where the risks and benefits are appropriate, DOE/NNSA sites will continue to maintain critical capabilities in house, while utilizing industry standards, hardware, and software.

3.27 Weapon Component and System Surveillance and Assessment

A B-2 drops a B61 Joint Test Assembly during a surveillance flight test.

The surveillance capability evaluates weapons and components across test regimes to demonstrate that stockpile systems continue to meet design and performance requirements. Such evaluations take place through inspections, laboratory and flight tests, destructive and nondestructive tests, and component and material appraisals. Comparing surveillance results over time provides the ability to detect, assess, and resolve aging trends and anomalous changes in the stockpile; potentially predict phenomena before the stockpile is affected; and address or mitigate issues or concerns. Specifically, surveillance addresses the following concerns:

- Component quality and assembly of refurbished warheads.
- The ability of the weapons to perform in DOD's STS environments.
- Growth of defects over time in aging warheads.
- The safety of the inactive stockpile.

Surveillance activities provide the assessment community with key data for determining the stockpile's safety, security, and reliability throughout each weapon's lengthy life cycle.

The Weapon Component and System Surveillance and Assessment capability is integral to all aspects of nuclear weapon and component research, design, development, testing, processing and manufacture, resulting in a strong interdependence with other Weapons Activities capabilities.

3.27.1 Contributions to Nuclear Security Enterprise Goals

The Weapon Component and System Surveillance and Assessment capability provides data to evaluate the condition of the stockpile in support of the annual assessments of safety, security, reliability, and performance. The cumulative body of surveillance data supports decisions regarding weapon life extensions, Alts, Mods, repairs, and rebuilds.

3.27.2 Status of Weapon Component and System Surveillance

The Weapon Component and System Surveillance capability can be subdivided into Stockpile Evaluation and Enhanced Surveillance activities. Stockpile Evaluation conducts surveillance evaluation of both the existing stockpile and new production. Enhanced Surveillance provides diagnostics, processes, and other tools to Stockpile Evaluation to predict and detect initial or age-related defects, assess reliability, and estimate component and system lifetimes.

Surveillance Capability Risk Assessment

The Office of the Nuclear Weapon Stockpile has developed and deployed a prototype Surveillance Capability Risk Assessment System. After completing an initial data call, the Risk Assessment System has informed risk management plans and driven actions to address surveillance capability concerns in the nuclear security enterprise. The current goal is to transition the system from a "snapshot" mechanism to a sustainable management tool.

Surveillance data are gathered through a number of methods. In the case of flight tests (also discussed in Section 3.17), recently produced weapons or those returned from the stockpile are disassembled; non-nuclear components, along with surrogate parts for nuclear components, are used to build a JTA, which is delivered to DOD for flight testing. In a similar manner, hardware from newly produced or returned stockpile weapons are utilized for system or component laboratory testing. Finally, in accordance with a 7-year baseline established by the NNSA's Surveillance Executive Steering Committee, the Surveillance program continues to provide data evaluating the condition of the stockpile in support of the annual assessments. The surveillance mission currently anticipates meeting national security laboratory needs with an acceptable level of risk.

3.27.3 Challenges and Strategies

Challenge	*Strategy to Address Challenge*
Increased workload throughout the enterprise, coupled with aging facilities and equipment, is a risk.	DOE/NNSA is deploying innovative management tools to facilitate a data-driven, risk-informed planning process that will guide investment decisions. Sites are also making efforts within budgets to recapitalize facilities and equipment in support of multiple capabilities.
Limited availability of test assets to surveil.	Shift to an agile surveillance approach that can respond to risks related to aging and continue developing a systematic capability risk assessment process. Develop new capabilities to surveil emerging characteristics in a stockpile that has exceeded its design life, including pursuing improved, novel, nondestructive techniques.
Existing JTAs delivered to DOD for flight testing are unsustainable due to sunset technologies and data limitations.	Develop new JTAs to improve diagnostics capabilities for detecting smaller changes in an aging stockpile and support missile qualification.
Capabilities that directly support surveillance have deteriorated in recent years and require recapitalization to sustain execution.	Working closely with programs that maintain these capabilities, DOE/NNSA has developed risk-driven plans for recapitalization of capabilities as needed to sustain performance of the Surveillance program.

3.28 Secure Transportation

The Secure Transportation Asset (STA) Program provides safe, secure transport of the Nation's nuclear weapons, weapon components, and SNM throughout the nuclear security enterprise. The pillars of STA are specialized vehicles, secure trailers, leading-edge communication systems, and highly trained Federal Agents.

3.28.1 Contributions to Nuclear Security Enterprise Goals

Nuclear weapon LEPs, LLC exchanges, surveillance, dismantlement, nonproliferation activities, and experimental programs rely on transport of weapons, components, and SNM on schedule and in a safe and secure manner. The STA capability supports DOE/NNSA's goal to reduce the danger and environmental risk of domestic transport of nuclear cargo, and consolidate storage of nuclear material.

This capability provides secure transport for a variety of Government agencies. Because of the control and coordination required and the potential security consequences of material loss or compromise, the STA is Government-owned and operated and is subject to the reporting requirements of the Government Performance and Results Act.

NNSA Defense Programs and DOD are the STA's highest-priority customers; however, this capability also provides secure transport for other DOE/NNSA programs and offices, such as the NNSA Nuclear Counterterrorism and Incident Response Program, NNSA Office of Naval Reactors, and DOE Office of Nuclear Energy. The STA Program has safely and securely completed 100 percent of shipments without compromise, loss of components, or release of radioactive material.

3.28.2 Status of Secure Transportation

The STA Program maintains assets to support DOE/NNSA missions based on changing customer needs and current and future threats. These assets include Federal Agent equipment, vehicles (armored tractors, trailers, and escort vehicles), and aircraft.

The process of identifying, designing, procuring, and manufacturing these vehicles takes several years. The vehicle fleet is being updated with next generation armored tractors and escort vehicles. The STA Program continues to design, develop, and test subsystems and components for the Mobile Guardian Transporter (MGT), which will replace the existing Safeguards Transporter (SGT). The life of the SGT will be extended until the MGT is produced and operational. The MGT will assure the safety and security of existing and planned cargoes, protect the public, and meet nuclear explosive safety standards. The STA Program is also reviewing options to replace its aging DC-9 aircraft.

The STA is committed to a stable human resources strategy to achieve an optimal workforce level and meet priorities and mission requirements. It takes many years to achieve any substantial growth in the Federal Agent workforce due to retirements, the stringent hiring process, and attrition.

The current STA mission capacity meets the prioritized DOE/NNSA stockpile refurbishment and modernization initiatives and other DOE workloads. The Secure Transportation Steering Committee will continue to balance and prioritize customer requests against STA capacity. Since its formal creation in 1974, the STA Program has maintained a legacy of no loss of cargo and no release of radioactive material from any shipment. However, aging transportation assets must be replaced to maintain this safe and secure convoy profile.

3.28.3 Challenges

The STA Program has structured resources to address near- and long-term stockpile needs. Programmatic challenges are listed below.

- **Replace the SGT trailer fleet**. SGTs began reaching end-of-design-life in 2018, years before the first MGT will enter production. The STA Program implemented risk-reduction initiatives and allocated resources to extend the life and maintain the capability of the SGT fleet until the MGTs are produced and operational.
- **Respond to sunset technology**. Resources reaching the end of service life must be evaluated and replacement activities carefully managed so that STA can achieve the greatest benefit through life cycle management, steady-state vehicle procurement, and maintenance initiatives.
- **Forecast and meet future workload**. Future workload planning depends on the DOE/NNSA and DOD shipping forecasts, consolidation of requests, synchronization of site activities, duration of various weapon activities, and handling and delivery requirements for specific cargo.
- **Strengthen staffing**. The STA Program is focused on recruiting, stabilizing, and retaining the Federal Agent workforce to keep pace with attrition and eligibility for retirement after 20 years. In addition, the STA Program is focused on hiring and retention of Federal pilots. The complexity of the hiring process, security clearance timelines, and Human Reliability Program certification process impacts the Federal pilot and Federal Agent workforce.

- **Maintain and update facilities**. Minor construction projects, life cycle replacements, repairs, and reduction of the deferred maintenance backlog are necessary to ensure cost-effective management. The STA Program will implement industry best practices to maintain facilities in a safe and operable condition and meet all security requirements. The STA Program's Facility Board prioritizes and matches mission needs to funding levels.
- **Replace aging aircraft**. The STA Program currently owns three aircraft: one DC-9 and two Boeing 737s. The DC-9 aircraft is over 48 years old, has limited performance, and is becoming difficult to maintain. Multiple aircraft types stress the pilot and maintenance workforce. The STA Program recently completed a Business Case Analysis for replacement of the DC-9 aircraft and evaluated purchase options of new or used aircraft, types of aircraft, and lease and buy options.

3.28.4 Long-Term Vision and Strategy

To shape the organization for future operations, the STA Program has established a 5-year strategic plan that includes key strategies that are focused on improvement and change to meet long-term goals and objectives through the Future Years Nuclear Security Program (FYNSP). The key strategies are: (1) strengthen communications, capabilities, and leadership throughout the entire workforce**;** (2) enhance the already strong safety and security focus throughout the organization; and (3) modernize and strengthen mission assets and infrastructure through continuous innovation.

3.29 Physical Security

The Office of Defense Nuclear Security (DNS) provides the physical security program for the Nation's nuclear materials and infrastructure assets, as well as the personnel security clearances of the workforce at the NNSA field offices and the eight management and operating (M&O) partner sites. Beginning in FY 2019, NNSA will assume responsibility for funding the clearances of NNSA Headquarters personnel, consistent with direction provided in the Joint Explanatory Statement attached to the *Fiscal Year 2017 Omnibus Appropriations Act*. DNS coordinates with other programs (e.g., Counterintelligence and Insider Threat) to protect NNSA assets from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile or noncompliant acts that may adversely affect national security, program continuity, and employee security. DNS also provides facility clearances for contractors performing classified work for NNSA and administers the classification program to ensure information is properly identified for handling and protection. The physical security mission is carried out at each field location by dedicated and highly trained security professionals who employ an array of weapons and technologies to address general and site-specific threats.

FY 2017 Defense Nuclear Security Accomplishments

- *Submitted the 10-Year Physical Security Refresh Plan to Congress.*
- *Approved deployment and operational testing of a Counter Unmanned Aircraft System.*
- *Instituted a Security Management Improvement Program to ensure continuous improvement of the security program.*

3.29.1 Contributions to Nuclear Security Enterprise Goals

The programs and capabilities mentioned in Section 3.29.2 are arrayed against a broad range of threats to DOE/NNSA Headquarters and field offices, national security laboratories, nuclear weapons production sites, and the Nevada National Security Site. Physical security includes the safeguards and security programs that provide the day-to-day secure environment necessary to implement DOE/NNSA's national security mission.

3.29.2 Status of Physical Security

DOE/NNSA has a network of programs and technical capabilities that are integrated to achieve the highest possible level of protection for personnel, sensitive information, weapons-grade SNM, and mission-critical facilities. DOE/NNSA deploys various technologies at M&O partner sites for alarm management and control, intrusion detection and assessment, access controls, barriers and locks, secure storage, material control and accountability, package inspection, communications, protective forces, and technical surveillance countermeasures. These technologies are described below.

Alarm Management and Control Systems. DOE/NNSA sites with Category I or II quantities of SNM are expected to use the proprietary Argus system that meets all DOE/NNSA requirements for intrusion detection and access control to protect these materials. Three Category I sites have fully implemented the system, and the fourth site will complete installation in the fourth quarter of FY 2019. Three of the four non-Category I sites employ non-Argus, commercial systems. Two of these sites are scheduled to replace legacy systems with Argus in the near future, leaving just one non-Argus site in the enterprise.

Intrusion Detection Systems. An integrated, multi-layered suite of barriers, sensors, and assessment systems, including the Perimeter Intrusion Detection and Assessment System (PIDAS) for Category I or II quantities of SNM, protects NNSA assets. For applications that are exterior to facilities within a PIDAS, most sites deploy both passive and active sensors (e.g., bi-static microwave sensors, infrared sensors, fence detection systems, buried-line sensors, unattended ground sensors, long-range radar systems, and electromagnetic field detection systems). For interior applications, all sites use balanced magnetic switches on doors and/or passive alarm devices on vaults and vault-type rooms.

Access Control Systems. Access control systems use a combination of entry control and contraband detection technology to ensure authorized entry and exit. NNSA is in various stages of implementing the Identity, Credential, and Access Management program according to the *Federal Identity, Credential, and Access Management (FICAM) Roadmap and Implementation Guidance*.

Barriers and Lock Systems. State-of-the-art barrier technologies are used at some facilities, along with low-technology barriers such as concrete blocks or razor wire.

Secure Storage Systems. These systems provide additional barriers when practical for specific materials.

Material Control and Accountability. NNSA has deployed specific technologies (e.g., accounting software, tamper-indicating devices and dispensers, measurement devices, and barcode readers) at sites with SNM. NNSA has sponsored a project to modernize a software application that will serve as the standard core nuclear material accountability system. This software application provides sites and facilities with basic nuclear accountability capabilities and can be extended to accommodate site- or facility-specific requirements.

Package Inspection Systems. Several sites have deployed x-ray inspection equipment at shipping and receiving facilities to prevent introduction of contraband into protected or material access areas.

Communication Systems. These systems allow members of NNSA's Protective Force to communicate securely and with system redundancy.

Protective Force Training Reform Initiative. In 2010, DNS worked closely with DOE's National Training Center and Protective Force in response to multiple external audit reports spanning the last two decades that addressed Protective Force training program deficiencies. Exhaustive analyses revealed that clear, nuclear security-focused training objectives and performance expectation parameters common to all NNSA Protective Force mission areas were needed. These analyses assisted Protective Force training managers in defining training content, methods of instructional delivery, and appropriate annual training hours. Overall, the analysis showed Protective Force training programs were decentralized and had little apparent continuity in program planning, management, and execution among the eight sites. The hallmark initiative under the training reform is the Enterprise Mission Essential Task List (EMETL).

Enterprise Mission Essential Task List. All DOE/NNSA field sites have implemented the EMETL, which fundamentally restructures Protective Force training with a primary focus on critical tasks that directly contribute to mission success. EMETL identifies real-time training focused on improving performance and provides a clear picture of the best options for utilizing precious resources (time, money, and personnel) for making needed improvements. EMETL requires sites to conduct rigorous, formal, eyes-on assessments of the Protective Force's ability to perform specific individual, collective, and leadership tasks to identify areas in which improvement is needed. This innovation improves stakeholders' understanding of actual performance capabilities, allows finite resources to be targeted toward areas with the highest priority for improvement, and ultimately improves mission performance. EMETL requires both on- and off-post and performance testing of various tasks, with continuous assessment by stakeholders each quarter. Local site Training, Operations, Performance Testing, Vulnerability Assessment groups and field offices are all stakeholder organizations within the construct of the EMETL program.

Protective Force Tactical Systems. DOE/NNSA tactical systems increase Protective Force lethality and survivability. These systems include hardened vehicles and fighting positions, Protective Force tracking systems, friend or foe identification systems, shooter detection systems, non-explosive mechanical and thermal breaching equipment, multiple integrated laser engagement system gear, and remotely operated weapons systems.

Technical Surveillance Countermeasures. Technical surveillance countermeasures are defined as the systematic physical and electronic examinations of designated areas by federally trained, qualified, and equipped persons to discover electronic eavesdropping devices and electronic security hazards and weaknesses.

DNS recently implemented a consolidated enterprise approach that will result in substantial cost savings.

Enterprise Safeguards and Security Planning and Analysis Program (ESSPAP). ESSPAP is the strategic process that NNSA uses to conduct vulnerability assessments and risk analyses to meet the intent of DOE's Design Basis Threat, which sets the safeguards and security standards for protecting Departmental operations and assets, including SNM and classified information. This process provides managers at all levels of the organization who have authority to accept risk with a consistent approach to guide and manage the safeguards and security program throughout the national security enterprise. ESSPAP standardizes vulnerability assessment methodology, modeling and simulation tools, and data analytics into a comprehensive enterprise security risk management process. The directive provides NNSA sites with programmatic technical guidance on conducting security analysis and planning activities to enable identification and communication of security risks in clear, concrete, and consistent terms.

Physical Access Controls (PACS) and Intrusion Detection Systems (IDS) Depot and Modernization. NNSA has established a PACS and IDS equipment depot to centrally fund, procure, and manage all security system-related parts for six of the eight field sites. NNSA is also developing a standardized security systems training program for operators and system maintainers.

Security Management Improvement Program (SMIP). SMIP drives continuous, enterprise-wide improvement of the DNS program through consistent, effective, and efficient execution and program integration. SMIP enhances the ability of field security programs to understand security conditions, enabling better-informed decisions on oversight and execution activities and the allocation of finite resources.

3.29.3 Challenges

A major challenge for NNSA, and the Government more broadly, is identifying and addressing new and emerging security threats. Each threat is assessed and prioritized according to national security importance, taking into consideration the effectiveness of existing security measures. Through tactical and strategic planning and collaboration with counterparts, DOE/NNSA has developed programs to meet security challenges. As systems age and technology advances, meeting current and future challenges remains difficult.

Challenges for DNS include the following:

- Identify emerging threats and ensure capabilities are developed and implemented to counter threats.
- Recruit, stabilize, and retain Protective Force personnel to keep pace with attrition and retirements.
- Develop time-phased maintenance programs and a master schedule for upgrades and replacements at all DOE/NNSA nuclear security enterprise sites.
- Integrate and standardize policies and procedures for safeguards and security at all DOE/NNSA nuclear security enterprise sites.
- Ensure security is considered in planning all new construction and any adjustments to facilities at the national security laboratories and nuclear weapons production sites.
- Assess and address the full range of threats, from protestor incursions to active, violent insiders or intruders.

3.29.4 Long-Term Vision and Strategy

Strategies for responding to physical security challenges are described below.

Center for Security Technology, Analysis, Response, and Testing (CSTART). DNS is continuing its efforts with CSTART to enhance standardization, integration, and cost-effectiveness across the DOE/NNSA nuclear security enterprise. This initiative, which DHS manages, uses a collaborative approach that includes working with SNL, LANL, and LLNL, as well as other DOE national laboratories, DOD, and the Nuclear Regulatory Commission, to achieve enterprise-wide solutions to security challenges. DNS uses CSTART to address the challenges of managing security risks for nuclear weapons and related programs, including the Security Infrastructure Revitalization Program; counter unmanned aircraft system (CUAS) solutions; command, control, and display equipment; ultra-high reliability wireless; enterprise vulnerability assessment; and the enterprise standard personnel positive identification and verification booth, field installation guide, and the *Physical Security Technology Standards Guide*.

Counter Unmanned Aircraft System. In 2015, the NNSA Administrator tasked DNS to develop and implement an enterprise-wide program to protect NNSA facilities against unauthorized unmanned aircraft systems (UAS). DNS rigorously tested and evaluated competing technology platforms, which led to the decision to deploy a mature, commercial off-the-shelf CUAS to meet this threat. Initial deployment and operational testing of the system is in process. The estimated schedule for full operational capability is October 2018.

DNS is confronting the following major issues deploying an enterprise-wide CUAS capability:

- Maintaining a CUAS protective envelope that meets or exceeds the evolving technical and payload capabilities of UAS that are readily available to adversaries.
- Cultivating a sufficient range of comprehensive scenarios against which the effectiveness of a CUAS may be assessed. Such assessments may include modeling and simulation to assist the

M&O partner sites with effectively developing tailored rules of engagement to mitigate unauthorized UAS.

Like other Government agencies, NNSA has encountered numerous incursions, adding a degree of urgency to the DNS effort to field a viable CUAS capability and policy for its use.

10-Year Physical Security Systems Refresh Plan. Historically, DOE's implementation of physical security technology has been site-centric, with no corporate direction on how to select, install, operate, and maintain technologies at all sites. This approach has led to solutions at each site that increase the funding requirements to manage multiple systems performing similar functions. NNSA has worked to address these issues and, in August 2017, sent a report to Congress detailing security system priorities over the next 10 years. The execution of the 10-Year Plan is codified in the Security Infrastructure Revitalization Program.

DNS Strategic Plan. The priorities in the DNS Strategic Plan include sustaining the security enhancements implemented at the sites since September 11, 2001; continuing reduction of physical security vulnerabilities; leading efforts to integrate security initiatives with DOE program offices, Government agencies, and international partners; and assisting NNSA sites in applying risk management principles and processes to achieve cost-effective physical security.

Layered Protection Areas. NNSA applies its physical security technology capabilities by using a "layered protection strategy" at the boundaries of designated protected areas and within material access areas around what is referred to as a "property protection area." Barriers of various types are used within these areas, along with personnel identification and verification procedures.

Departmental Collaboration. DNS participates in the Construction Working Group, the Integrated Planning Group, and the Management Council to maintain close collaboration with other parts of NNSA, including Defense Programs. Under one of the Security Roadmap initiatives, DNS revitalized collaboration with the Nuclear Regulatory Commission, DHS, the United Kingdom's Ministry of Defence, and DOD to identify opportunities for collaborating on respective nuclear security programs. DNS also provides specialized nuclear security support for NNSA stakeholders who are engaged in nuclear nonproliferation, emergency response, homeland security, intelligence work, and the work of other U.S. Government agencies in these areas.

3.30 Information Technology and Cybersecurity

The cybersecurity infrastructure supports cybersecurity operations and activities at NNSA sites through a defense-in-depth approach that consists of three major components: personnel, technology, and operations.

3.30.1 Contributions to Nuclear Security Enterprise Goals

The Information Technology (IT) and Cybersecurity Program contributes to the nuclear security enterprise in the following ways:

- Enabling classified and unclassified collaborative solutions for weapons activities throughout the enterprise.
- Providing the technology infrastructure and protections for all collateral classified networks within NNSA and DOE.
- Informing and advising incident responders of other Government organizations about known threats.

- Coordinating with other Government programs (e.g., Intelligence, DOD, and DHS) to establish and maintain strong cybersecurity defenses to ensure electronic information and information assets are performing necessary operations and are protected from compromise, unauthorized access, and malicious acts that will adversely affect national and economic security and operational readiness.
- Fostering collaboration and coordination with international partners.
- Defending electronic information and information assets from current and evolving threats to business and mission operations.
- Maintaining the integrity and availability of Internet-based functions and transactions that are essential to NNSA's mission, operational needs, and Federal obligations.
- Providing dedicated, highly trained professionals who employ an array of technologies to address general and site-specific threats to business and mission operations.

Cyber Warfare

Aggressive cyber warfare capabilities are emerging and adversaries are expending considerable effort designing and using cyber weapons in attempts to infiltrate, disrupt or disable networked systems critical to NNSA business and mission operations. While information assets today remain secure and effective, NNSA is taking steps to address challenges to network defense, authentication, data integrity, and secure, assured, and reliable information flow across enterprise networks. These steps encompass a wide range of cyber and physical security activities that comprise a defense-in-depth strategy against current and emerging dangers. Under this multilayered strategy, NNSA strives to prevent malicious acts of adversaries from obtaining nuclear weapons information, and technology.

3.30.2 Status of Information Technology and Cybersecurity

NNSA's IT and Cybersecurity program maintains management, operations, and technical security safeguards for adequate protection of information assets. The tools deployed (**Table 3–2)**, and the workforce that develops and uses them, provide the first lines of defense against known adversaries and emerging threats.

Investment Prioritization Methodology

The 2002 *Federal Information Security Management Act* (FISMA) requires agencies to develop and implement an organization-wide information security program to address identification and prioritization of threats as applied to the agency's information security. NNSA's IT and Cybersecurity Program meets the FISMA threat-based requirements through application of the National Institute of Standards and Technology risk management framework, as influenced by DOE Order 205.1B, Cyber Security Program, and further outlined in NNSA Baseline Cybersecurity Program policy.

NNSA's Chief Information Security Officer and IT and Cybersecurity Program and other IT managers use results from multiple ongoing activities to identify and prioritize needed investments based on threats and the degree of risk posed to NNSA information assets and business operations. These activities include the following areas:

- Intelligence analyses
- System authorization activities
- FISMA Performance Reports
- Program reviews, audits, and inspections
- Performance Evaluation and Measurement Plan
- Technical impact assessments
- Operational impact assessments

Table 3–2. NNSA cybersecurity technologies

Cybersecurity Technology	*Security Focus*
Intrusion Detection System	Inspects all inbound and outbound network activity and identifies suspicious patterns.
Intrusion Prevention System	Monitors networks and/or system activities for malicious activities, such as security threats or policy violations.
Vulnerability Scanning	Identifies vulnerabilities that can be exploited or threaten computing systems in a network.
Firewalls	Prevents unauthorized access to or from a private network.
Multilayered Malware Protection	Searches a hard disk or other media for known viruses, Trojans, spyware, and many other kinds of malware and removes them.
Encryption	Protects sensitive information during storage and transmission and reduces the risk of intentional and accidental compromise or alteration of data.
Data Loss Prevention	Protects the confidentiality and integrity of mission-essential data on classified and unclassified networks and devices.
Network Monitoring	Discerns the security posture of the environment at that given instant; collects the various alerts; assigns a standardized criticality level; logs all of the information to a centralized database; and concurrently displays network traffic in a summarized view.
Enterprise Forensics	Provides real-time, remote or client-side inspections at the binary level of all data on a given system.
Automated Security Control Assessment	Provides guidance and outreach to promote a higher level of understanding and acceptance of requirements and assists senior NNSA management in program implementation.
Supply Chain Risk Management	Ensures the trustworthiness of the supply chain for national security systems, new technologies and products, and managed services to counter adversaries.
Continuous Monitoring	Maintains ongoing awareness based on three unique tiers: (1) organization, (2) mission and business, and (3) information system levels. Includes assessment and peer reviews of IT and Cybersecurity Program elements and continues to mature methodologies to address evolving threats.

3.30.3 Challenges

The cyber threat landscape is always evolving, with the most sophisticated threats changing to adapt to whatever defenses are mounted against them. NNSA is committed to providing an IT infrastructure to protect the highly complex, global nature of the stockpile stewardship and management missions using a collaborative, intelligence-driven approach to cyber operations and a response that engages the full capabilities of the nuclear security enterprise, DOE, and the Federal Government.

Mission-enhancing scientific computing and networking capabilities need to be robust and reliable. Networking capabilities must include first-in-class cores, have distribution layers, and provide pervasive indoor and outdoor wireless access. Not all buildings support network speeds that are fast enough for today's scientific computing and, with technology's reliance on computers, capacities are being exceeded across the NNSA complex. Continued investment is needed in network communications systems and central networking and telecommunications facilities.

> ***Resource Management Challenges***
>
> *Resource requirements for cybersecurity and information technology requirements will vary directly with any increases in weapons program workloads. Additional work locations, increasing workforce numbers, and adding shifts will result in additional demand for cyber and information technology resources to ensure a secure and innovative work environment.*

3.30.4 Long-Term Vision and Strategy

The NNSA Office of the Chief Information Officer (OCIO) is focused on assuring and securing NNSA information assets. The OCIO continually builds on past successes and addresses new and rapidly evolving IT and cybersecurity challenges. Using an integrated, multi-site approach, NNSA will provide increased benefits to the management and staff of the eight M&O partners through increased efficiencies, reduced redundancies, and closer alignment with mission activities. NNSA will accomplish these improvements by careful planning and cooperation among leadership, customers, and stakeholders. The strategy includes the following elements:

- Establish and measure progress against a suite of updated program metrics and key performance indicators.
- Continue to provide agency-wide cybersecurity guidance and outreach to promote a higher level of understanding and acceptance of requirements and to assist senior NNSA management in program implementation. The guidance and outreach will allow program offices and contractor-run sites to increase oversight and monitoring of compliance with Federal mandates such as the FISMA and 2014 *Federal Information Technology Acquisition Reform Act*, as well as Cyber Sprint, the National Insider Threat Program, Continuous Diagnostic Monitoring, and Incident Handling.
- Create new computing capacity through a network of DOE/NNSA application hosting environments that will achieve enhanced solutions to IT and cybersecurity issues by integrating sites and operating environments. The strategy to accomplish this new capacity will include the following activities:
  - Modernize current services by capitalizing on cloud technology to increase performance, strengthen security, and realize efficiencies.
  - Provide secure delivery of managed services to meet business needs across NNSA.
- Continue to deploy a physical and logical architecture solution that streamlines business processes and maintains strong authentication capabilities to maintain compliance with Homeland Security Presidential Directive 12, the Office of Management and Budget (OMB) Cyber Sprint Multifactor Authentication mandates, and the FICAM Roadmap and Implementation Guidance issued by the Federal Chief Information Officer Council.
- Improve interoperability by enhancing the nuclear enterprise's architecture, policies, and standards. Specifically focus efforts on updating technical and data standards to achieve enterprise-wide interoperability and modernize existing applications, networks, and system services to leverage application programming interfaces and optimize them for mobile use.
- Continue a baseline pilot program that includes a suite of tools to provide a unified communications system. This suite will include instant messaging, voice, web conferencing, video conferencing, and email capabilities.
- Continue modernization of the Enterprise Secure Network by enhancing the core services and collaborative capabilities and consolidating disparate networks.
- Bolster the enterprise network security posture by addressing known critical vulnerabilities and strengthening M&O cybersecurity operations at each NNSA site.
- Modernize the Cybersecurity infrastructure, which is comprised of almost 100 sensors and over 70 data acquisition servers dispersed nationwide for NNSA's Information Assurance Response Center (IARC). IARC is responsible for providing 24-hour, 365-days per year cybersecurity services

to 66 current (and any future) NNSA and DOE networking enclaves. IARC's services and service levels meet strict Federal requirements that permit sites to maintain mission-essential access to the Federal classified networks, SIPRNET, and the Enterprise Secure Network. IARC also provides near-real-time network defense and incident response services that protect these classified and unclassified enclaves and information from attacks. As a participant with the Joint Cybersecurity Coordination Center Program, IARC also supports enterprise-level cyber threat management and situational awareness for DOE/NNSA.

- Implement the NNSA Application Modernization Strategy, which seeks to minimize the number of disparate NNSA Federal business and mission support IT applications in favor of a platform-based approach. Implementation will facilitate reductions in hardware, software, and labor costs via rapid application development, single sign-on, and maximum reuse of hardware infrastructure, software licenses, custom code, logic/workflows, and data objects. The NNSA Application Modernization Strategy is an organized effort to cultivate enterprise-wide adoption of shared infrastructure capabilities by the NNSA Federal and M&O communities.
- Continue to mature continuous monitoring capabilities to provide strong cybersecurity situational awareness to NNSA senior leadership.
- Implement a Telecommunications Security Program to deliver more effective oversight and greatly reduce negative impacts to mission programs while increasing visibility, oversight of risks, and governance of this critical function.
- Develop an integrated IT investment strategy that considers, not only networking and cybersecurity hardware, but also real property assets, including communication hubs and associated utilities.

3.31 Infrastructure and Operations

As the 2018 *Nuclear Posture Review* points out, DOE/NNSA is long overdue to create a modern, efficient nuclear security enterprise for its missions that will ensure a resilient, enduring, and credible stockpile; reduce the risk to the mission; and improve staff, public, and environmental safety. The increased load on the existing infrastructure demanded by multiple concurrent LEPs, along with the RDT&E activities in the Stockpile Stewardship Program, have highlighted this concern.

Safely operating and modernizing DOE/NNSA infrastructure to meet mission demands, now and in the future, involves many complex challenges that are made more difficult because that infrastructure is failing at an increasing rate due to age and condition. To address these challenges, DOE/NNSA has made significant efforts to modernize the infrastructure, eliminate excess facilities, and improve management practices. DOE/NNSA has also increased resources allocated to improving the condition and functionality of the infrastructure and disposing of unneeded facilities.

> *"Over the past several decades, the U.S. nuclear weapons infrastructure has suffered the effects of aging and underfunding. Over half of NNSA's infrastructure is over 40 years old, and a quarter dates back to the Manhattan Project era. All previous NPRs have highlighted the need to maintain a modern nuclear weapons infrastructure, but the United States has fallen short in sustaining a modern infrastructure that is resilient and has the capacity to respond to unforeseen developments. There is now no margin for further delay in recapitalizing the physical infrastructure needed to produce strategic materials and components for U.S. nuclear weapons."*
>
> *Nuclear Posture Review 2018*

3.31.1 Contributions to Nuclear Security Enterprise Goals

DOE/NNSA's physical infrastructure is funded and managed under two categories: General Purpose Infrastructure and Programmatic Infrastructure:

- **General Purpose Infrastructure** includes infrastructure that is not specifically dedicated to programmatic efforts (such as roads, office buildings, and site utilities), but supports mission execution. This category also includes offices, operational support, general laboratories, general building systems (e.g., fire suppression and heating, ventilation, and air conditioning [HVAC]) in production facilities, and excess (unused) infrastructure. The NNSA Office of Safety, Infrastructure, and Operations plans and manages these aspects of physical infrastructure and is responsible for updating the aging general infrastructure. Maintenance of general infrastructure is key to mission support. For example, the availability of modern HVAC systems is necessary to maintain temperature control when manufacturing parts to support life extension development schedules.
- **Programmatic Infrastructure** includes specialized experimental facilities, high-performance computers, diagnostic equipment, processes, and other capabilities housed within the buildings. Programmatic infrastructure allows DOE/NNSA to conduct research, tests, production, sustainment, and disposition for national security missions and is managed through the relevant capability that is directly supported.

These two categories differ in a number of respects, leading to distinct approaches and processes for the short- and long-term management of physical assets. Both must be maintained safely until revitalization or disposition of these assets. DOE/NNSA's infrastructure vision, mission, and general purpose scope are shown in **Figure 3–5**.

3.31.2 Status of Infrastructure and Operations

Some aspects of the infrastructure are failing at an increasing rate because of age and condition, posing unacceptable risks in terms of availability, capacity, and reliability for weapons activities capabilities and the safety of the workforce, as well as the public and the environment. DOE/NNSA is taking steps to arrest the declining state of general purpose infrastructure by enhancing and optimizing resources, including deploying innovative management tools to facilitate a data-driven, risk-informed planning process that will guide investment decisions. Sites are also making efforts within site budgets to recapitalize facilities and equipment in support of multiple capabilities.

However, as the 2018 *Nuclear Posture Review* points out, "There is now no margin for further delay in recapitalizing the physical infrastructure to produce strategic materials and components for U.S. nuclear weapons." Despite recent accomplishments, significant additional infrastructure investments and recapitalization efforts are still needed to arrest the rate of decline of facilities and infrastructure.

NNSA's FY 2017 infrastructure operations and modernization accomplishments are detailed below:

Recapitalize and Maintain

In FY 2017, DOE/NNSA completed 47 recapitalization projects, a 56 percent increase from 2016. This improved performance reflects the impact of advanced planning based on detailed data, the use of the reporting tools and processes mentioned above, and the response to increased funding. The following are examples of several completed recapitalization projects that address specific criteria in the risk-based assessments:

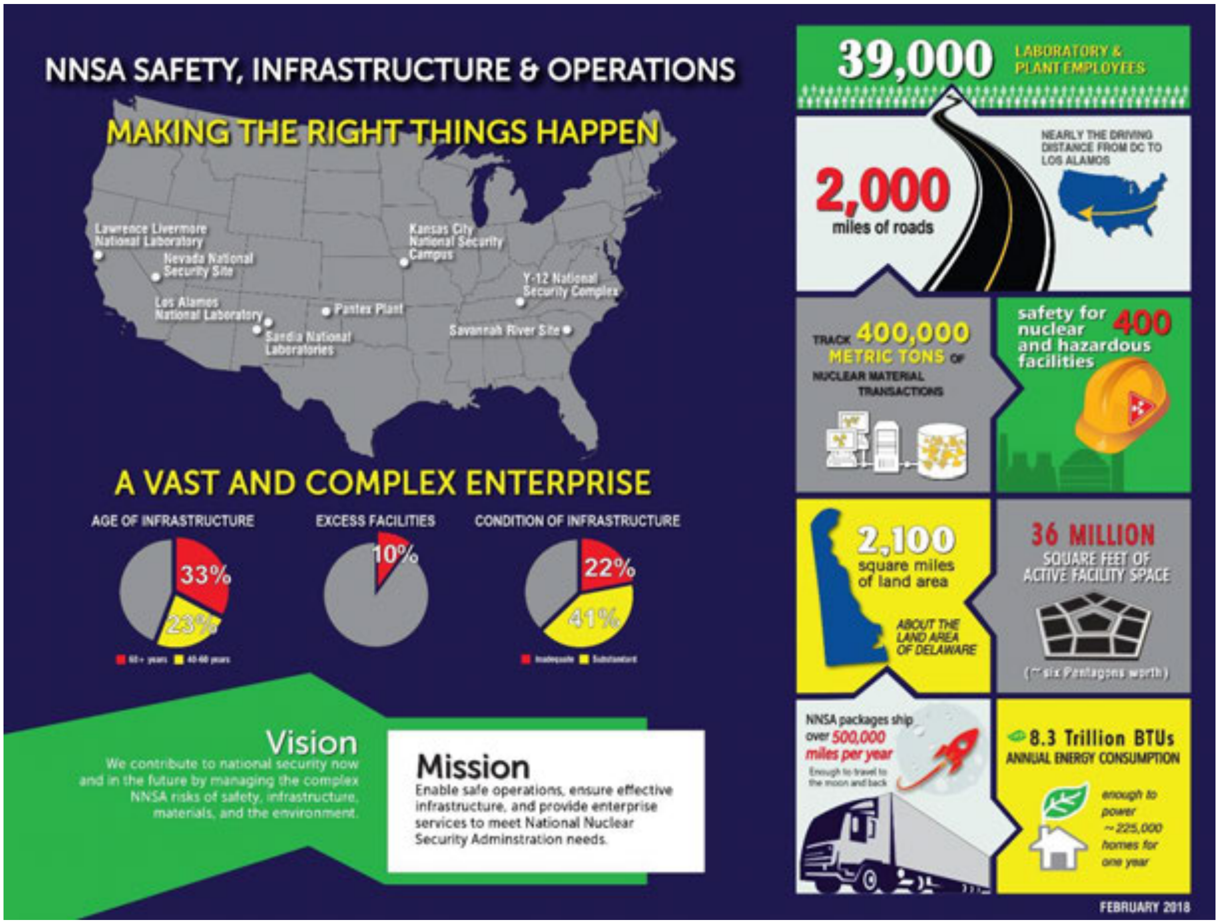


Figure 3–5. NNSA infrastructure vision, mission, and general purpose scope

- **SNL Building 905 Addition and Renovation**. DOE/NNSA added 15,000 square feet to and renovated 6,000 square feet in the Energetic Components Facility. This project relieved severe office overcrowding, restored nonhazardous laboratory space to its original function, and created needed support spaces, including conference rooms and a shared library.
- **SNL Building 870 Renovation**. DOE/NNSA achieved significant recapitalization and increased system reliability for the "backbone" mechanical infrastructure in SNL's primary neutron generator production facility. DOE/NNSA upgraded an obsolete pneumatic controls system with direct digital control; replaced a number of marginally performing air handling units; and increased cooling reliability and efficiency.
- **LANL TA-55 Facility Control System Upgrades.** DOE/NNSA modified embedded systems that provide information about plant conditions and monitor the safe operability of PF-4. These enhancements are required to support the redundancy and operability of the nuclear production facilities.
- **Pantex Flame Detection Systems and Radiation Alarm Monitoring Systems Fiber Optic Network Replacement under the Pantex Bay and Cell Safety System Improvements Portfolio**. NNSA replaced more than 12 miles of telephone lines with a fiber network to accelerate and modernize transmission of signals from the new Flame Detection Systems and Radiation Alarm Monitoring Systems in production bays and cells to the site's Emergency Operations Center.

- **Nevada National Security Site U1a Fire Protection Installation.** Site management addressed active fire suppression system vulnerabilities by installing fire barriers, air compressors, and fan controls and removing combustible legacy wiring, all of which were needed to maintain the operability of present and future experiments performed in this facility.
- **Nevada National Security Site Hill 200 Electrical Power Line Upgrade.** In January 2017, site management replacement a 1.7-mile segment of a 23-mile, 60-year-old power transmission line that was at high risk of failure. The transmission line and poles were rerouted from an inaccessible hilltop to an easier, safer road level adjacent to Mercury Highway. Transmission line concerns were realized when the twin wooden power transmission poles broke at several locations in the old 1.7-mile section of Hill 200 in March 2017.
- **Y-12 9201-1 Elevator #1 Replacement.** DOE/NNSA replaced a deficient component that could have resulted in a catastrophic cylinder failure, potentially leading to injury or death and loss of finished DSW weapons components. This overdue activity arrested deferred maintenance and improved productivity.
- **LLNL B321 Complex HVAC Modernization**. DOE/NNSA replaced the HVAC controls in B321A, C, and E to meet the program requirement to maintain close temperature control and a high degree of HVAC infrastructure reliability for machining capabilities to support the W80-4 LEP. The complex had an antiquated control system that was installed in 1987 and no longer met program requirements. The Building 321 Complex serves several LLNL programs with unique, on-demand capabilities that are unavailable or impractical to obtain from the commercial marketplace.
- **LLNL B133 Replace Mission Critical HVAC.** DOE/NNSA replaced the existing, outdated control system for the chiller plant and cooling towers supporting a large office/laboratory facility housing Weapons and Global Security missions, thus halting the growth of deferred maintenance.
- **Roofing Asset Management Program (RAMP).** DOE/NNSA completed over 752,000 square feet of roof replacements and repairs and pre-approved 17 new contractors.
- **Cooling and Heating Asset Management Program (CHAMP).** DOE/NNSA completed pilot projects at SRS, SNL, and the Nevada National Security Site. A design and construction management contract was awarded in April 2017. Since then, DOE/NNSA completed nine HVAC assessments and LLNL Building 311 Chiller Replacement.

Acquire Through Construction

- **Administrative Support Complex at Pantex**. Construction was completed and the new facility opened in April 2018 as a leased building. The Administrative Support Complex, now named the John C. Drummond Center, will house approximately 1,100 employees who previously occupied functionally inadequate and technologically obsolete buildings. The new facility helps eliminate approximately $20 million in deferred maintenance.
- **Approval of Design and Construction for the Albuquerque Complex Project**. This project obtained CD-2/3 approval in April 2018 with construction to be completed by 2022. The project will design and construct approximately 333,000 square feet of Leadership in Energy and Environment Design (LEED) Gold certified office space for approximately 1,200 employees. The project will include approximately 22,000 square feet of vault-type rooms and/or Sensitive Compartmented Information Facility space. The proximity of the Albuquerque Complex to two DOE/NNSA national laboratories and the Air Force Nuclear Weapons Center at Kirtland Air Force Base makes it an ideal location for an NNSA field installation. NNSA has a long-term commitment at this installation, and it will remain the primary field support office for NNSA and house multiple

organizations that fulfill unique and essential roles within the nuclear weapons enterprise by providing programmatic, technical support, legal, security, procurement, human resources, business, and administrative functions that directly support the DOE/NNSA national security mission.

Disposition

During the next 10 years, DOE/NNSA's total disposition requirement (currently excess facilities, plus facilities proposed as excess to mission requirements at DOE/NNSA sites through FY 2027) is about 10 million gross square feet. Deferred maintenance and long periods between shutdown and demolition can combine to create increased risk. DOE/NNSA's highest disposition priorities are to stabilize degraded process-contaminated facilities, characterize hazards and conditions, remove hazardous materials, and place facilities in the lowest risk condition possible until DOE's Office of Environmental Management can accept the transfer of responsibility.

While process-contaminated facilities pose the greatest hazards, non-process contaminated facilities also pose risks to staff, the public, and the environment due to structural degradation, industrial contamination, and increased vulnerability to fire. Personnel entering these facilities to perform required maintenance and surveillance are at risk from the degraded conditions.

In FY 2017, NNSA's budget included more than $250 million to continue reducing the risks posed by excess facilities and to demolish buildings. NNSA's FY 2017 funding supported the following work:

- Transfer of the Bannister Road Federal Complex to the private sector for redevelopment and remediation.
- Continued risk reduction at Y-12's Alpha 5 and Beta 4 to reduce risks identified by the Government Accountability Office (GAO) and Office of the Inspector General.[7]
- Demolition of the Alpha 5 Annex and Buildings 9111, 9112, and 9616-10 at Y-12.
- Disposal of Buildings TA-16-0280 and TA-3-0035 and characterization of Building TA-16-0306 in the HE area at LANL.
- De-inventory of Building 236H and disposal of Building 232-1H at SRS.

Bannister Facility Disposition

3.31.3 Challenges

Three main challenges face NNSA with respect to sustainment, modernization, and operation of the infrastructure:

- The growing need for refurbishment or modernization of key infrastructure assets.
- Reducing deferred maintenance, especially maintenance associated with mission-essential assets.
- The backlog of excess assets awaiting decontamination and decommissioning, which results in ongoing costs to manage risks in unoccupied space.

[7] IG Audit Report, "The Department of Energy's Management of High-Risk Excess Facilities", DOE/IG-0931, January 23, 2015. GAO, Report to the Committee on Armed Services, U.S. Senate, "DOE Facilities: Better Prioritization and Life Cycle Costs Analysis Would Improve Disposition Planning", GAO-15-272, March 2015.

These interrelated challenges must be considered holistically in order to develop an integrated approach to investment planning that ensures use of resources is prioritized to address the greatest risks. Despite efforts to plan and prioritize infrastructure needs, NNSA is constantly challenged by the magnitude of failing and obsolete infrastructure.

Planning and managing the extensive, diverse general purpose infrastructure across DOE/NNSA's eight sites requires a deep understanding of the function, age, and condition of an asset so that it can be constructed and kept fit for mission use. To that end, a variety of new tools, techniques, and approaches have been designed and deployed to enhance NNSA's ability to manage an exceedingly diverse and complex suite of infrastructure assets. In addition, NNSA is focused on ways to operate more efficiently and prioritize its investments better across its nuclear security enterprise. These new approaches have already yielded some success, but many challenges remain, and NNSA must sustain these efforts over the next 25 years to ensure the ability to support its mission needs fully.

Figure 3–6 illustrates the cyclical nature of asset management from acquisition to disposition and captures the evolving interplay among these elements to support DOE/NNSA's national security missions.

Figure 3–6. Asset life cycle portfolio management

3.31.4 Long-Term Vision and Strategy

NNSA is working to right-size and modernize its aging infrastructure and has formulated strategies to recapitalize key capabilities within its nuclear security enterprise. NNSA continues to develop and implement an integrated approach to investment planning to ensure that resources are prioritized to address the greatest needs with respect to consolidation, modernization, replacement, and disposition of the infrastructure. NNSA is also devising and deploying approaches for more efficient use of allocated funding in accordance with the following goals:

- **Modernize**: Arrest the declining state of NNSA infrastructure, improve productivity, lower operating costs, increase the percentage of facilities in good condition, decrease deferred maintenance, and reduce infrastructure gaps and risks.
- **Streamline**: Shrink the NNSA footprint, reduce energy consumption, improve sustainability, eliminate excess facilities, decrease underutilized space, and reduce carrying costs.
- **Sustain**: Make cost-effective infrastructure investments in accordance with commitments to maintain new facilities; repurpose sound but underutilized facilities; and expand use of supply chain procurements that increase purchasing power to repair building systems that are common NNSA-wide.

In the past fiscal year, NNSA has made significant progress in deploying tools to make data-driven, risk-informed investment decisions to address its primary infrastructure challenges, as summarized below. These tools are described in detail in the FY 2018 SSMP, Section 4.3.3.1.

NNSA is developing and deploying a number of long-term strategies to address its general purpose infrastructure challenges. Addressing these challenges requires balanced investment decision-making across the four key elements shown in Figure 3–6 above: acquire, maintain, recapitalize, and dispose. The MAP outlines NNSA's infrastructure vision to meet mission requirements over the next several years, provides an integrated view of NNSA's infrastructure, and highlights current and future infrastructure gaps and their risk to mission execution.

The MAP is the result of an in-depth, rigorous process, where "Infrastructure Deep Dives" are conducted at DOE/NNSA sites throughout each year. Deep Dives facilitate a holistic understanding of the demands that program drivers place on DOE/NNSA's infrastructure; the current infrastructure conditions, gaps, and risks; and the prioritized infrastructure investments that are necessary to reduce those risks.

DOE/NNSA is seeking to strategically balance use of all its available resources to modernize, streamline, and sustain the infrastructure. As demonstrated in the MAP, DOE/NNSA is currently implementing processes to identify and understand the infrastructure's condition, functionality, gaps, and risks, as well as their impacts. These processes are assisting DOE/NNSA in making integrated investment decisions concerning all infrastructure resources according to a comprehensive NNSA-wide long-range vision. Ongoing efforts, such as expanding asset management programs and comprehensive area planning, are being implemented to improve conditions and functionality faster and more economically while gaining operational efficiencies. Combined with increased funding in the future, these strategies will allow NNSA to more rapidly and effectively address the issues of an aging infrastructure across its nuclear security enterprise.

Capital Construction Projects

DOE/NNSA's general purpose infrastructure capital investments modernize its aging nuclear security enterprise by replacing existing facilities and Weapons Activities capabilities that are beyond their intended lifetimes. The projects below, as well as other planned capital improvements, are part of the longer-term strategy to ensure that NNSA can meet future mission demands.

- **Emergency Operations Centers at Y-12, LLNL, and SNL.** This project will improve emergency management response and survive high-consequence natural phenomena. The first Emergency Operations Center at Y-12 is being planned and will more effectively and efficiently support missions by consolidating the Plant Shift Superintendent's Office, the Emergency Command Center, the Technical Support Center, and the Fire Department Alarm Room in a survivable facility. The current onsite facility is not compliant with Comprehensive Emergency Management System requirements to be capable of supporting continuous emergency operations for an extended period of time and surviving various severe events, such as earthquakes and tornadoes.
- **Expand Electrical Distribution System at LLNL.** This project began construction in 2018 and will expand the electrical distribution systems along the east side of the site and provide a new electrical connection to the SNL-California site. Additionally, it will supplement the existing distribution system with new 15-kilovolt underground electrical distribution systems, load grid switchgear, and connection for additional future electrical supply. This result will be improved site capability, capacity, and reliability.
- **Construction to Replace TA-3 Substation at LANL**. This new substation, which will be completed in FY 2018 or early FY 2019, will be a modern substation with components designed to provide

increased distribution capacity, improved reliability, reduced maintenance, support for greater operational flexibility, and increased staff safety. The new substation will provide separate power feeds to both LANL and Los Alamos County.

- **Construction of a New Fire Station at Y-12.** The current Y-12 fire station was built 70 years ago and is located within the most highly protected area of the plant, with a proximity to hazardous operations. Seismic, tornado, hazardous material release, and security events could render the existing fire station inaccessible. Many of the hazardous materials releases analyzed in the Emergency Planning Hazard Assessments would have a very short travel time before impacting the fire station. Moving the new fire station out of the protected area will improve response time and enable better access to the new facility by first responders.
- **New Power Transmission System at Nevada National Security Site.** This project involves designing and constructing a 138-kilovolt line that will replace and upgrade approximately 23 miles of the degraded existing power transmission system to provide reliable power and communications distribution within the Nevada National Security Site Mission Corridor in Mercury, Nevada. The reliability of the existing system continues to be at risk as poles fail, which can result in unscheduled outages that could impact the mission and operations.

Public-Private Partnerships

DOE/NNSA is using public private partnerships where appropriate and cost-effective (e.g., the lease of KCNSC and the John C. Drummond Center at Pantex). DOE/NNSA will consider alternative financing in its AoAs by performing life cycle cost analyses that take into account all relevant cost drivers and third-party financing feasibility, based on the application of criteria in OMB Circular A-11.[8] It is not likely, however, that operating lease solutions will be viable for many of the enduring infrastructure needs described elsewhere in this SSMP. In some cases, a capital lease may be possible. The requirement for the full amount of the lease to be in hand at the start of the lease means capital leases are not viable strategies for avoiding the large upfront cost of ownership.

3.32 Measures for a Resilient, Flexible, and Responsive Nuclear Security Enterprise

The Office of Defense Programs, in conjunction with the national laboratories, sites, and plants, is developing long-term measures for determining success in meeting the goal of a resilient, flexible, and responsive enterprise. Success will require strengthening the capabilities base of the DOE/NNSA nuclear security enterprise, including personnel, facilities, equipment, science, engineering, computing, technology, materials, production, manufacturing processes, and business practices. Additionally, measures will be developed to identify how quickly the weapons complex should be able to complete activities such as LEPs and making necessary modifications to weapons. During FY 2019, the Office of Defense Programs will establish a framework and rationale for the current and future capabilities and capacities of the DOE/NNSA nuclear security enterprise to inform decision-makers about which capabilities should be downgraded, upgraded, replaced, or acquired.

[8] *OMB Circular No. A-11, Preparation, Submission, and Execution of the Budget*, 2017, Executive Office of the President, Office of Management and Budget, July.

Chapter 4
Budget and Fiscal Estimates

Chapter 4 is an overview of the key programmatic elements proposed in the Weapons Activities budget request for Fiscal Year (FY) 2019. The chapter displays budgetary information based on the program of record, including out-years (FY 2020 through FY 2023). The FY 2019 budget request is foundational for the 2018 *Nuclear Posture Review*. DOE/NNSA will continue to work with DOD through the Nuclear Weapons Council to translate Nuclear Posture Review policy into requirements.

Each programmatic section in this chapter compares the FY 2019 budget request to the FY 2018 enacted budget and includes program accomplishments, changes from the FY 2018 SSMP, and a milestones and objectives chart projecting long-term strategies. Information on the status of the 30 Weapon Activities capabilities can be found in Chapter 3, "Capabilities That Support the Nuclear Security Enterprise." This is also followed by a section that describes cost projections beyond the Future Years Nuclear Security Program (FYNSP) and the basis of those cost projections.

4.1 Fiscal Year 2019 Nuclear Security Program Budget

Table 4–1 is a list of program budget requests for Weapons Activities for FY 2019–FY 2023.

Table 4–1. Overview of Future Years Nuclear Security Program budget request for Weapons Activities in fiscal years 2019 through 2023[a]

Activity	*Fiscal Year (dollars in millions)*					
	2018 Enacted	*2019 Request*	*2020 Request*	*2021 Request*	*2022 Request*	*2023 Request*
Directed Stockpile Work	4,009.4	4,666.2	5,097.9	5,412.2	5,635.3	5,838.4
Science Program	474.5	564.9	572.3	637.8	604.7	571.7
Engineering Program	183.1	211.4	226.5	235.9	245.9	255.7
Inertial Confinement Fusion Ignition and High Yield Program	544.9	418.9	428.0	437.5	447.2	457.0
Advanced Simulation and Computing Program	746.2	703.4	717.8	703.0	799.7	782.3
Advanced Manufacturing Development	85.5	96.8	105.1	117.6	119.6	123.2
Secure Transportation Asset	291.2	278.6	339.7	332.4	339.9	347.6
Infrastructure and Operations	3,117.8	3,002.7	3,233.6	3,343.0	3,357.6	3,440.7
Defense Nuclear Security	770.6	690.6	796.9	773.1	773.9	785.1
Information Technology and Cybersecurity	186.7	221.2	291.3	281.2	291.2	291.7
Legacy Contractor Pensions	232.1	162.3	72.8	63.8	59.5	55.3
Weapons Activities Total	***10,642.1***	***11,017.1***	***11,881.9***	***12,337.5***	***12,674.6***	***12,948.6***

[a] The budgetary information in this SSMP reflects the FY 2019 President's Budget Request and not the appropriation from H.R. 5895 - Energy and Water, Legislative Branch, and Military Construction and Veterans Affairs Appropriations Act, 2019. Totals may not add because of rounding.

Figure 4–1 illustrates the level of funding proposed for FY 2019–FY 2023 compared with the Weapons Activities purchasing power in prior years (in 2010 dollars). The figure also displays the composition of funding in major elements over time. Program funding totals have been adjusted to reflect an equivalent comparison of year-to-year funding or funding among elements. One adjustment removed the Nuclear Counterterrorism Incident Response funding (about $250 million annually), which moved to the Defense Nuclear Nonproliferation appropriation in FY 2016. In addition, most programmatic construction was moved to Infrastructure – Construction. In the beginning of the Stockpile Stewardship Program, programmatic construction was funded by the sponsoring program.

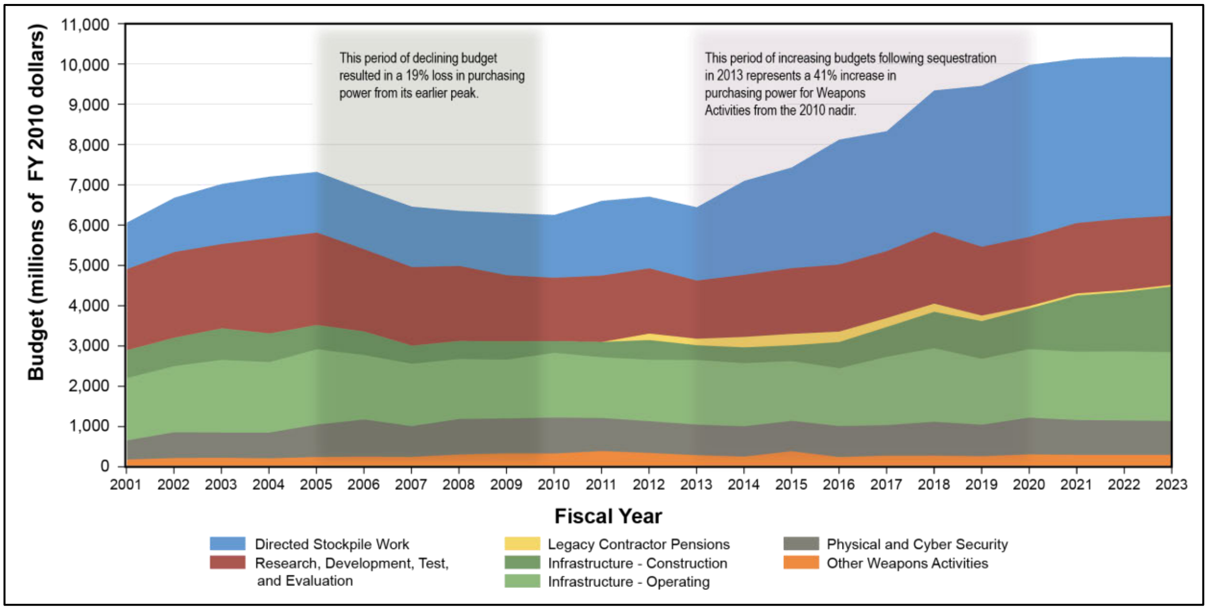


Figure 4–1. Weapons Activities historical purchasing power – fiscal years 2001 through 2023

The most significant change over the period displayed in Figure 4–1 is the increase in purchasing power for Directed Stockpile Work (DSW), which, as of the FY 2019 request, is nearly quadruple what it was in FY 2001. Part of this increase is the result of changes to the budget structure over the intervening years. A significant amount of this increase can be attributed to funding for multiple LEPs and the DSW activities that support those LEPs. For example, pit production activities, originally funded as a campaign, became part of DSW in FY 2009 and were renamed Plutonium Sustainment in FY 2010. In addition, funding for Tritium Sustainment was added to DSW in the FY 2016 FYNSP.[1]

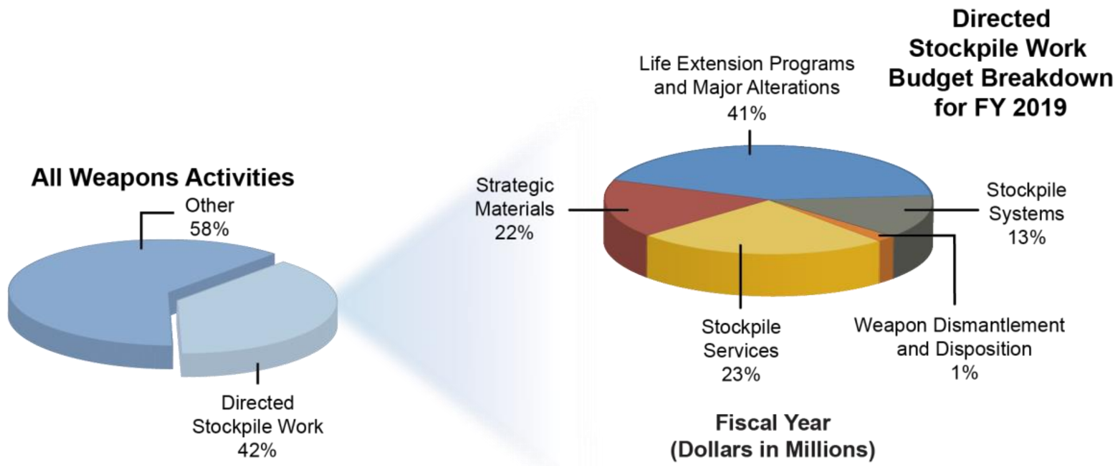
The pie chart figures that follow in each section enumerate the FY 2019 budget request; the tables compare the FY 2019 request to the FY 2018 enacted budget.

4.2 Directed Stockpile Work

4.2.1 Directed Stockpile Work Budget

The Stockpile Systems and Stockpile Services lines in **Figure 4–2** include the Surveillance program funding listed in **Table 4–2**.

[1] See FY 2016 SSMP, Chapter 2, Section 2.4.6, pp. 2-33 to 2-37.



	Fiscal Year (Dollars in Millions)					
	2018	2019	2020	2021	2022	2023
Life Extension Programs and Major Alterations	1,744.1	1,920.0	1,922.4	2,133.7	2,067.0	2,016.1
Stockpile Systems	501.9	619.5	599.6	603.4	607.7	611.0
Weapon Dismantlement and Disposition	56.0	56.0	56.0	56.0	56.0	56.0
Stockpile Services	998.8	1,068.4	1,117.5	1,139.3	1,170.5	1,211.2
Strategic Materials	708.7	1,002.4	1,402.3	1,479.8	1,734.1	1,944.2
Total Directed Stockpile Work	4,009.4	4,666.2	5,097.9	5,412.2	5,635.3	5,838.4

Note: Numbers may not add due to rounding

Figure 4–2. Directed Stockpile Work funding schedule for fiscal years 2018 through 2023

Table 4–2. Surveillance program funding for fiscal years 2013 through 2023

	Fiscal Year (dollars in millions)										
	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
Surveillance Program Funding [a]	217	225	236	217	213	231	243	237	251	257	265

[a] Surveillance numbers for FY 2018 and FY 2019 represent current planning estimates. Prior year numbers reflect actual expenditures.

4.2.2 Directed Stockpile Work Accomplishments

Major DSW accomplishments since the FY 2018 SSMP, in addition to the Annual Assessment Reports, Laboratory Director Letters to the President, and scheduled replacements of limited life components (LLCs), are detailed in the following sections.

4.2.2.1 Life Extension Programs

W76-1 Life Extension Program

The W76-1 LEP continued to be ahead of cumulative production and deliveries to the Navy within allocated budgets. The program remains on schedule to complete all warhead production and deliveries by the end of FY 2019.

- Completed 95 percent of the cumulative warhead production quantities as of May 2018, ahead of the production baseline.
- Delivered 91 percent of the cumulative warhead production quantities to the Navy as of May 2018, on target with the delivery baseline.

W88 Alteration 370

The W88 Alt 370 Program continued fabrication of pre-production Process Prove-In (PPI) and Qualification Evaluation (QE) functional hardware at the component; subassembly; and integrated arming, fuzing, and firing (AF&F) assembly levels for final qualification and validation.

- Obtained DOE/NNSA approval of Phase 6.4, Production Engineering.
- Published the Baseline Cost Report.
- Fully integrated the additional scope associated with conventional high explosive (CHE) refresh.
- Completed follow-on Commander Evaluation Test – 53 qualification flight test.
- Completed Nuclear System Final Design Review.
- Fabricated pre-production (PPI and QE) functional hardware at the component; subassembly; and integrated AF&F assembly levels for final qualification/validation (October-December 2017 and January-March 2018).
- Conducted remaining Final Design Reviews, including the System Final Design Review (October and December 2017 and January 2018).
- Delivered Commander Evaluation Test -1 flight test bodies (first quarter of FY 2018).
- Built two hydrodynamic test articles to be tested in the third and fourth quarter of FY 2018.

B61-12 Life Extension Program

The B61-12 is in Phase 6.4 (Production Engineering) and will receive authorization for Phase 6.5 (First Production) by September 2019. The program remains on schedule and budget.

- Completed three system qualification flight tests at the Tonopah Test Range (following completion of three system development flight tests in FY 2015).
- Completed first compatibility flight test with the Air Force B-2 in June 2017.
- Completed two hydrodynamic physics tests at LANL to verify the performance of the B61-12 nuclear explosive package in cold temperature environments.
- Completed Final Design Reviews for major components and successfully initiated component PPI and QE activities at the DOE/NNSA nuclear weapon production facilities.
- Maintained 11 Interface Requirements Agreements with other programs to document B61-12 dependencies on programmatic deliverables.
- Loaded B61-12 gas transfer system (GTS) reservoirs 18 months ahead of schedule.

W80-4 Life Extension Program

The W80-4 LEP is currently in Phase 6.2A (Design Definition and Cost Study). DOE/NNSA will continue to refine the design and synchronize activities with the Long Range Stand Off (LRSO) missile development team.

- Performed System Requirement Gate and System Feasibility Gate Reviews in FY 2017.
- Conducted an Inter-Laboratory Peer Review in FY 2017.
- Completed stand-up of Product Realization Teams.
- Provided input to the LRSO Project Officers Group Phase 6.2 Report, identifying preferred design options for the Nuclear Weapons Council Standing and Safety Committee.
- Completed LEP interface requirements agreements with the other DOE/NNSA programs responsible for providing key capabilities essential to execution of W80-4 program plans.

- Obtained approval to enter Phase 6.2A (Design Definition and Cost Study) in FY 2018 and presented a plan to develop the LEP's Weapon Design and Cost Report, which will better define the cost range and preliminary schedules.

4.2.2.2 Stockpile Systems

- Delivered all scheduled LLCs for the B61, W76, W78, W80, B83, W87, and W88.
- Conducted stockpile surveillance activities to ensure adequate data was available to assess the health of the stockpile.
- Completed the first production unit of new B61 joint test assembly (JTA) configurations via successful conduct of the JTA Modernization project.
- Conducted cable pull-down test of B61-11.
- Continued planning and early development for the W76 JTA 3 (JTA 1 refresh).
- Completed renewal of the W76 10-Year Nuclear Explosive Safety Study for assembly and disassembly to allow continuation of nuclear explosive operations.
- Started W78 repairs.
- Completed W80-1 Alt 369 first production unit.
- Completed Customer Requirements Review and Preliminary Design Review for JTA6R development.
- Met DOD requirements for W87 small ferroelectric neutron generator retrofits.
- Initiated W87 Joint Environmental Test Unit Product Realization Team to support Ground-Based Strategic Deterrent.
- Continued development of W88 Alt 940 integrated surety architecture transportation solution.
- Continued development for next W88 neutron generator and GTS LLC cycle.

4.2.2.3 Weapons Dismantlement and Disposition

- Provided critical material for Naval Reactors, the Lithium Strategy, and LEPs through completing weapon and canned subassembly dismantlement requirements.
- Exceeded component disposition site goals and managed limited storage space for future LEP requirements.
- Completed W84 safety testing planning.

4.2.2.4 Stockpile Services

- Completed the first restart of equipment at Y-12, supporting the Lithium Bridging Strategy ahead of schedule.
- Continued efforts to remove single points of failure throughout production operations.
- Initiated an Environmental Room Controls Upgrade Project at Y-12 that will support extending the life of the assembly and disassembly operations area.
- Reduced product acceptance time for application-specific integrated circuit (ASIC) products by certifying more inspectors at SNL and deploying the bar-coded processing electronic production control system.
- Implemented the Common Tester Architecture to allow plug and play testers on the shop floor.
- Completed analytical tests for production quality assurance and reduced the average backlog of work orders at KCNSC.

- Archived past weapons data and converted sunset technology files to state-of-the-art data storage and security systems.
- Transitioned a matured integrated surety architecture capability to stockpile systems for further development and integration activities.
- Progressed the development of new initiation systems and materials to enhance the safety and reliability of the detonation.
- Completed significant progress toward re-establishing depleted uranium machining capabilities at Y-12.
- Installed and certified a replacement centrifuge arm at the Weapons Evaluation Test Laboratory.
- Provided direct support to Stockpile Systems for flight tests.
- Expedited throughput of product definition that is critical to support for modernization programs ranging from DOE/NNSA national security laboratories to nuclear weapons production sites through Product Realization Information Management and Exchange (PRIME).
- DOE/NNSA's Office of Technology Maturation's Technology Development Strategic Plan for the early development of innovative technologies.
- Began establishment of the High Operational Tempo Sounding Rocket Flight Test (HOT SHOT) program. HOT SHOT is intended to provide a lower-cost alternative to conventional flight tests, as well as the ability to duplicate many of the integrated reentry vehicle environments to qualify components, technologies, and subsystems.
- Matured new process technologies (electro-refiner, calciner, direct chip melt) to allow transfer of capabilities into other nuclear facilities at Y-12.

4.2.2.5 Strategic Materials

This section lists the FY 2017 accomplishments, as well as some FY 2018 accomplishments, for each of the five strategic materials and sustainment activities.

Uranium

- Initiated planning and prioritization efforts to implement the Building 9212 Exit Strategy.
- Increased the reliability of existing uranium capabilities in casting sustainment and machining sustainment investments.
- Removed enriched uranium material from Area 5 to achieve the Y-12 de-inventory milestone and continued enabling efforts to establish and maintain target working inventory levels.

Plutonium

- Fabricated two development W87-like pits.
- Continued investments to replace end-of-life pit production equipment, installed equipment to increase production capacity, and supported certification activities to reduce mission risk.

Tritium

- Submitted license amendment request to irradiate up to 1,792 tritium-producing burnable absorber rods (TPBARS) in Watts Bar Unit 2 to the Nuclear Regulatory Commission for approval. Loaded 1,104 TPBARs into Watts Bar Unit 1.
- Extracted tritium from 900 TPBARs at SRS's Tritium Extraction Facility and conducted three back-to-back extraction cycles.
- Provided 100 percent on-time delivery of GTSs, with 127 DOD schedule change requests.

- Maintained a 0.04 percent GTS Cost of Nonconformance versus an FY 2017 goal of less than 0.25 percent.
- Conducted an independent project review in November 2017 and independent cost review for the Tritium Production Capability line item in February 2018. (The preferred alternative was selected in July 2016.)
- Met Material Recycle and Recovery (MRR) Program Production and Planning Directive goals for recovery and recycle of tritium from returned reservoirs. (Also see Strategic Materials Sustainment.)

Domestic Uranium Enrichment

- Initiated Analysis of Alternatives (AoAs) to identify and evaluate solutions to the low-enriched uranium mission need.
- Completed design of the OR-1 centrifuge at Oak Ridge National Laboratory.
- Initiated down-blending offering for Tritium Down-Blend campaign to extend need date for low-enriched uranium fuel for tritium production to 2041.

Lithium

- Restarted salvage operations.
- Began execution of the Material Conversion Equipment Restart project.
- Met all DSW deliverables for material and parts production.
- Completed non-metallic options evaluation for future LEP production.

Strategic Materials Sustainment

- Continued to complete recycle and recovery of tritium at SRS ahead of schedule in support of mission requirements and improved operational interface with DOE's Office of Science in managing tritium production byproducts that are intrinsically valuable to the Nation.
- Y-12 continues to minimize technology risk and provide justification for increased utilization on the production microwave with the completion of a carbon reduction study report.
- Accomplished significant work on risk reduction activities and vault material disposition at LANL, including continuing to reduce the material-at-risk (MAR) on the LANL Plutonium Facility (PF-4) main floor and implementing a push inventory management tool for transuranic (TRU) waste to ensure efficient supply chain management.
- Completed first LANL waste shipment to the Waste Isolation Pilot Plant since its reopening on November 16, 2017, using the Mobile Loading Unit at Technical Area (TA)-55. The first shipment of four waste drums from TA-55 to the TRU Waste Facility occurred in the week of October 10, 2017. As of March 30, 2018, 28 TRU drums have been shipped to the TRU Waste Facility. It is expected that the operational tempo will increase to a level sustaining operational needs.
- Demonstrated the ability to produce purified enriched uranium metal at Y-12 to meet Defense Programs requirements.

4.2.3 Directed Stockpile Work Changes from the FY 2018 SSMP

4.2.3.1 Life Extension Programs and Major Alterations

- The B61-12 LEP had no substantive changes from the FY 2018 SSMP.
- The W88 Alt 370 had no substantive changes from the FY 2018 SSMP.

- The W80-4 LEP had no substantive changes from the FY 2018 SSMP as of the date of this SSMP. Completion of the Weapons Design and Cost Report will provide the first bottom-up cost and schedule estimates and may result in changes to DOE/NNSA's DSW work plans.

4.2.3.2 Stockpile Systems

- No substantive changes from the FY 2018 SSMP.

4.2.3.3 Weapons Dismantlement and Disposition

- No substantive changes from the FY 2018 SSMP.

4.2.3.4 Stockpile Services

Production Support

- Continued growth of workforce and equipment base capabilities, as required to support the increased system modernization workload.

Research and Development Support

- Expanded investment in weapon data archiving activities, including preservation of testing data and computer platforms for making data available to weapon scientists and support of implementation for Nuclear Enterprise Assurance and supply chain risk management for research and development (R&D) activities.

Research and Development Certification and Safety

- Increased investments in low-cost alternative demonstrators for future systems (e.g., the W78 Replacement Warhead) to demonstrate capability enhancements.

Management Technology and Production

- Continued growth in multi-weapon activities, as needed to support fielding the Alt and Mod systems following the first production unit.
- Defense Programs began establishment of the HOT SHOT program. HOT SHOT is intended to provide a lower-cost alternative to conventional flight tests, as well as the ability to duplicate many of the integrated reentry vehicle environments to qualify components, technologies, and subsystems.

4.2.3.5 Strategic Materials

Uranium Sustainment

- An update to the Uranium Mission Strategy was issued in May 2017. This document provides an integrated strategy to sustain and modernize uranium capabilities and infrastructure. The focus for the strategy is directly tied to the overarching modernization strategy, the risk reduction activities to ensure a seamless transition to the new strategic objectives, and the ongoing activities to sustain successful stewardship of uranium.

Plutonium Sustainment

- The number of development W87 pits increased in line with mission goals.
- On May 10, 2018, the Administrator informed Congress that NNSA's recommended alternative is to repurpose the SRS Mixed Oxide Fuel Fabrication Facility for the production of 50 War Reserve plutonium pits per year in 2030, while maximizing pit production at LANL with at least 30 pits per year by 2026. A conceptual design for repurposing MFFF will be used to develop CD-1 for the Deputy Secretary's final review and decision

Tritium Sustainment

- Transport of TPBARs between the Tennessee Valley Authority and SRS is being re-evaluated due to increased TPBAR irradiation. Preliminary modeling indicates that higher-capacity casks (casks holding greater than 300 TPBARs each) will be needed to meet the Tennessee Valley Authority and SRS operating schedules. Limited opportunities at the Tennessee Valley Authority will be available to load and ship TPBARs to SRS and vice versa, so increased capacity per shipment is considered a mission need and an overall cost-effective investment. (This program scope is being transferred from the Component Manufacturing Development program.)

Domestic Uranium Enrichment

- No substantive changes from the FY 2018 SSMP.

Lithium

- The addition of a Lithium Sustainment funding line is reflected in the in FY 2019 budget request.

Strategic Materials Sustainment

- No substantive changes from the FY 2018 SSMP. Efforts to re-establish the capability to produce depleted uranium and depleted uranium-alloyed component feedstock were initiated by the MRR Program.

4.2.4 Directed Stockpile Work Milestones and Objectives

Figure 4–3 illustrates ongoing activities with key annual deliverables for weapon assessment, surveillance, and maintenance. **Figure 4–4** illustrates milestones for LEPs, Alts, component production, and dismantlement.

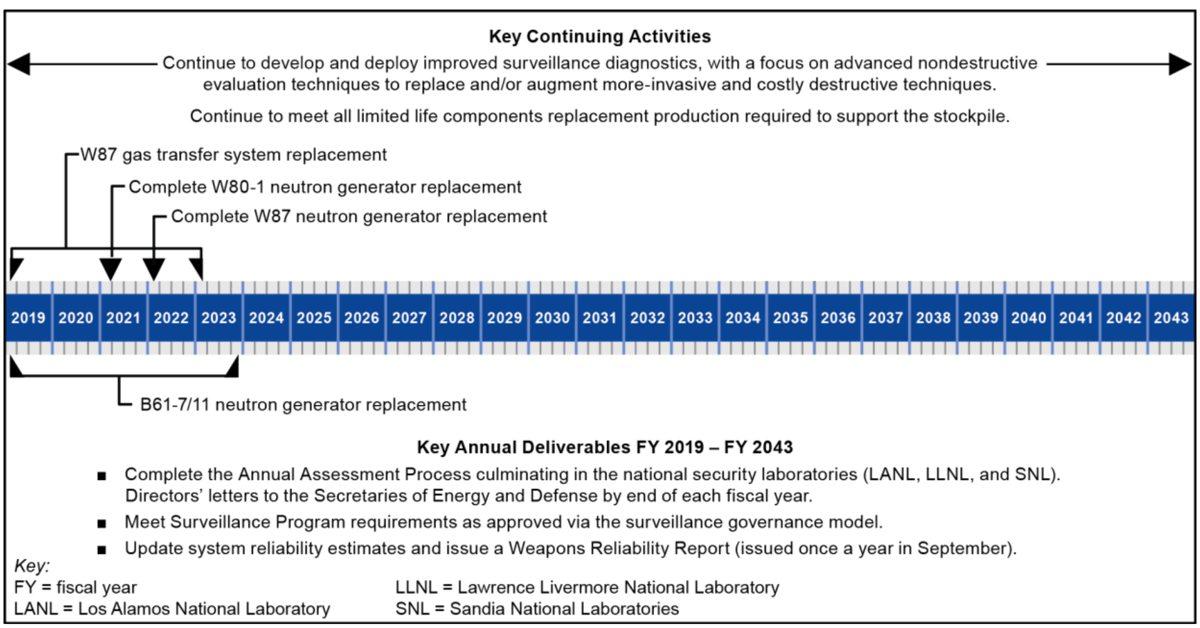


Figure 4–3. Goals, milestones, and key annual activities for weapon assessment, surveillance, and maintenance

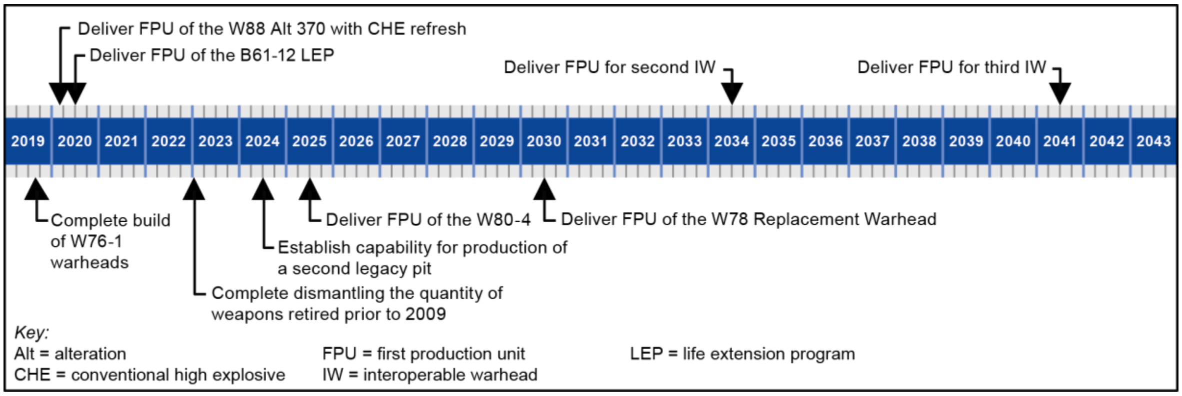


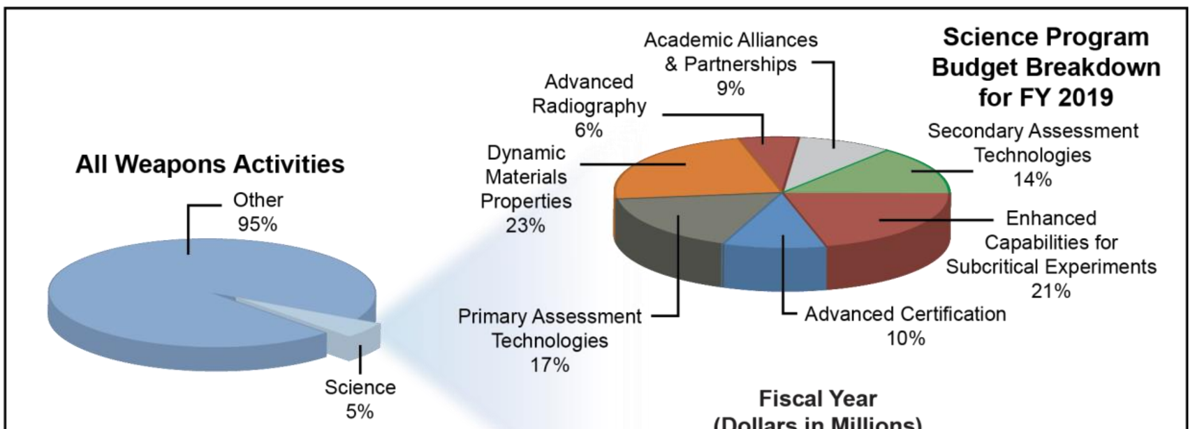
Figure 4–4. Milestones for life extension programs, major weapons component production, and weapons alteration and dismantlement[2]

4.3 Research, Development, Test, and Evaluation

4.3.1 Science Program

4.3.1.1 Science Program Budget

Science Program funding for FY 2018–2023 is illustrated in **Figure 4–5**.



Fiscal Year (Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Advanced Certification	57.7	57.7	57.7	62.7	64.1	66.1
Primary Assessment Technologies	89.3	95.1	95.2	125.7	129.0	127.4
Dynamic Materials Properties	120.0	131.0	136.0	159.8	162.9	134.4
Advanced Radiography	37.6	32.5	32.5	56.0	67.4	68.8
Secondary Assessment Technologies	76.8	77.6	77.6	82.1	84.0	85.8
Academic Alliances & Partnerships	53.0	53.4	53.4	55.1	56.0	56.7
Enhanced Capabilities for Subcritical Experiments	40.1	117.6	120.0	96.5	41.5	32.4
Total Science	474.5	564.9	572.3	637.8	604.7	571.7

Note: Numbers may not add due to rounding

Figure 4–5. Science Program funding schedule for fiscal years 2018 through 2023

[2] Reference above to IWs are not necessarily in conformance with future ballistic missile systems as referred to in the 2018 *Nuclear Posture Review*. The nomenclature here matches the unchanged financial Budget and Reporting codes.

4.3.1.2 Science Program Accomplishments

Major accomplishments and significant contributions by the Science Program and subprograms since the FY 2018 SSMP are detailed in this section.

Advanced Certification

- Validated an LLNL design concept for the W80-4 in a hydrodynamic test executed at the Dual-Axis Radiographic Hydrodynamic Test (DARHT).
- Conducted two hydrodynamic tests as part of the Certification Readiness Exercises for pit re-use and the use of insensitive high explosives (IHE) for primary options for the future stockpile.
- Conducted hubcap experiments with advanced manufactured components in support of the Joint Technology Demonstrator.

Primary Assessment Technologies

- Executed the Eurydice surrogate and Vega subcritical experiments, completing the Lyra subcritical experiment series to inform materials models used in annual assessments.
- Completed the Level 1 Advanced Safety Concepts milestone and complimentary Predictive Capability Framework (PCF) pegpost for the future stockpile.

Dynamic Materials Properties

- Executed plutonium material strength experiments at the National Ignition Facility (NIF) and obtained scientifically significant plutonium strength data at pressures relevant to the stockpile.
- Delivered plutonium data from NIF, Joint Actinide Shock Physics Experimental Research (JASPER), Z pulsed power facility (Z), and small-scale experiments at TA-55 to validate the plutonium equation of state and plutonium aging models that are directly relevant to stockpile assessments, stockpile certification, and future stockpile options, including the B61-12 LEP.
- Completed first set of physics experiments on SNL's Thor intermediate-scale, pulsed power accelerator.
- Delivered high explosives (HE) data from experiments at the Dynamic Compression Sector that support the development of more advanced models of the detonation and performance of IHE.

Advanced Radiography

- Invented a new, laser-triggered gas switch that may reduce the cost and complexity of underground pulsed-power drivers for advanced radiography, as well as eliminate the need for the use of sulfur hexafluoride in those drivers.
- Demonstrated a 6th generation linear transformer driver cavity that meets performance, reliability, and lifetime requirements for next generation pulsed power systems for future hostile environments and high energy density physics missions.

Secondary Assessment Technologies

- Modeled underground nuclear explosive tests and validated weapons design codes to inform future secondary reuse or remanufacture decisions.
- Concluded a high energy density (HED) Shear campaign at NIF that provided an essential data set to understand shear forces in the HED regime of the stockpile.
- Used the Advanced Radiographic Capability at NIF to obtain data on an HED platform.

Academic Alliances and Partnerships

- Completed review of Stewardship Science Academic Alliances Center of Excellence applications for the FY 2018 academic programs to continue strengthening and expanding the program between the academic community and the scientists at DOE/NNSA laboratories.

Enhanced Capabilities for Subcritical Experiments

- Achieved CD-1 (Approve Alternative Selection and Cost Range) for the U1a Complex Enhancements Project, 17-D-640.
- Completed an Independent Cost Review and an Independent Project Review of the CD-1 package for the Advanced Sources and Detectors Major Item of Equipment that included a conceptual design report.
- Conducted two static neutron diagnosed subcritical experiment series of tests with special nuclear material (SNM) to inform options for a diagnostic source.

4.3.1.3 Science Program Changes from the FY 2018 SSMP

No substantive changes from the FY 2018 SSMP.

4.3.1.4 Science Program Milestones and Objectives

Science milestones and objectives are illustrated in **Figure 4–6**.

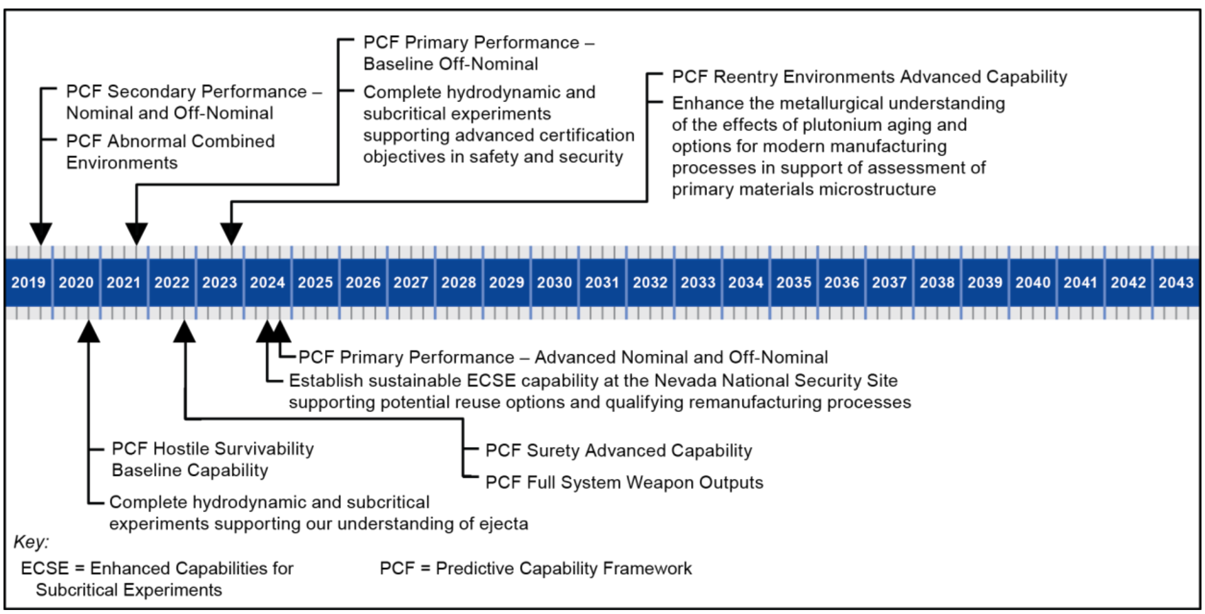
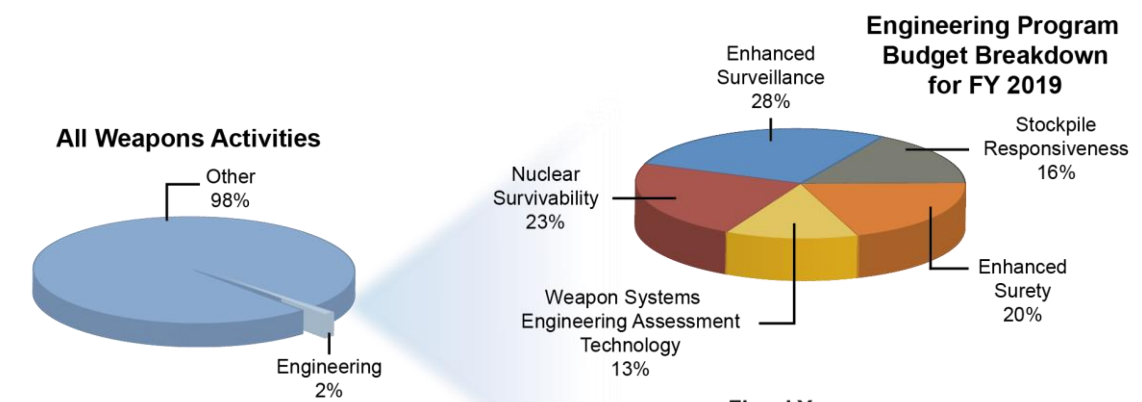


Figure 4–6. Experimental and analysis milestones and objectives led by the Science Program

4.3.2 Engineering Program

4.3.2.1 Engineering Program Budget

Engineering Program funding for FY 2018–2023 is illustrated in **Figure 4–7**.



Fiscal Year (Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Enhanced Surety	39.7	43.2	46.5	49.6	51.7	56.8
Weapon Systems Engineering Assessment Technology	23.0	27.5	35.9	36.7	37.5	38.3
Nuclear Survivability	45.2	48.2	48.9	51.0	53.0	55.0
Enhanced Surveillance	45.1	58.4	60.3	62.3	63.5	64.9
Stockpile Responsiveness	30.0	34.0	34.8	36.3	40.1	40.8
Total Engineering	183.1	211.4	226.5	235.9	245.9	255.7

Note: Numbers may not add due to rounding

Figure 4–7. Engineering Program funding schedule for fiscal years 2018 through 2023

4.3.2.2 Engineering Program Accomplishments

Major accomplishments and significant contributions from the Engineering Program and its subprograms since the FY 2018 SSMP are detailed in this section.

Enhanced Surety

- Launched a full-scale 6- to 8-year multi point safety experiment to study long-term maturity compatibility and aging effects.
- Redesigned a surety component, including modeling, fabrication, and assembly, that increased the life of the component by 10-fold and reduced the size by 75 percent for use in future reentry body and reentry vehicle-required systems.
- Completed and delivered next-generation surety hardware builds that are integrated with advanced architectures to the joint technology demonstrator team.

Weapons Systems Engineering Assessment Technology

- Completed a demonstration test that combined acceleration, spin, and vibration on mock hardware provided by the W87 Alt Fuze program.
- Exercised a micro-digital-image-correlation diagnostic for observing and quantifying the damage and failure of HE at the crystal-binder length scale. This supports the development of high-fidelity mock HE, reducing risk and addressing the safety challenges associated with environmental testing.
- Measured coefficient of thermal expansion data of two enduring systems’ case parts.

Nuclear Survivability

- Completed relevant program dependencies for the W88 Alt 370 program, including uncertainty quantification threat assessment of III-V electronics, device and component photocurrent and photoconductivity tests, and cable and terminal protection device evidence.
- Calculated initial threat response for the latest builds of four III-V heterojunction bipolar transistors-based discrete and small-scaled integrated circuits in the W88 Alt 370 fireset.
- Began research effort to understand system-generated electromagnetic pulse and source region electromagnetic pulse effects in detonator cable assemblies, including design of the detonator electromagnetic response chamber.
- Performed experimental campaigns at NIF and the Omega Laser Facility (Omega) for the hot uranium experiment for the Output Uncertainty Quantification effort.

Enhanced Surveillance

- Developed new acoustic/vibration diagnostic technique that nondestructively provides detailed information on timing, aging trends, and the performance of safety components and launch accelerometers in both laboratory and flight tests.
- Completed destructive and nondestructive thermal battery component and materials aging tests and accelerated aging studies of lithium and iron disulfide chemistry batteries, using the B61 main and pulsed batteries as representative examples.
- Developed new code for simulation of integrated aging effects in LEP components.
- Performed significant number of material aging studies to identify aging signatures in weapons materials via the development of material aging models.

4.3.2.3 Engineering Program Changes from the FY 2018 SSMP

- Increased support for early confidence testing of multi-point safety subsystems for future weapons.
- Continued development of weapon security technologies for several Air Force venues.
- Added development of experimental test facilities for future delivery systems, investments in ground test capabilities for coupled environments, development of new diagnostics to collect adequate data from testing, and development of advanced methodologies for measuring engineering performance of materials, components, and systems for future qualification.
- Added support for experimental laboratory platforms and modeling capabilities to quantify margins and uncertainties for key failure modes, as well as studies of evolving threats and mitigating technologies for survivability.
- Added support for advanced imaging development and testing (neutron imaging and x-ray graded collimation); scintillator development and diagnostics, identification, and quantification of aging processes in high-risk materials; and development and validation of accelerated aging techniques for materials used in non-nuclear components.
- The Stockpile Responsiveness Program will exercise capabilities through the execution of two challenge problems in support of *Nuclear Posture Review* objectives.

4.3.2.4 Engineering Program Milestones and Objectives

Engineering milestones and objectives are illustrated in **Figure 4–8**.

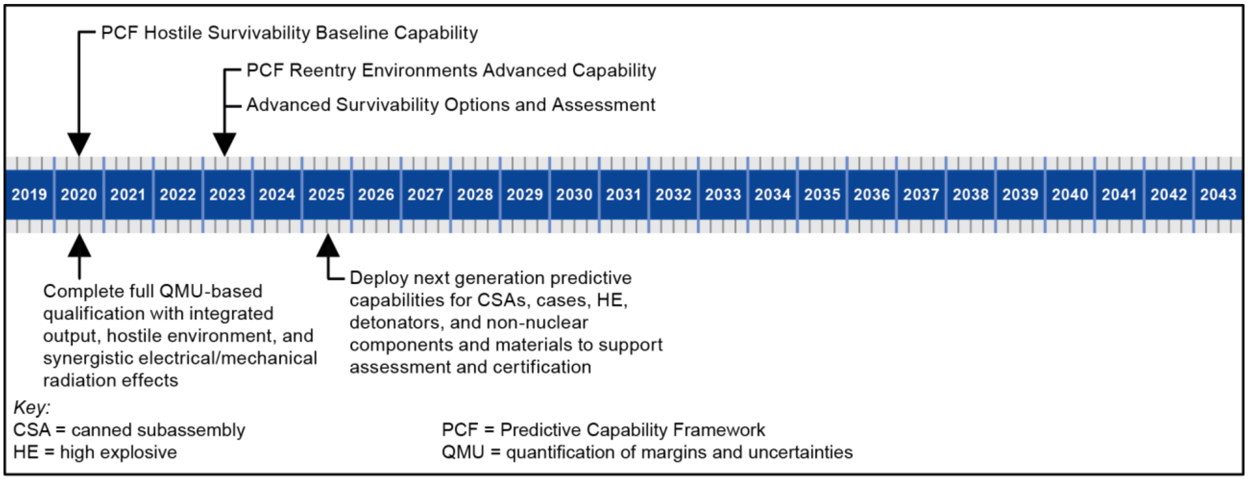
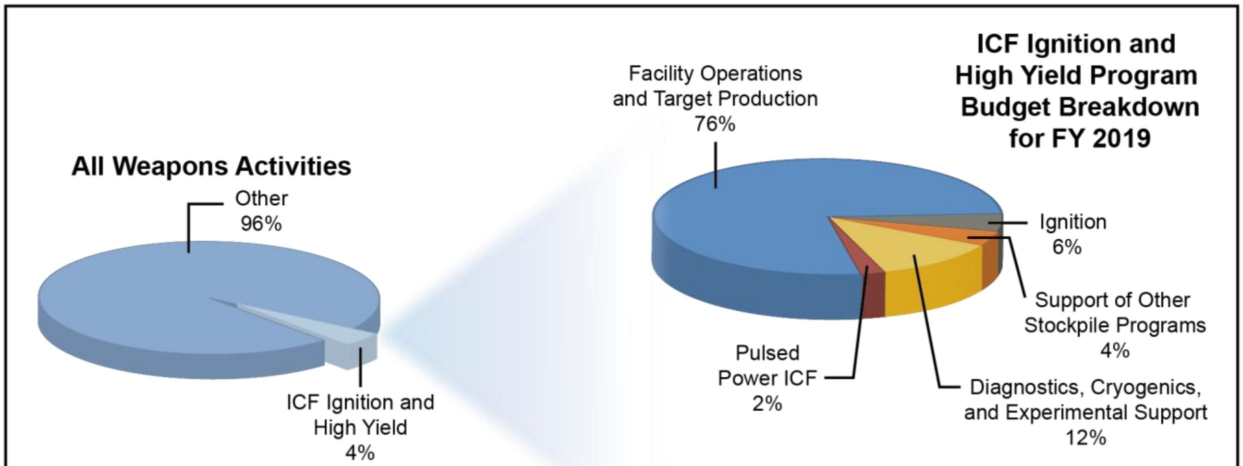


Figure 4–8. Engineering and technological milestones and objectives led by the Engineering Program

4.3.3 Inertial Confinement Fusion Ignition and High Yield Program

4.3.3.1 Inertial Confinement Fusion Ignition and High Yield Program Budget

The funding schedule for this program is illustrated in **Figure 4–9**.



Fiscal Year (Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Ignition	79.6	22.4	29.9	36.6	37.4	38.2
Support of Other Stockpile Programs	23.6	17.4	17.4	16.8	17.1	17.5
Diagnostics, Cryogenics, and Experimental Support	77.9	51.5	47.1	62.9	64.2	65.7
Pulsed Power ICF	7.6	8.3	9.5	8.7	8.9	9.1
Joint Program in High Energy Density Laboratory Plasmas	9.5	0.0	10.0	0.0	0.0	0.0
Facility Operations and Target Production	346.8	319.3	314.1	312.5	319.4	326.5
Total ICF Ignition and High Yield	544.9	418.9	428.0	437.5	447.2	457.0

Key:
ICF = Inertial Confinement Fusion

Note: Numbers may not add due to rounding

Figure 4–9. Inertial Confinement Fusion Ignition and High Yield Program funding schedule for fiscal years 2018 through 2023

4.3.3.2 Inertial Confinement Fusion Ignition and High Yield Program Accomplishments

Major accomplishments and significant contributions from the Inertial Confinement Fusion Ignition and High Yield (ICF) Program and subprograms are detailed in the following six subsections.

Ignition

- Held inaugural “Red Team” meeting to conduct an internal review of the ICF Program.
- Generated highest fusion yield-to-date at NIF (54 kilojoule total fusion yield; 1.7×10^{16} primary deuterium neutrons) by advancing hohlraum drive symmetry control and reducing fill-tube degradation effects. Much research remains as this yield is approximately a factor of 30 less than the “ignition” energy range that would signify neutron energy output greater than the input energy.
- Validated physical processes occurring during an implosion with the convergence ratio necessary to achieve ignition on NIF.
- Achieved a record yield for cryogenic deuterium-tritium laser-direct-drive implosions on the Omega.
- Demonstrated improved laser coupling in laser-direct-drive implosions using wavelength detuning at NIF.
- Modeled engineering features on liquid layer experiments using Advanced Simulation and Computing (ASC) code.

Support of Other Stockpile Programs

- In stockpile related work, conducted two plutonium strength experiments at NIF to compare with weapons performance assessment models.
- Supported measurement at Z of the equation of state of a uranium alloy relevant to future subcritical experiments.
- Completed STAR and Z experiments for cross-platform comparisons with NIF and other facilities as part of the national tantalum strength milestone.
- Set new Z facility records for less than 20 kilo-electron volt x-ray output (increase of greater than 50 percent) and peak current to a radiation source for vulnerability and hardening studies.
- Used the Advanced Radiographic Capability to measure the evolution of targets relevant to stockpile surveillance and weapons performance assessment.
- Completed a multi-year NIF campaign to validate an important ASC mix model.

Diagnostics, Cryogenics, and Experimental Support

- Introduced the first transformational diagnostics at NIF, Z, and Omega to provide dramatic improvements in HED measurement capability.
- Obtained first images with the Polar Neutron Imaging System at NIF to constrain symmetry assumptions of the hot core.
- Deployed new laser-tracker-based diagnostic alignment system to increase the accuracy and efficiency of instrument pointing.
- Recorded the first images with the R&D 100 Award-winning ultrafast X-ray Imager detectors at Z.
- Installed a third NIF target positioner and a fourth diagnostic inserter to increase experimental flexibility and efficiency.

Pulsed Power Inertial Confinement Fusion

- Increased magnetized liner inertial fusion (MagLIF) initial target magnetization by 50 percent, resulting in an increase in neutron yield by 66 percent and a new record for this ICF concept.
- Increased laser energy coupled to MagLIF fuel to greater than 1 kilojoule using two co-injected laser beams.
- Improved MagLIF yield reproducibility, reducing variability from greater than or equal to 15 percent to ±10 percent by coating liners.

Joint Program in High Energy Density Laboratory Plasmas

- Provided more than 300 HED experiments for academic users to train the next generation of stockpile stewards.

Facility Operations and Target Production

- Commissioned Centipede pulser for the ECSE project as part of multi-year plan for multi-pulse radiography.
- Demonstrated multiple shots at 2.5 megajoule full-NIF-equivalent performance on one quadrant of NIF, paving the path to full NIF operation at 2.5 megajoule with modest optical system changes (40 percent increase in total energy). The total energy increase in the capsule center has not been experimentally determined.
- Increased NIF operating efficiency and shot rate at high energies by reducing the damage per high-energy shot to the grating debris shields.
- Commissioned world's most advanced linear transformer driver cavity test facility where a single cavity produced 950 kiloamperes and 88 gigawatts output.

4.3.3.3 Inertial Confinement Fusion Ignition and High Yield Program Changes from the FY 2018 SSMP

- Completed the milestone, *Assessed requirements for a high-yield platform to support LEP and long-term stockpile modernization*.
- Completed the milestone, *Obtain deuterium-tritium burn and other data required to support the FY 2019 PCF pegpost*.
- Completed the milestone, *Use symmetrically driven implosions to investigate performance scaling and cliffs*.
- The FY 2020 milestone, *Obtain time-resolved diffraction data at a scale that can support high-pressure, high-Z material studies*, was postponed to FY 2021 to meet high-priority NNSA mission needs.
- To meet high-priority NNSA mission needs, the FY 2020 milestone, *Determine the efficacy of NIF for ignition and credible physics-scaling to multi-megajoule yields for all ICF approaches* was postponed to FY 2025.
- To meet high-priority NNSA mission needs, the FY 2021 milestone, *Deliver capability on the NIF to measure high-Z material temperatures enabling high fidelity equation of state measurements*, was postponed to FY 2024.

- The FY 2022 milestone, *Establish mission need for a high yield platform to support LEP and long-term stockpile modernization*, was postponed to FY 2026 to meet high-priority NNSA mission needs.
- The FY 2022 milestone, *Conduct major program review to assess the facility investments needed to meet future stockpile stewardship requirements*, was postponed to FY 2027 to meet high-priority NNSA mission needs.

4.3.3.4 Inertial Confinement Fusion Ignition and High Yield Program Milestones and Objectives

Program milestones and objectives based on experiments at the different facilities, are illustrated in **Figure 4–10**.

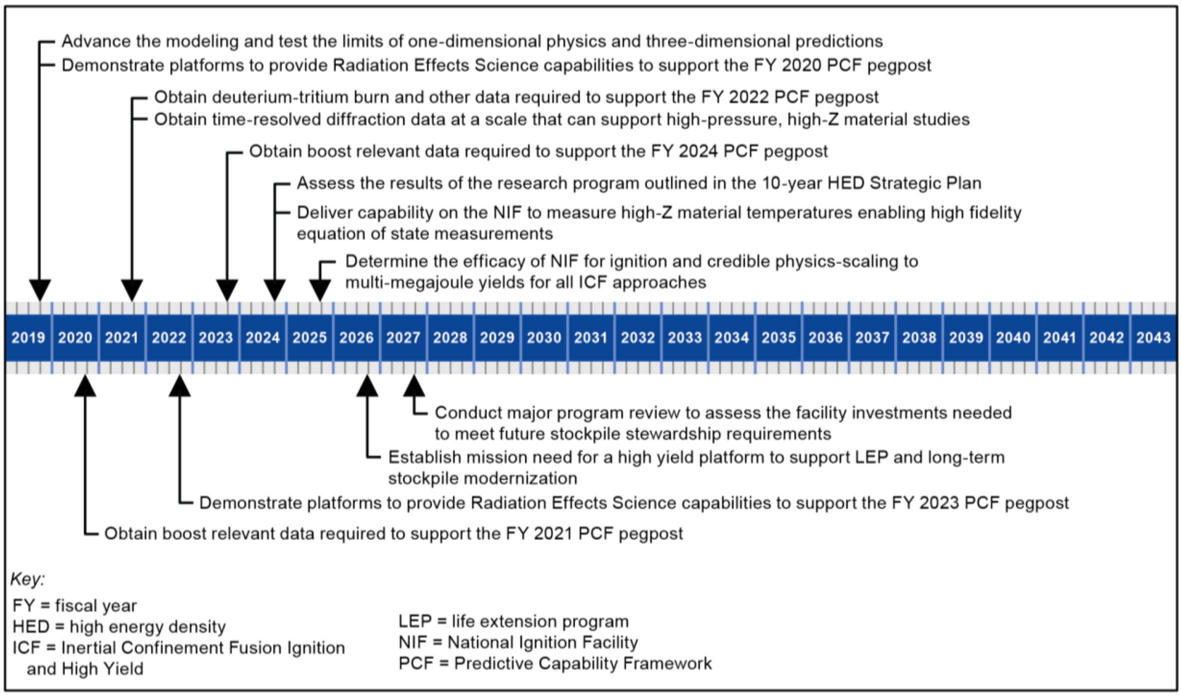
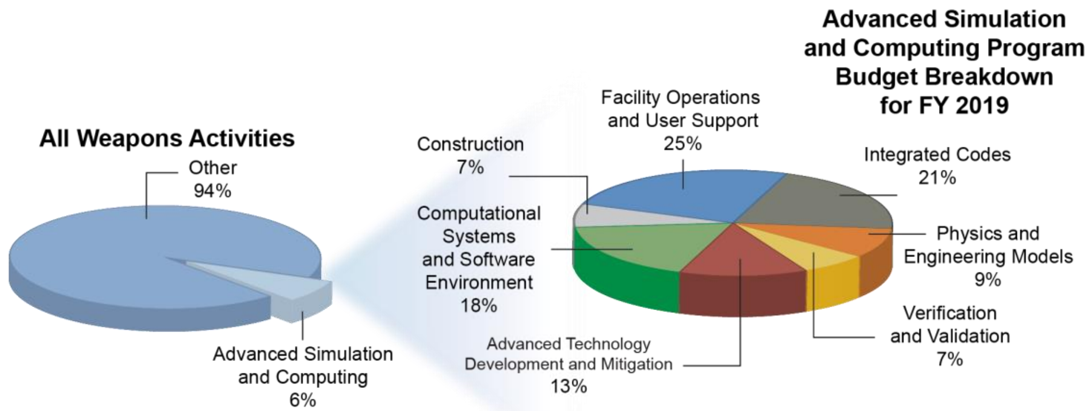


Figure 4–10. Milestones and objectives based on experiments on DOE/NNSA's high energy density facilities led by the Inertial Confinement Fusion Ignition and High Yield Program

4.3.4 Advanced Simulation and Computing Program

4.3.4.1 Advanced Simulation and Computing Program Budget

The funding schedule for this program is illustrated in **Figure 4–11**. The funding schedule for the NNSA Exascale Computing Initiative, which is executed with the ASC program's budget, is presented in Appendix B, Table B–1.



Fiscal Year (Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Integrated Codes	151.8	146.6	146.6	146.6	149.7	152.9
Physics and Engineering Models	66.9	63.6	63.6	63.6	65.2	66.8
Verification and Validation	51.1	51.8	51.9	54.9	60.9	61.9
Computational Systems and Software Environment	121.5	123.6	161.4	174.2	277.5	285.4
Facility Operations and User Support	160.0	175.7	175.7	175.7	177.5	179.3
Advanced Technology Development and Mitigation	170.0	95.1	50.0	61.0	56.0	36.0
Construction	25.0	47.0	68.7	27.0	13.0	0.0
Total Advanced Simulation and Computing	746.2	703.4	717.8	703.0	799.7	782.3

Note: Numbers may not add due to rounding

Figure 4–11. Advanced Simulation and Computing Program funding schedule for fiscal years 2018 through 2023

4.3.4.2 Advanced Simulation and Computing Program Accomplishments

Major accomplishments and significant contributions from the ASC Program and subprograms since the FY 2018 SSMP are detailed in the following six subsections.

Integrated Codes

- Demonstrated improvements of ASC production weapons codes on Sierra Early Access Systems.
- Supported stockpile safety, security, and reliability by conducting thermal/mechanical modeling for crash and burn use cases at SNL.
- Completed a capability assessment for simulating weapons performance in limited hostile environments at LANL.

Physics and Engineering Modes

- Delivered improved code capabilities and physics models to support the FY 2019 PCF pegpost.
- Validated models and assessed the overall simulation capability for acoustic vibrations during reentry.
- Improved performance of IHE detonation models at non-ambient temperature conditions and for corner turning.

Verification and Validation

- Delivered capability for verification and validation assessments of code implementations of physics models and numerical algorithms in support of future capability framework pegposts.
- Completed verification on multi-physics performance model for a single-cell thermal battery.
- Established verification test problems and suites for code physics validation.

Computational Systems and Software Environment

- Finished evaluation of proposals for Crossroads system that is scheduled to be deployed in FY 2021 as replacement for Trinity.
- Accepted Sierra initial delivery system and finalized application development environment software stack for the full system to be deployed in early FY 2019.

Facility Operations and Use Support

- Completed advanced infrastructure planning report for the Exascale Computing Facility Modernization project, including detailed construction project drawings and specifications, in order to execute the project and proceed to Critical Decision (CD)-2/3.
- Completed required documentation for readiness for construction approval of the Exascale-Class Computer Cooling Equipment project.

Advanced Technology Development and Mitigation

- Deployed initial capability of an ARM-based advanced architecture prototype system and tri-laboratory software environment to explore an alternative architecture path for beyond exascale computing.
- Demonstrated capabilities and assessed feasibilities of tri-laboratory next-generation codes on the Sierra Early Access Systems.

4.3.4.3 Advanced Simulation and Computing Program Changes from the FY 2018 SSMP

Several changes to the milestones and objectives occurred as indicated in **Figure 4–12**.

- The Advanced Technology System (ATS)-3 milestones slipped 1 year because the industry did not meet the program's technology needs and budget parameters for system acquisition.
- The ATS-5 milestones slipped 1 year due to a revised program deployment schedule.

4.3.4.4 Advanced Simulation and Computing Program Milestones and Objectives

Milestone and objectives for this program are illustrated in Figure 4–12.

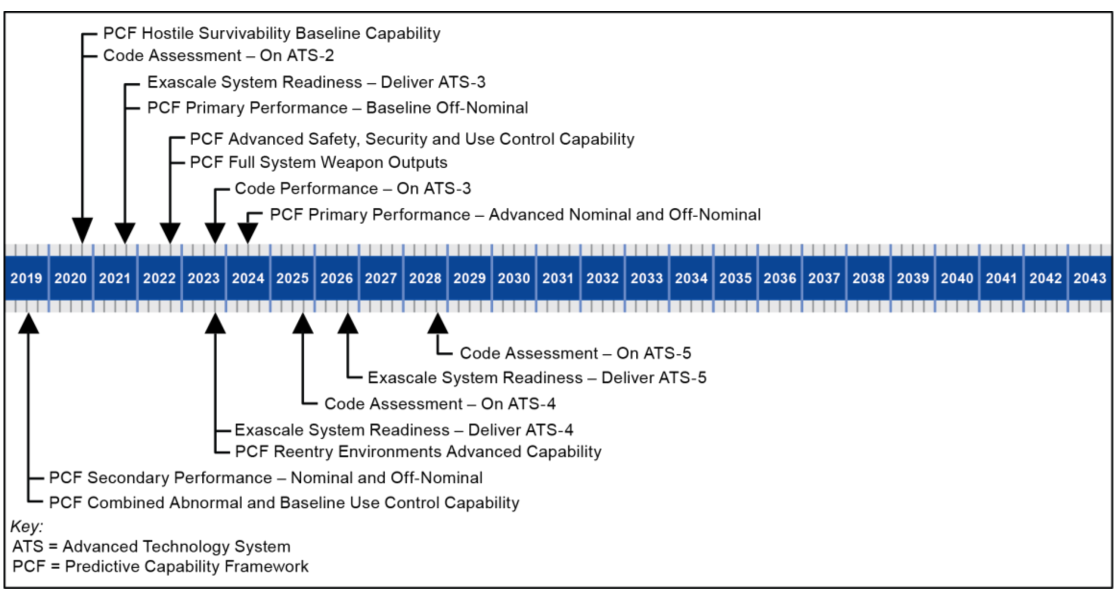
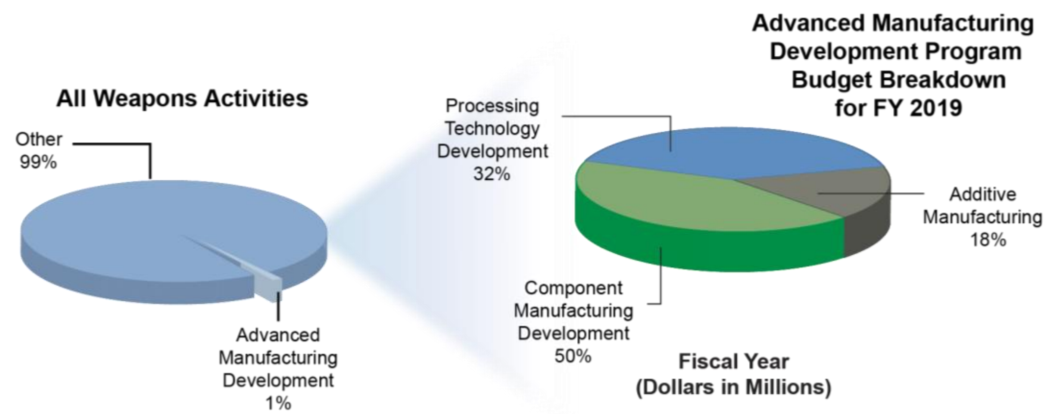


Figure 4–12. Milestones and objectives of the Advanced Simulation and Computing Program

4.3.5 Advanced Manufacturing Development Program

4.3.5.1 Advanced Manufacturing Development Program Budget

The funding schedule for this program is illustrated in **Figure 4–13**.



Fiscal Year (Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Additive Manufacturing	12.0	17.4	18.5	19.8	19.8	20.2
Component Manufacturing Development	38.6	48.5	58.4	68.6	70.0	71.5
Processing Technology Development	34.9	30.9	28.2	29.2	29.8	31.5
Total Advanced Manufacturing Development	85.5	96.8	105.1	117.6	119.6	123.2

Note: Numbers may not add due to rounding

Figure 4–13. Advanced Manufacturing Development Program funding schedule for fiscal years 2018 through 2023

4.3.5.2 Advanced Manufacturing Development Program Accomplishments

Major accomplishments and significant contributions from the Advanced Manufacturing Development Program and subprograms since the FY 2018 SSMP are detailed as follows.

- Developed direct ink write technology that is now the preferred manufacturing method for the W88 Alt 370. This new technology helps reduce the pad production schedule by 50 percent.
- Developed first small batch of additively manufactured chip slapper detonators (baselined for insertion in the B61-12 LEP), reducing process development time by 50 percent.[3]
- Introduced new additively manufactured electrical connection to prevent the accumulation of frost on safety components, reducing the cost of developing a solution.
- Developed coating that results in a quicker, cleaner, and less labor-intensive cleaning process for removing contaminates from dismantled components.
- Aligned product acceptance testers to assure readiness in meeting War Reserve production capacity for the B61-12 LEP, W88 Alt 370, and MK21 Fuze programs.
- Charted path to qualify and certify newly manufactured IHE in support of B61-12, W80-4, and future weapon systems. This path will reduce the future shortage of one of the components in IHE and help meet legacy characteristics and performance requirements.
- Transitioned ASIC production control software to the Electronic Production Control System, which automates tracking of ASICs through production. The Electronic Production Control System reduces human error in recording information and reduces costs.

[3] With advanced manufacturing processes having become standard practice for major aspects of LEP execution, AMD no longer tracks its total cost saving relative to previous manufacturing methods.

4.3.5.3 Advanced Manufacturing Development Program Changes from the FY 2018 SSMP

The milestone, *Transfer tritium processing technologies to Tritium Sustainment Program* (FY 2020), has been removed from the chart because the scope transfer has been completed.

4.3.5.4 Advanced Manufacturing Development Program Milestones and Objectives

Program milestones and objectives are illustrated in **Figure 4–14**.

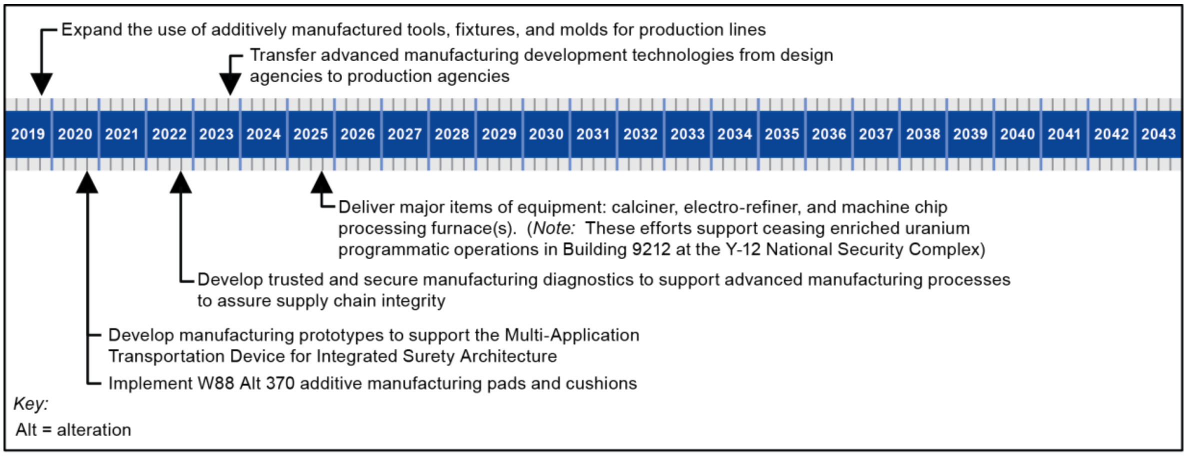
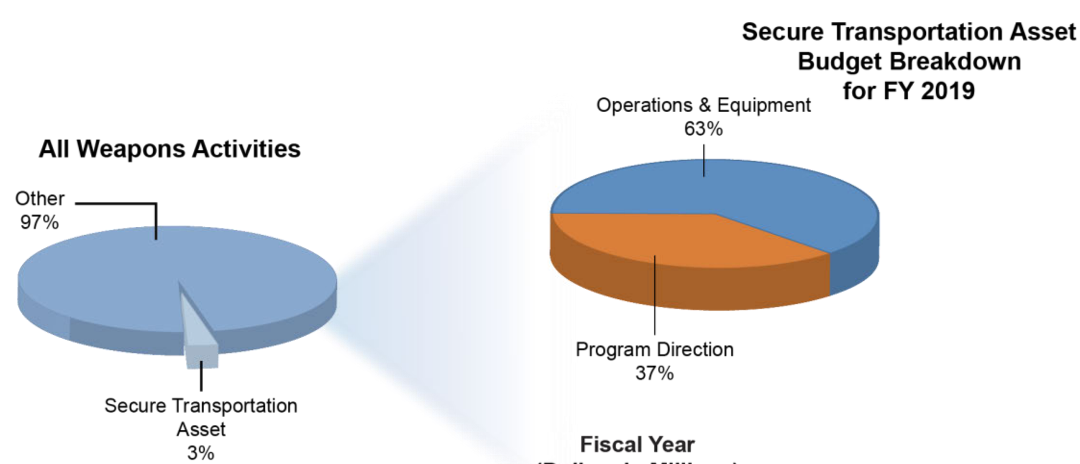


Figure 4–14. Milestones and objectives for Advanced Manufacturing Development Program

4.4 Secure Transportation Asset

4.4.1 Secure Transportation Asset Budget

The funding schedule or this program is illustrated in **Figure 4–15**.



Fiscal Year
(Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Operations & Equipment	185.6	176.6	226.9	215.8	220.1	224.9
Program Direction	105.6	102.0	112.8	116.6	119.9	122.8
Total Secure Transportation Asset	291.2	278.6	339.7	332.4	339.9	347.6

Note: Numbers may not add due to rounding

Figure 4–15. Secure Transportation Asset funding schedule for fiscal years 2018 through 2023

4.4.2 Secure Transportation Asset Accomplishments

In FY 2017, the Secure Transportation Asset (STA) program accomplished the following:

- Completed 100 percent of shipments safely and securely, without compromise, loss of components, or release of radioactive material.
- Enhanced reliability and availability of mission support communications.
- Developed and implemented Safeguards Transporter (SGT) risk reduction initiatives, thereby extending the life of the SGT.
- Accepted delivery of 14 escort vehicles (light chassis), eight support vehicles, and seven replacement armored tractors.
- Completed Mobile Guardian Transporter (MGT) crash unit manufacturing readiness review.

4.4.3 Secure Transportation Asset Changes from the FY 2018 SSMP

- STA conducted a Business Case Analysis to replace its aging DC-9 aircraft. This was previously listed as an AoA.
- Identified the following new key strategies for STA's 5-year strategic plan:
  - Strengthen communications, capabilities, and leadership throughout the entire workforce.
  - Enhance strong safety and security focus throughout the organization.
  - Modernize and strengthen mission assets and infrastructure through continuous innovation.
- Rephrased milestone, *Last SGT certification expires,* to *Last SGT reaches end of design life-cycle*.
- Changed references to "RAT II" to "next-generation armored tractor" for clarification.
- Rephrased milestone, *Complete RAT II Design,* to *Complete next-generation armored tractor specifications and requirements*.
- Changed the date of the milestone, *MGT production begins,* from FY 2024 to FY 2025 to address DOE/NNSA higher-priority items within the FY 2019 FYNSP.
- Changed the date of the milestone, *Complete MGT production,* from FY 2033 to FY 2034 to address NNSA higher-priority items within the FY 2019 FYNSP.

4.4.4 Secure Transportation Asset Milestones and Objectives

The milestones in **Figure 4–16** move STA toward defined goals. STA continuously evaluates the operational environment to ensure safe and secure transport of nuclear weapons and SNM. To stabilize operating budgets and support steady-state production, STA has adjusted out-year plans for all escort vehicles, armored tractors, and facilities maintenance and upgrades. Aviation conducted a business case analysis in support of the DC-9 aircraft replacement.

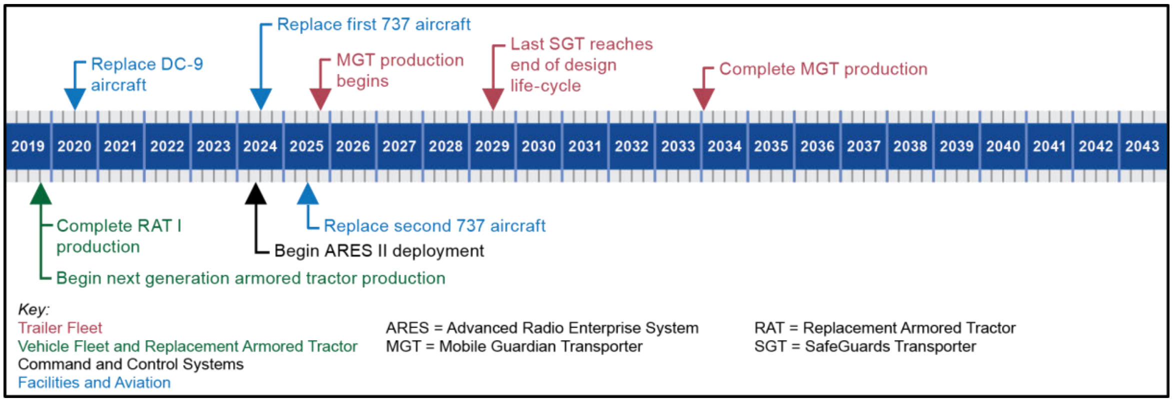


Figure 4–16. Secure Transportation Asset Program milestones and objectives

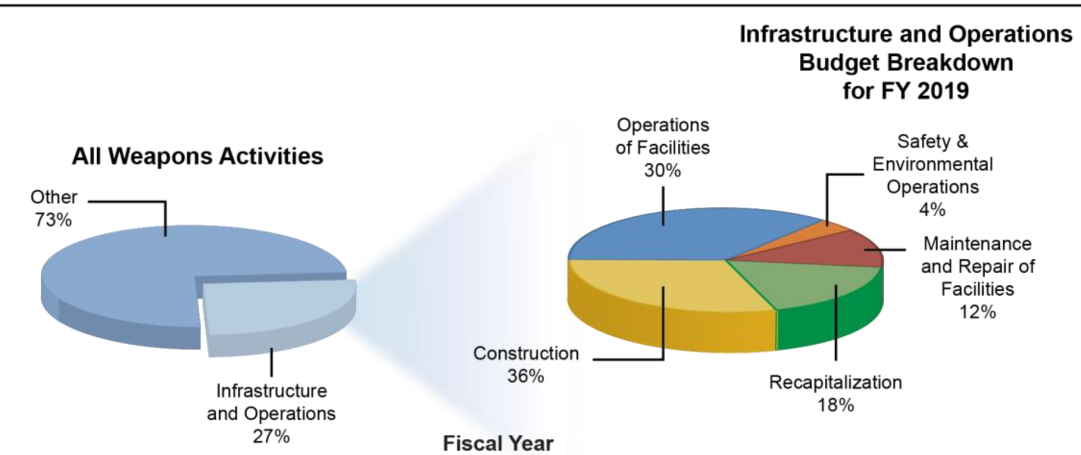
4.5 Infrastructure and Operations

DOE/NNSA has made significant progress in improving infrastructure planning and management tools, including implementing tools to reshape its nuclear security enterprise and improve infrastructure investment planning and implementation for future needs.

Despite planning and prioritization of infrastructure needs, DOE/NNSA continues to be challenged by the magnitude of failing and obsolete infrastructure. Recognizing that unplanned failures will occur, DOE/NNSA is maintaining the flexibility to respond to emerging issues. NNSA is also implementing a prioritization process that maximizes risk reduction per infrastructure dollar invested to optimize the use of infrastructure resources.

4.5.1 Infrastructure and Operations Budget

The funding schedule for Infrastructure and Operations is illustrated in **Figure 4–17**.



Fiscal Year (Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Operations of Facilities	848.5	891.0	925.0	945.0	971.0	986.0
Safety & Environmental Operations	110.0	115.0	119.0	120.0	122.0	122.0
Maintenance and Repair of Facilities	515.1	365.0	390.0	407.0	419.0	432.0
Recapitalization	612.7	540.7	596.0	600.9	631.0	636.7
Construction	1,031.5	1,091.0	1,203.6	1,270.1	1,214.6	1,264.0
Total Infrastructure and Operations	3,117.8	3,002.7	3,233.6	3,343.0	3,357.6	3,440.7

Note: Numbers may not add due to rounding

Figure 4–17. Infrastructure and Operations funding schedule for fiscal years 2018 through 2023

4.5.2 Infrastructure and Operations Accomplishments

The following five subsections detail NNSA's infrastructure operations and modernization accomplishments in FY 2017.

General Purpose Infrastructure – Including Minor Construction and Maintenance

- **Disposition Completed for Former Bannister Road Federal Complex, Kansas City**
  - DOE/NNSA saved approximately $700 million in a successful, 4-year effort after the Former Bannister Road Federal Complex in Kansas City was transferred to a private developer. With zero safety issues and the General Services Administration providing 106 acres of surplus land, DOE/NNSA transferred the combined property to a private developer who accepted responsibility for demolition and for undertaking environmental actions in accordance with the Missouri Hazardous Waste Management Facility permit. DOE/NNSA, in collaboration with the State of Missouri, funded the demolition and environmental remediation activities through an Environmental Services Cooperative Agreement. After these activities are completed, the developer will pursue and fund redevelopment of the site.
- **SNL's Primary Neutron Generator Production Facility**
  - Significantly recapitalized and increased system reliability for the backbone mechanical infrastructure in SNL's primary neutron generator production facility.
  - Upgraded an obsolete pneumatic controls system with direct digital control, replaced many marginally performing air handling units, and increased cooling reliability and efficiency.

Recapitalize and Maintain

In FY 2017, DOE/NNSA completed 47 recapitalization projects, a 56 percent increase from 2016. This improved performance reflects the impact of advanced planning based on detailed data and the use of the reporting tools and processes described above and is the result of increased funding. The following are examples of several completed recapitalization projects that address specific criteria in the risk-based assessments:

- **Building 905 Addition and Renovation at SNL**
  - SNL added 15,000 square feet to the Energetic Components Facility and renovated 6,000 square feet. This project relieved severe office overcrowding; restored nonhazardous laboratory space to original function; created needed support spaces, including conference rooms and a shared library; and achieved Leadership in Energy and Environmental Design (LEED) Gold certification.
- **TA-55 Facility Control System Upgrades (programmatic risk) at LANL**
  - Modified embedded systems that provide information about plant conditions and monitor the safe operability of PF-4. These enhancements are required to support the redundancy and operability of the nuclear production facilities.
- **Flame Detection Systems and Radiation Alarm Monitoring Systems Fiber Optic Network Replacement under the Pantex Bay and Cell Safety System Improvements Portfolio (safety risk)**
  - Replaced more than 12 miles of telephone lines with a fiber network to accelerate and modernize transmission of signals from the new Flame Detection Systems and Radiation Alarm Monitoring Systems in production bays and cells to Pantex's Emergency Operations Center.

- **U1a Fire Protection Installation (safety risk) at the Nevada National Security Site**
  - Addressed active fire suppression system vulnerabilities by installing fire barriers, air compressors, and fan controls and removing combustible legacy wiring. These improvements were needed to maintain the operability of the present and future experiments performed in this facility.
- **Hill 200 Electrical Power Line Upgrade at the Nevada National Security Site (return on investment and deferred maintenance)**
  - Replaced 1.7-mile segment of a 23-mile 60-year-old power transmission line that was at high risk of failure in January 2018. Transmission line and poles were rerouted from an inaccessible hilltop to an easier and safer road level next to Mercury Highway. (Transmission line concerns were realized when twin wooden power transmission poles broke at several locations in the old Hill 200 1.7-mile section in March 2017.)
- **9201-1 Elevator #1 Replacement at Y-12 (deferred maintenance reduction)**
  - Replaced deficient component that could have caused a catastrophic cylinder failure, resulting in injury or death and loss of finished DSW weapons components.
  - This overdue activity arrested deferred maintenance and improved productivity.
- **B321 Complex Heating, Ventilation, and Air Conditioning (HVAC) Modernization at LLNL (programmatic risk)**
  - Replaced HVAC controls in B321A, C, and E to meet the program requirement of maintaining close temperature control and a high degree of HVAC infrastructure reliability for machining capabilities to support the W80-4 LEP.
- **B133 Replace Mission-Critical HVAC at LLNL (programmatic risk)**
  - Replaced existing, outdated control system for the chiller plant and cooling towers supporting a large office/laboratory facility housing weapons and global security missions.

A comparison of investments in Maintenance and Recapitalization to benchmarks, based on the percentage of Replacement Plant Value and derived from the DOE Real Property Asset Management Plan and associated guidance, is summarized in **Table 4–3**.

Table 4–3. Projected fiscal year 2018 NNSA infrastructure maintenance and recapitalization investments

		FY 2017 [a]	*FY 2018*	*FY 2019*
Replacement Plant Value (RPV) ($B)		52.4	50.4	51.4
Maintenance Benchmark 2 to 4% RPV	Maintenance and Repair of Facilities Investments ($K)	324,000	515,138	365,000
	Other DOE/NNSA Maintenance Investments (direct and indirect funded) ($K)	492,395	494,604	507,550
	Total DOE/NNSA Maintenance Investments ($K)	816,395	1,009,742	872,550
	Maintenance as % RPV	1.56%	2.00%	1.70%
Recapitalization Benchmark 1%	Infrastructure & Safety Recapitalization Investments ($K)	630,509	482,661	431,631
	Total DOE/NNSA Recapitalization Investments	743,148	612,661	540,688
	Recapitalization as % RPV	1.42%	1.22%	1.05%

$B = billion dollars
$K = thousand dollars
[a] The FY 2017 Infrastructure & Safety Recapitalization amount includes a one-time increase of $200 million for the disposition of the Kansas City Bannister Road Federal Complex, which is not included in RPV estimates for FY 2017–2019.

Disposition

In FY 2017, DOE/NNSA's budget included more than $250 million to continue reducing the risks posed by excess facilities and to demolish buildings. FY 2017 funding for DOE/NNSA supported:

- Continued risk reduction at Y-12's Alpha 5 and Beta 4 to reduce risks identified by the Government Accountability Office (GAO) and Office of the Inspector General;
- Demolition of Alpha 5 Annex and Buildings 9111, 9112, and 9616-10 at Y-12;
- Disposal of Buildings TA-16-0280 and TA-3-0035 and characterization of Building TA-16-0306 in the HE area at LANL; and
- De-inventory of Building 236H and disposal of Building 232-1H at SRS.

Planned disposition activities in FY 2018 include:

- Characterization and planning for disposition of the TA-16-0460 complex at LANL;
- Disposition of the Kirtland Operations NC-135 site; the Mercury Dorms and Bowling Alley at the Nevada National Security Site; SNL's Mt. Haleakala site; Building 11-015A at Pantex; and Building 363 at LLNL; and
- Risk reduction activities at Y-12's Alpha 5 and Beta 4.

Roof Asset Management Program (RAMP) and Cooling and Heating Asset Management Program (CHAMP)

RAMP

- Completed over 770,000 square feet of roofs replacement and repairs.
- Introduced technical assurance roof coring strategy to verify the composition of existing roofs prior to design.
- Pre-approved 17 new contractors.
- Started FY 2018 roof designs in fall of 2017.
- Have $31 million in roof projects ready to award in FY 2018.

CHAMP

- Completed pilot projects at SRS, SNL, and the Nevada National Security Site.
- Awarded CHAMP Design and Construction Management contract in April 2017.
- Completed nine HVAC assessments in FY 2017.
- Completed LLNL Building 311 Chiller Replacement in fall of 2017.
- Began FY 2018 Designs.

Capital Construction Projects, Including Major Construction

DOE/NNSA's infrastructure capital investments modernize its aging nuclear security enterprise by replacing existing facilities and weapons activities capabilities that are beyond intended lifetimes. The projects below, as well as other planned capital improvements, are necessary to provide capabilities to meet future mission demands.

- **Uranium Processing Facility at Y-12.** Continued progress on construction of new-build Uranium Processing Facility subprojects, including pouring the foundations for the mechanical and electrical, salvage and accountability, and main processing buildings.

- **Chemistry and Metallurgy Research Replacement at LANL.** The Chemistry and Metallurgy Research Replacement (CMRR) project at LANL is on track to achieve the CD-4 milestone by FY 2022 on budget and schedule.
- **Albuquerque Complex Project.** Received Approval of Design and Construction for the Albuquerque Complex Project at SNL on April 20, 2018, with completion by 2022. This project will design and construct approximately 333,000 square feet of LEED Gold office space for approximately 1,200 employees that provide programmatic, technical support, legal, security, procurement, human resources, business, and administrative functions that directly support DOE/NNSA's national security missions. DOE/NNSA has a long-term commitment at this installation, and it will remain the primary field support office for DOE/NNSA.
- **Emergency Operations Center at Y-12.** DOE/NNSA completed design and began construction planning. The project will improve the emergency management response and ability to survive high-consequence natural phenomena. The Emergency Operations Center will more effectively and efficiently support Y-12's missions by consolidating the Plant Shift Superintendent's Office, the Emergency Command Center, the Technical Support Center, and the Fire Department Alarm Room in a single survivable facility.
- **Expand Electrical Distribution System at LLNL.** DOE/NNSA began design and construction in 2018 to improve capability, capacity, and reliability at the site. This project will expand the electrical distribution systems along the east side of the site and provide a new electrical connection to the Sandia-California site. Additionally, the project will supplement the existing distribution system with new 15-kilovolt underground electrical distribution systems, load grid switchgear, and a connection for added future electrical supply.
- **Construction to replace TA-3 substation at LANL.** A new modern replacement substation will be completed in early FY 2019 and have components that are designed to provide increased distribution capacity, improved reliability, reduced maintenance, support for greater operational flexibility, and increased staff safety. The project will provide separate power feeds to both LANL and Los Alamos County.

4.5.3 Infrastructure and Operations Changes from the FY 2018 SSMP

DOE/NNSA has established, per the *National Defense Authorization Act for Fiscal Year 2018*, the Infrastructure Modernization Initiative program with the goal of reducing deferred maintenance and repair needs by no less than 30 percent by 2025.

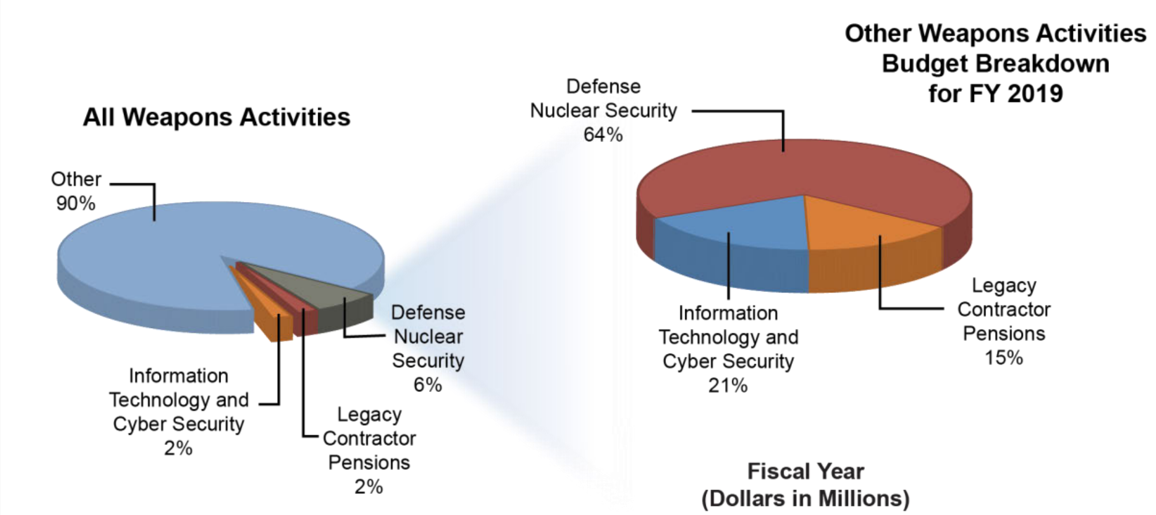
4.5.4 Infrastructure and Operations Milestones and Objectives

Major capital acquisition project schedules are reflected in Figure 4–33, DOE/NNSA major capital acquisition projects and project proposals, in Section 4.7.5.

4.6 Other Weapons Activities

4.6.1 Other Weapons Activities Budget

The funding schedule for Other Weapons Activities is illustrated in **Figure 4–18**.



Fiscal Year (Dollars in Millions)

	2018	2019	2020	2021	2022	2023
Defense Nuclear Security	770.6	690.6	796.9	773.1	773.9	785.1
Information Technology & Cyber Security	186.7	221.2	291.3	281.2	291.2	291.7
Legacy Contractor Pensions	232.1	162.3	72.8	63.8	59.5	55.3
Adjustments	0.0	0.0	0.0	0.0	0.0	
Total Other Weapons Activities	1,189.4	1,074.1	1,161.0	1,118.1	1,124.6	1,132.1

Figure 4–18. Other Weapons Activities funding schedule for fiscal years 2018 through 2023

4.6.2 Defense Nuclear Security

4.6.2.1 FY 2017 Accomplishments for Defense Nuclear Security

NNSA's missions are carried out in a secure environment protected by safeguards and security personnel, layers of physical security technology, and sophisticated cybersecurity systems. Together, this approach protects DOE/NNSA's facilities, SNM, employees, networks, and information. In FY 2017, NNSA's Defense Nuclear Security Program maintained a path of continual improvement, implementing 42 of the 56 key initiatives contained in the NNSA Security Roadmap, along with a number of other activities that contribute to program effectiveness, including the following:

- The Security Management Improvement Program helps ensure continuous improvement of the physical security program and relies on Headquarters and field collaboration to prioritize and implement risk-based solutions within an effective oversight regimen. Baseline visits at two laboratories were completed, and visits to the remaining sites are scheduled.
- The Test and Evaluation program assessed alternatives for a system to address the threat posed by unmanned aircraft systems. Operational testing and employment is underway at LANL, to be followed by installation of protective measures at the three additional sites housing critical SNM.
- An enterprise-wide Security Culture campaign was initiated, with site-by-site visits and awareness presentations to the workforce emphasizing an individual commitment toward the goal of "Protecting What is Ours," the program's theme.
- A Security Infrastructure Revitalization Plan was completed. This plan is the implementing document for a 10-year effort to refresh and replace vital security technology and infrastructure.

The Security Infrastructure Revitalization Plan provides a time-phased, prioritized approach to system refresh requirements.

- First two Tactical Casualty Care Courses for Protective Force members were completed. This course is a crowning achievement in DOE/NNSA's Protective Force Training Reform initiative.

The Headquarters Security Officer organization implements all aspects of the DOE security program for NNSA Headquarters operations, which serve approximately 2,500 stakeholders. The organization also handles the NNSA Headquarters Facility Survey and Approval Program and assists all NNSA Headquarters offices in preparing for third-party security assessments and surveys. In FY 2017, the office facilitated approximately 300 VIP and foreign national visits to Headquarters offices.

NNSA continues to provide comprehensive support in the areas of Personnel and Facility Clearance processing. In FY 2017, over 27,000 adjudicative actions were performed, and three national-level requirements were implemented on schedule. In support of critical NNSA classified work, over 50,000 pages were reviewed. NNSA's automated clearance work flow system was selected by DOE/NNSA leadership as the system for all DOE cognizant personnel security offices. Four of the eight offices, comprising over 80 percent of DOE clearances, are now operating on this system.

4.6.2.2 Changes from the FY 2018 SSMP for Defense Nuclear Security

The Prioritization and Resource Allocation Decision Environment tool was used to develop an objective standardized approach for prioritizing the large number of potential refresh projects at each location. The tool provides an optimal, cost-effective schedule of recommended physical security system investments over a 10-year period, as outlined in the *10-Year Physical Security Systems Refresh Plan* submitted to Congress in August 2017. This assumes that appropriate funding is provided in each of the years represented. If that does not occur, projects will slide into later years, resulting in increased costs.

Changes to milestones in the *10-Year Physical Security Systems Refresh Plan* included the following:

- *Complete Zone 4 and 12 PIDAS Refurbishment at Pantex Plant* (FY 2028), was changed to *Complete Pantex PIDAS Physical Security System Components and Infrastructure Refresh* (2020-2021).
- *PIDAS Modernization/CAS relocation at Y-12* (FY 2028), was changed to *Complete Y-12 perimeter area reduction, PIDAS modernization, and entry control facility upgrade* (2022-2023).
- *Complete entry control facility upgrade at Y-12* (FY 2037-2038), was changed to *Complete Y-12 protected area reduction, PIDAS modernization, and entry control facility upgrade* (FY 2023).
- *Complete NNSS and LANL PIDAS Modernization* (2027-2028), was added.
- *Complete Security System Refresh Projects across NNSA Enterprise as outlined in the 10-Year Physical Security Systems Refresh Plan submitted to Congress, August 2017* (2027-2028), was added.

4.6.2.3 Milestones and Objectives for Defense Nuclear Security

Program milestones and objectives are illustrated in **Figure 4–19**.

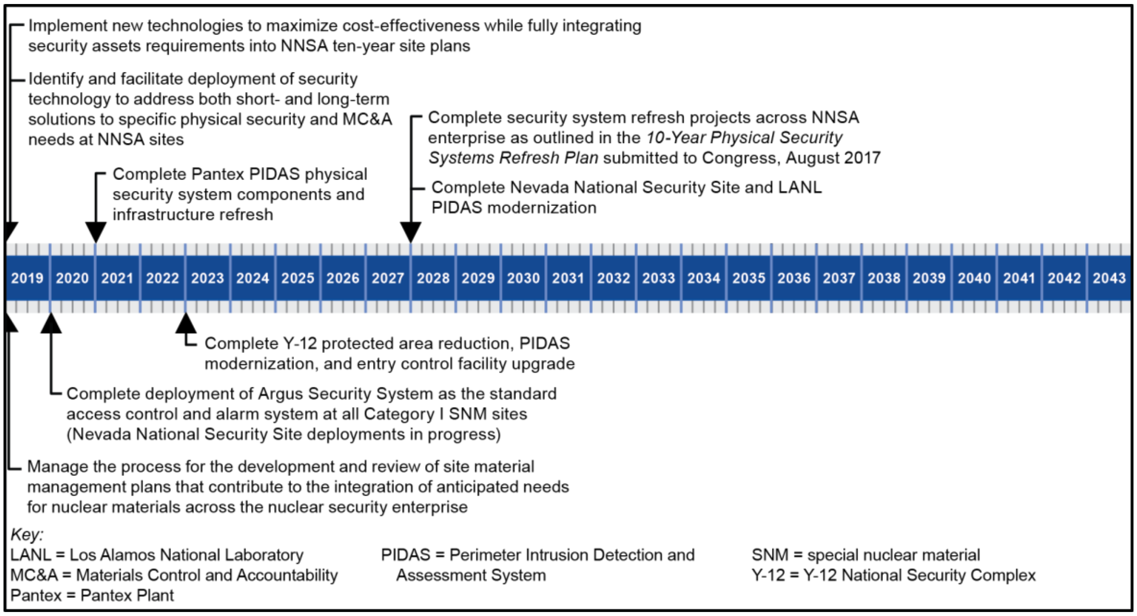


Figure 4–19. Defense Nuclear Security program milestones and objectives timeline

4.6.3 Information Technology and Cybersecurity

4.6.3.1 2017 Accomplishments for Information Technology and Cybersecurity

DOE/NNSA prioritizes the delivery of information technology (IT) and cybersecurity solutions that support and secure DOE/NNSA's nuclear security missions. Protection of all IT assets includes both prevention of intrusions and attacks that aim to harm and mitigation of infiltration. In the current cyber and political environment, it is critical to maintain the public's confidence in DOE/NNSA's ability to protect agency assets from threats and demonstrate dedication to security and diligence by use of established cyber defenses and continuous monitoring, as well as leveraging modern IT tools and processes for optimal workforce performance and security controls. Major accomplishments in FY 2017 included the following:

- Continued recapitalization of the Enterprise Secure Computing program and completed implementation of a virtual desktop infrastructure nationwide.
- Assessed operational readiness across the enterprise through the efforts of the IT and Cybersecurity Program Budget Re-baseline Analysis. Additional completed efforts completed included development of an updated IT and Cybersecurity Program Work Breakdown Structure.
- Published the 2017-2019 NNSA Office of the Associate Administrator for Information Management and Chief Information Officer Strategic Implementation Plan. The plan sets forth six strategic principles to support achievement of DOE/NNSA's mission to maintain and enhance the safety, security, and effectiveness of the U.S. nuclear weapons stockpile and is aligned with the U.S. Department of Energy National Nuclear Security Administration Enterprise Strategic Vision (August 2015)[4] and the Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats (FY 2016–FY 2020).[5] The plan is supported by crosscutting activities of advancing

[4] The DOE/NNSA Enterprise Strategic Vision (August 2015) can be found at https://www.energy.gov/sites/prod/files/migrated/nnsa/2017/11/f45/Final_Strategic_Vision_2015_9-3_screen%20quality.pdf
[5] *Prevent, Counter, and Respond-A Strategic Plan to Reduce Global Nuclear Threats (FY 2016-FY 2020)* can be found at https://nnsa.energy.gov/aboutus/ourprograms/dnn/npcr

science, technology, and engineering; supporting our people and modernizing our infrastructure; and developing a management culture that is directly mapped to the U.S. Department of Energy Cyber Strategy[6] and DOE's 2015 Strategic Sustainability Performance Plan.[7]

Through regular coordination with leadership, IT organizations, partners in the laboratories and field, and associates across the Federal IT space, DOE/NNSA identified an opportunity to push modernization efforts and implement an IT construct that will use brokered and managed information management services. Worked with the DOE Office of the Chief Information Officer (OCIO) to modernize and strengthen the Department's aging IT infrastructure and to provide innovative ways to consume, leverage, share, and safeguard information and related assets. DOE/NNSA's focus on a managed service model takes advantage of emerging technologies and provides opportunities to participate in economies of scale and rely on industry's rapid development and testing practices for a safe, secure, and modern technology. Additional accomplishments included the following:

- Maintained a defense-in-depth approach to achieving cybersecurity in a highly networked complex environment for 62,812 users of 194 Federal Information Security Management Act (FISMA) systems.
- Completed Assessment Methodology for conducting assessments against IT requirements at DOE/NNSA sites. These assessments will enable the NNSA OCIO to design a more enterprise-centric approach for the IT program.
- Completed a number of IT and Cybersecurity Program Inspections. For example, inspected unclassified environments at LLNL, the Office of Secure Transportation, and the Mixed Oxide Fuel Fabrication Facility at SRS. Conducted Command Cyber Readiness Inspections (CCRIs) of the NNSA SECRET Network nodes at LANL, SRS, and Pacific Northwest National Laboratory for the Defense Information Systems Agency. CCRIs assess the readiness of sites to maintain secure connection to the NNSA SECRET Network. Also conducted CCRIs on NNSA Enterprise Secure Network nodes at Pantex and Headquarters-East to determine the sites' readiness to maintain secure connection.
- Published the updated NNSA Supplemental Directive, *Baseline Cybersecurity Program*. This directive incorporates and requires an IT and Cybersecurity Program consistent with the unified cybersecurity framework in national policies, instructions, standards, and guidelines. The Committee on National Security Systems and the National Institute of Standards and Technology issues the guidelines. By implementing the updated directive, DOE/NNSA program offices and sites can effectively meet FISMA, the Cybersecurity Act of 2015, and other Federal requirements to ensure cost-effective security controls and investments that are aligned with current threats.
- Participated in interagency and foreign partnerships and projects that will increase data-sharing capabilities and mitigate nuclear threats at home and abroad. The Joint Development Environment (JODE) project is the key to ensuring the success of augmenting classified collaboration between the United States and the United Kingdom (UK). The first phase of enhancing classified U.S.-UK communications began in December 2015, with the team embarking on an effort to expand the communication capabilities of the existing Enterprise Secure Network UK Gateway. That phase was completed and deployed in July 2017; the team also began planning execution of subsequent phases in FY 2017.
- Maintained the SysAdmin, Audit, Network, and Security Voucher Program. The SysAdmin, Audit, Network, and Security program provides DOE/NNSA personnel performing cybersecurity

[6] The *U.S. Department of Energy Cyber Strategy* can be found at http://energy.gov/cio/downloads/doe-cyber-strategy-0
[7] DOE's *2015 DOE Sustainability Performance Plan* can be found at http://www.energy.gov/management/spo/downloads/2015-strategic-sustainability-performance-plan

management, operations, and oversight functions information security courses to maintain cybersecurity professional certifications in accordance with Federal requirements.

- Established SNL as the lead laboratory responsible for creating the NNSA Center of Excellence for Cyber Threat Intelligence. The vision for the Center is for each site to have the opportunity to play a role as leader, member, or supporter. The initial phase was focused on implementing tools to collect and analyze data sets to address a broad range of enterprise cybersecurity requirements. The NNSA Center of Excellence will also encourage technology transfer to maximize the use of cybersecurity products developed at SNL for other Government agencies.
- Began modernization of the cybersecurity infrastructure for the Information Assurance Response Center, which provides near-real-time network defense and incident response services.
- Completed the draft model for the iJC3 East-West capabilities.

4.6.3.2 Changes from the FY 2018 SSMP for Information Technology and Cybersecurity

- Extended the milestone, *Information Technology Service Management (ITSM) implementation,* from FY 2019 to June 30, 2022, to address evolving requirements.
- Extended the milestone, *Department of Homeland Security (DHS) Continuous Diagnostics Program dashboard development and implementation,* from FY 2022 to FY 2024 (September 30, 2024). The milestone was modified to accommodate DHS's and DOE's progression with requirements, architecture development, and project plans/implementation targets.

4.6.3.3 Milestones and Objectives for Information Technology and Cybersecurity

Program milestones and objectives are illustrated in **Figure 4–20**.

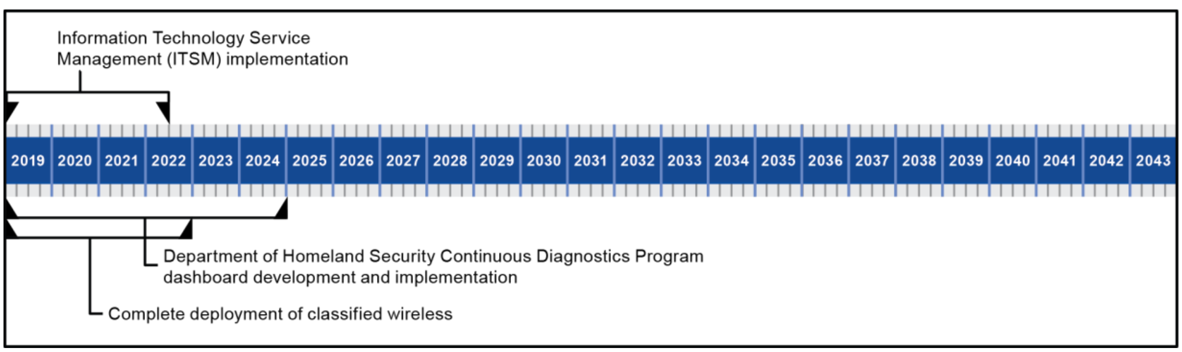


Figure 4–20. Information Technology and Cybersecurity milestones and objectives timeline

4.7 Budget Estimate Requirements beyond Fiscal Year 2019 and Basis of Estimates

4.7.1 Estimate of Weapons Activities Program Costs Executability and Associated Risk

Figure 4–21 depicts updated Weapons Activities required funding beyond the FYSNP, based on the program in the FY 2019 President's Budget request. As noted at the beginning of this chapter, the FY 2019 budget request is foundational for the 2018 *Nuclear Posture Review*. Figure 4–21 displays NNSA's budget estimates for the 24 years beyond FY 2019, based on the program of record described in Chapters 1 through 3. The figure displays the relative makeup of the Weapons Activities Program in terms of major portfolios for the period from FY 2018 through FY 2043, based on estimated program costs. This information illustrates the potential evolution in program makeup. It does not represent the precise costs for any of the portfolios other than for FY 2019–FY 2023.

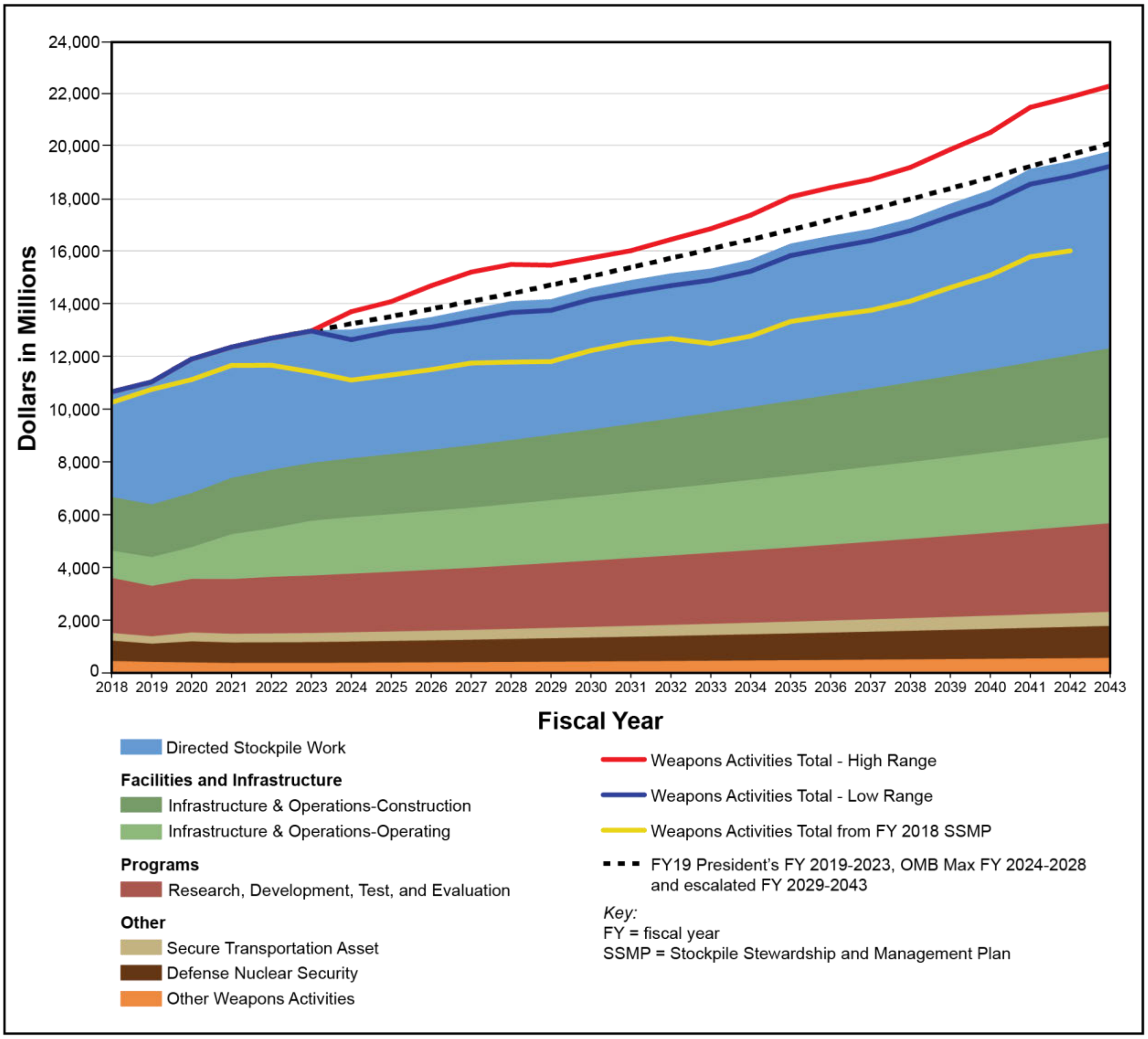


Figure 4–21. Estimated out-year budget estimates for NNSA Weapons Activities in then-year dollars

The projected future cost for the program for FY 2020–FY 2043 should be interpreted as the range between the red high-range total lines and the green low-range total lines for Weapons Activities in the figure, which represent a quantification of risk. This total cost range is necessary due to the uncertainties (risks) related to the individual components of the estimates, the LEPs, and the construction costs described later in this chapter.

The yellow line in Figure 4–21 represents the nominal total from Figure 8-19 in the FY 2018 SSMP and portrays the relative magnitude of the cost projections. As can be seen in this year's figure, the budget estimates for the FY 2019–FY 2023 period reflect both an increase in costs for some programs and activities and a bringing forward of some costs as originally reflected in the FY 2023–FY 2027 period. Such costs are for construction of facilities for which planning and estimates have matured within the past year, as discussed in Section 4.7.5.2.

The nominal cost of the program from FY 2018–FY 2019 increases by approximately 3.5 percent, and over the FY 2020–FY 2023 period, the cost increases at an annual average rate of approximately 4.1 percent. The greater-than-inflation increases to the program estimated over the FY 2019–FY 2023 period reflect the execution of programs or efforts for which funding over that period increases at more than a current services rate because of planned increases in work scopes. These efforts include the LEPs, construction projects, and strategic materials increases to meet demands.

Regarding affordability, the nominal cost of the program does not exceed the escalated line after the FYNSP years. In the out-years, after the FYNSP, the escalation line generally falls within the high to low cost range. Therefore the program, as planned, is generally affordable and executable, as a result of the FY 2019 – 2023 programming process, adjustments of funding levels mandated by Congress in current applicable budget acts, and the formal process of multi-agency budget development.

4.7.2 Basis for Cost Estimates

As noted in Section 4.7.1, Figure 4–21 displays the request for FY 2019–FY 2023 and an estimate of program costs for the years beyond FY 2023. The FY 2019–2023 request numbers were generated as part of the DOE planning and programming process and reflect the roll-up of individual estimates developed interactively by NNSA's management and operating (M&O) partners and Federal program managers using historical cost data, current plans for programs and projects, and expert judgment. Similar inputs were generated and used to develop budget estimates for FY 2020–FY 2023, which will be refined during the FY 2020–2024 budget process. The budget estimates for FY 2024 and beyond reflect the costs of continuing the program of record described in this SSMP.

The basis for the cost estimates beyond the FYNSP varies, depending on the individual programs or subprograms. Some portions of the Weapons Activities Program are assumed to continue beyond the FYNSP at the same level of effort as during the FYNSP.[8] For these cost projections, escalation factors based on numbers provided by the Office of Management and Budget for 2019 were used.

Some portions of the program will not proceed at the same level of effort for FY 2024 through FY 2043. This applies to major construction projects, LEPs, and, because of the future evolution in the current stockpile configuration, stockpile sustainment, as represented by the funding lines for stockpile systems. The estimates and the basis for each of these elements of the Weapons Activities program are described in more detail in the following sections.

4.7.3 Stockpile Sustainment

Sustainment costs include warhead-specific assessment activities; LLC exchanges; required and routine maintenance; safety studies; periodic repairs; resolution and timely closure of significant finding investigations; military liaison work; and surveillance to ensure the continued safety, security, and effectiveness of the stockpile. These costs are incurred every year that a weapon is in the stockpile. Figure 2–2 in Chapter 2 provides a roadmap of currently planned activities for legacy weapons.

[8] Projection of budget estimates for these efforts in this way assumes the continued manageability of whatever risks are present during the FYNSP at the same level of effort following the FYNSP period, as is typically is represented by the funding level of the last year of the FYNSP.

Figure 4–22 enumerates, in then-year dollars, the annual sustainment cost for FY 2019 through FY 2023 that is attributable to a particular warhead type based on updated FY 2019 numbers, as well as an estimate of the total sustainment cost by year for warheads of all types for FY 2024 through FY 2043.

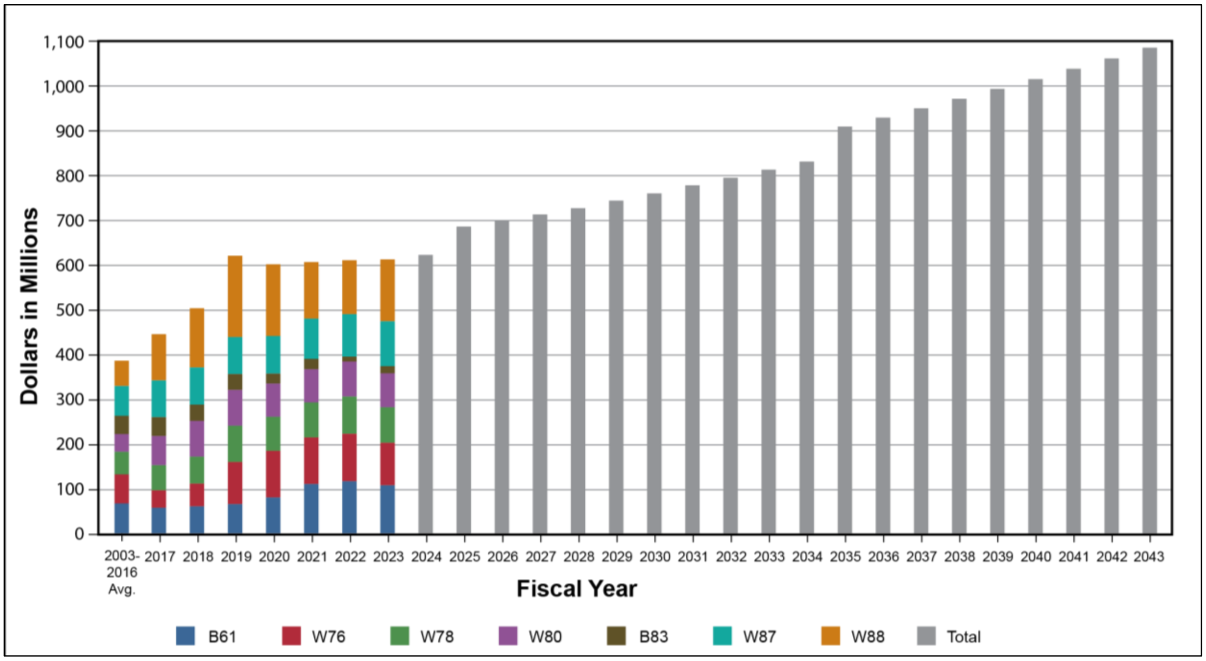


Figure 4–22. Estimate of warhead-specific sustainment costs

4.7.4 Life Extension Programs and Major Alterations

LEPs are undertaken separately from stockpile sustainment, with the goal of extending the lives of warheads for several more decades. Although major Alts also make component changes, those changes do not address all of the aging issues in a warhead that would require an LEP. Figure 2–3 in Chapter 2 provides a roadmap of currently planned activities for legacy weapons.

4.7.4.1 Cost Estimates throughout the *Phase 6.x Process*

LEPs and major Alts are governed by the *Phase 6.x Process* and supplemented with DOE/NNSA and Defense Programs guidance. Various organizations perform cost estimates throughout the process; the initial estimate is the Defense Programs independent cost estimate (ICE) for the SSMP.[9] These are initiated more than a decade prior to the program's feasibility study and are considered planning estimates for long-term projections and budget deliberations when the program enters the FYNSP. Defense Programs ICEs are notably:

- Performed by an independent organization separate from the Federal program office;[10]
- Based on a known scope and cost uncertainty at the time and updated annually for the SSMP;[11]

[9] Defense Programs ICEs are performed by the Office of Cost Policy and Analysis for LEPs and major Alts every year for the SSMP.
[10] GAO extolls the value of ICEs using a different methodology and the potential benefit to decision-makers in its *GAO Cost Estimating and Assessment Guide*.
[11] Planning estimates assume scopes are in line with current policy objectives (such as a commitment to surety upgrades), in addition to extending the warhead life. The cost estimate range reflects the uncertainty in implementing a single assumed point solution, rather than the range of every possible design solution.

- Inclusive of both LEP (development and production) and non-LEP line-item costs that are critical to program success (namely Other Program Money and DOD costs);[12] and
- Unconstrained from future budget availability, which may differ from future budget amounts if programming is constrained.

These Defense Programs ICEs are:

- Performed using a "top-down" analogy method that is consistent with early-stage planning;[13]
- Informed by ongoing program costs (development of the W76-1, B61-12, and W88 Alt 370; production of the W76-1) and the evaluation of the relative complexities of the future systems;[14] and
- Based on time-phased development[15] costs using standard, well-known Rayleigh profiles, as well as production costs using a nonlinear cost growth profile similar to that of the W76-1.

As LEPs or Alt progress through the *Phase 6.x Process*, the DP program office works in conjunction with the national security laboratories, weapons plants, and test site to produce the Weapons Design and Cost Report prior to Phase 6.3, the Baseline Cost Report (BCR) prior to Phase 6.4, and the BCR Update prior to Phase 6.5.

An NNSA independent cost review (ICR) is conducted prior to Phase 6.2A, and an NNSA ICE is conducted prior to entry into Phases 6.3, 6.4, and 6.5.[16] The NNSA Administrator approves the program baseline prior to Phase 6.3 based on consideration of the program office estimate and the NNSA ICE. This baseline supersedes previous planning estimates and becomes the program of record, which is transmitted annually to Congress as part of the Selected Acquisition Report (SAR).

4.7.4.2 Fiscal Year 2019 through Fiscal Year 2043 Estimates

Figures 4–23 through **4–30** and **Tables 4–4** through **4–11** provide cost estimates for each LEP and major Alt for the 25-year SSMP timeframe, including:

- Program estimates (available for the W76-1, B61-12, and W88 Alt 370);
- Defense Programs ICEs for every system, including a high and low range; and
- A summary table with high, low, and nominal (proposed budget or SAR Value) estimates for DOE/NNSA and DOD, in both constant FY 2018 and then-year dollars.[17, 18]

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[12] The weapon programs depend on an adequately funded base of other DOE/NNSA capabilities, are incremental to that base, and reflect both program's budgeted line item and increments to other critical activities (such as early-stage technology maturation [called Other Program Money]). As the overall program integrator, the Federal program manager identifies the funding streams needed for the program to be successful.

[13] Additional detail on the cost estimating methodology of Defense Programs ICEs can be found in the technical paper "Planning For The Future: Methodologies for Estimating U.S. Nuclear Stockpile Cost" (Lewis *et al.* 2016, *Cost Engineering*, 58 [5], pp. 6-12).

[14] These program and subject matter experts evaluate the relative scope complexity between the near-complete W76-1, B61-12, and W88 Alt 370 compared to each planned future LEP, which aids in providing a cost estimate range based on underlying technical and cost uncertainties.

[15] Development costs include all design agency and production development costs, which is how DOD defines research, development, test, and evaluation and is consistent with Rayleigh profile usage in cost estimating.

[16] NNSA ICEs are statutorily performed by the Office of Cost Estimating and Program Evaluation.

[17] DOD amounts reflect the weapon components for which they are responsible, such as arming and fuzing. While not budgeted or executed by DOE/NNSA, these costs reflect the program's best approximation and are published for transparency because they better reflect anticipated all-in costs.

[18] The total estimated cost is provided because LEP profiles have later portions that extend beyond the published 25-year SSMP timeframe.

As a result of the 2018 *Nuclear Posture Review*, the W76-2 Program will leverage efforts of the W76-1 LEP to provide a low-yield version of the W76 warhead. The President budgeted $50 million in FY 2019 for the short term procurement of the W76-2. In FY 2019 R&D for the sea-launched cruise missile was not budgeted in the request, and the intent was to defer the study until FY 2020. The sea-launched cruise missile will be a major new addition in the next decade. DOE/NNSA will continue to work with DOD through the Nuclear Weapons Council to translate Nuclear Posture Review policy into requirements.

The funding values in the figures (bars) and the proposed budget line in the tables reflect the SAR values for those programs that have a published SAR. For early-stage programs without a program estimate (such as the W80-4 and the W78 Replacement Warhead) the figures and tables reflect the current proposed FYNSP budget and, for years beyond the FYNSP, the midpoint between the Defense Programs ICE high and low. This funding is included in the LEP DSW total in Figure 4–21.

Things to note when comparing estimates to one another:

- The constant-year estimates in the tables are the most comparable because inflation effects become significant over these timeframes. Consideration should also be given to the varying quantities of warheads being refurbished for each system. The classified Annex provides additional information on production quantities.
- Published estimate ranges are meant to reflect the underlying programmatic uncertainty at that point in time. Early-stage programs, particularly those before Phase 6.3, may experience significant scope changes, as the Nuclear Weapons Council may update and/or down-select design options and significantly impact the work scope and cost estimate.
- The SAR totals in each table do not include pre-Phase 6.2 costs, but these costs are included in the Defense Programs ICEs for completeness.
- When comparing a top-down Defense Programs ICE to the official bottom-up program counterpart (such as for the B61-12), DOE/NNSA primarily compares the total estimate amounts and the general shape of the time-phased profiles. If these two are in relative agreement, DOE/NNSA has increased confidence in the program estimate. DOE/NNSA does not perform or encourage additional year-by-year comparisons between the two published estimates.[19]

[19] The Defense Programs ICE profile reflects an idealized schedule and unconstrained budget, whereas the program profile is based on an integrated baseline schedule and programming results. This makes reconciling minor year-by-year profile discrepancies between the estimates generally infeasible; when differences arise, DOE/NNSA has much greater confidence in the year-by-year phasing of its baselined program estimate.

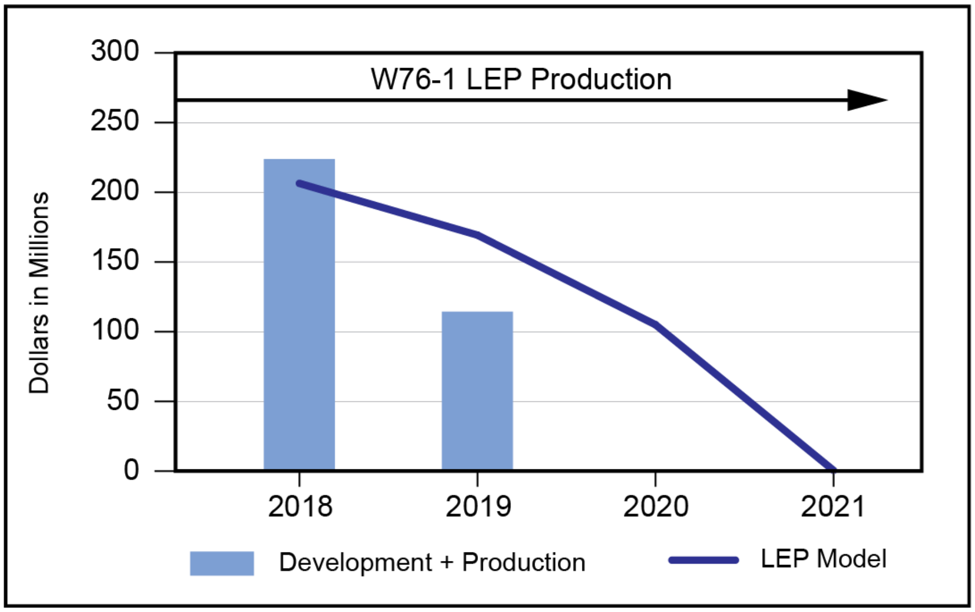

Figure 4–23. W76-1 Life Extension Program cost fiscal year 2018 to completion

Table 4–4. Total estimated cost for W76 Life Extension Program

FY 2001 – FY 2020 (Dollars in Billions)	*NNSA*		*DOD*	
	FY 2018 Dollars	*Then-Year Dollars*	*FY 2018 Dollars*	*Then-Year Dollars*
SAR Value	4.2	3.6	Not in NNSA SAR	Not in NNSA SAR

SAR = Selected Acquisition Report

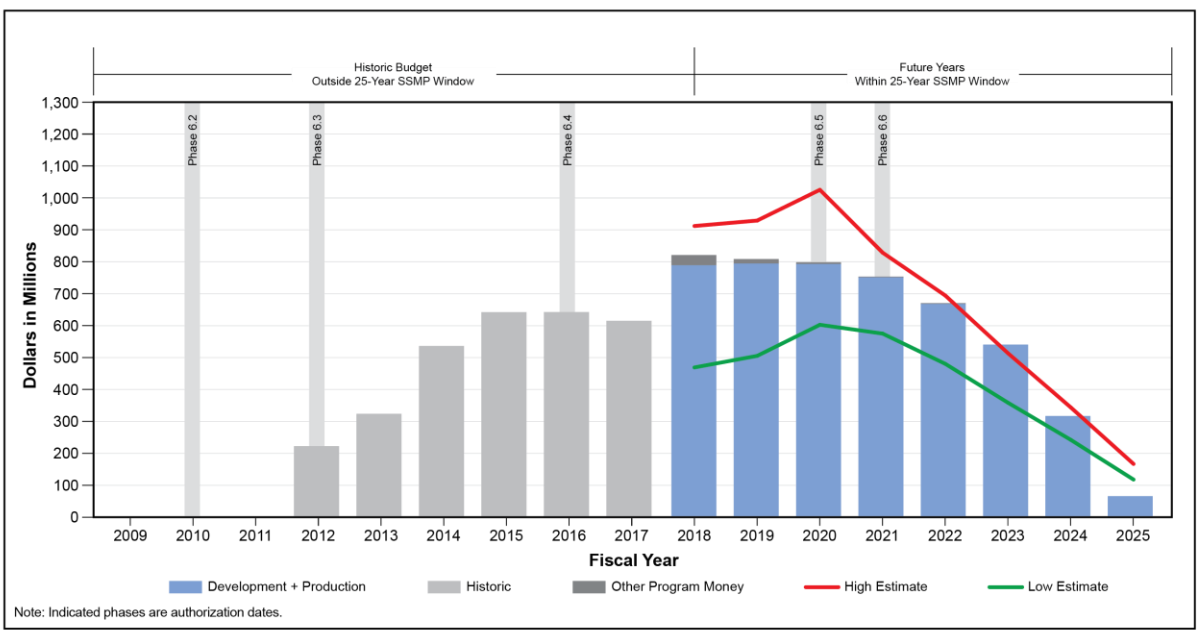

Figure 4–24. B61-12 Life Extension Program cost fiscal year 2018 to completion

The nominal values for development and production in Figure 4–24 and Table 4–5 reflect DOE/NNSA's FY 2016 Baseline Cost Report as the B61-12 LEP entered Phase 6.4 (Production Engineering).

Table 4–5. Total estimated cost for B61-12 Life Extension Program

FY 2009 – FY 2025 (Dollars in Billions)	*NNSA*		*DOD*	
	FY 2018 Dollars	*Then-Year Dollars*	*FY 2018 Dollars*	*Then-Year Dollars*
High Total	9.4	9.5	0.2	0.2
Low Total	7.3	7.3	0.1	0.1
SAR Total (FY 2012 – FY 2025)	7.4	7.6	Not in NNSA SAR	Not in NNSA SAR

SAR = Selected Acquisition Report

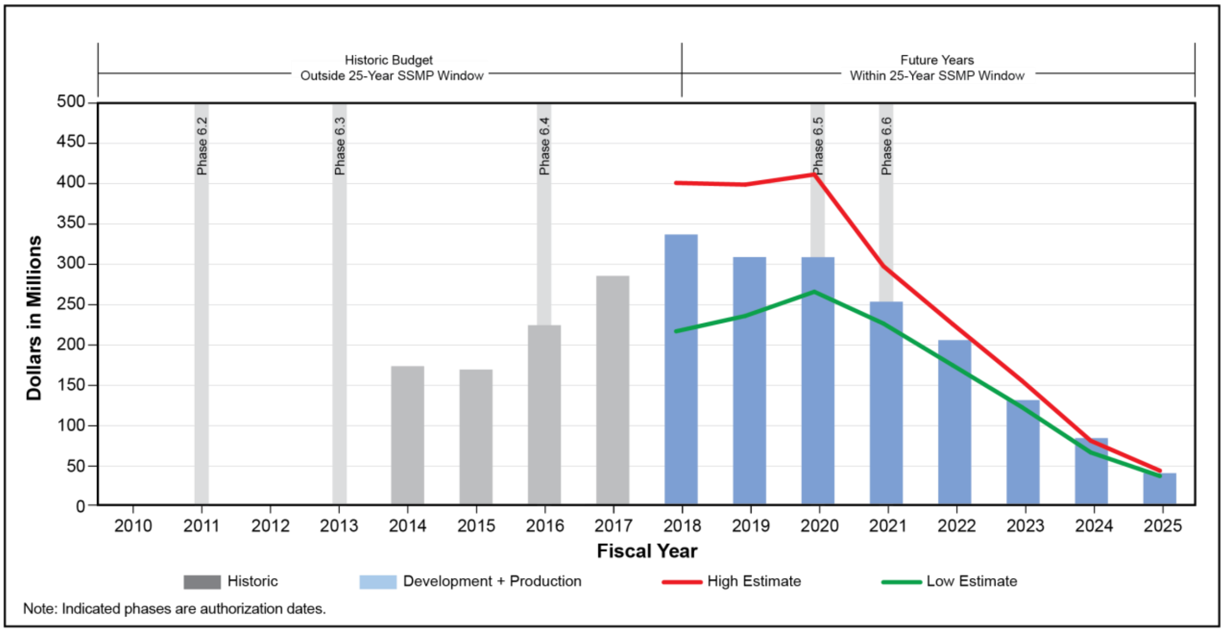

Figure 4–25. W88 Alteration 370 (with conventional high explosive refresh) cost fiscal year 2018 to completion

In November 2014, the Nuclear Weapons Council approved additions to the scope for the CHE refresh as part of the W88 Alt 370. DOE/NNSA has completed a Baseline Cost Report that included the CHE refresh and other changes. The numbers in Figure 4–25 and Table 4–6 reflect the updated baseline.

Table 4–6. Total estimated cost for W88 Alteration 370 (with conventional high explosive refresh) Program

FY 2010 – FY 2025 (Dollars in Billions)	*NNSA*		*DOD*	
	FY 2018 Dollars	*Then-Year Dollars*	*FY 2018 Dollars*	*Then-Year Dollars*
High Total	3.1	3.1	1.0	1.0
Low Total	2.4	2.4	0.9	0.9
SAR Total (FY 2013 – FY 2025)	2.5	2.6	Not in NNSA SAR	Not in NNSA SAR

SAR = Selected Acquisition Report

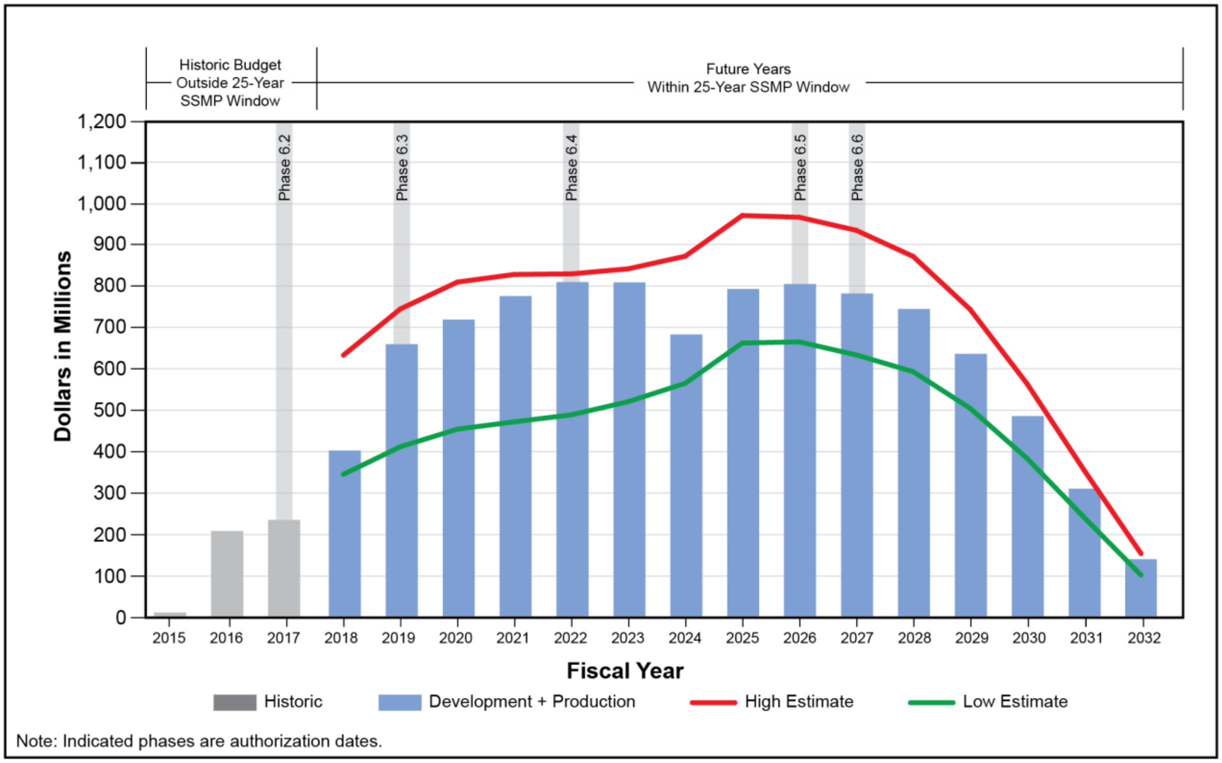

Figure 4–26. W80-4 Life Extension Program cost fiscal year 2018 to completion[20]

Table 4–7. Total estimated cost for W80-4 Life Extension Program

FY 2015 – FY 2032 (Dollars in Billions)	*NNSA*		*DOD*	
	FY 2018 Dollars	*Then-Year Dollars*	*FY 2018 Dollars*	*Then-Year Dollars*
High Total	10.3	11.7	0.2	0.3
Low Total	6.7	7.6	0.1	0.1
Proposed Budget	NA	10.0	NA	0.2

[20] For the W80-4 Warhead, Other Program Money scope and funds are managed by the Federal program office and are included in the budget line above.

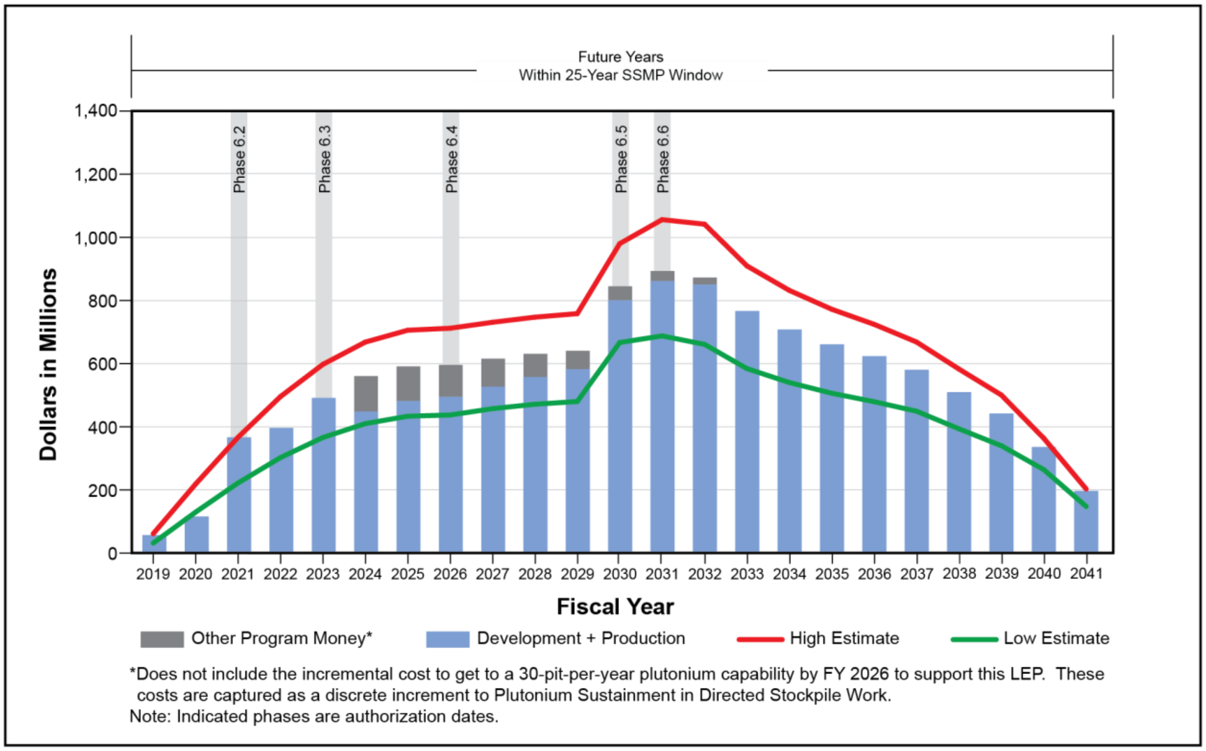

Figure 4–27. W78 Replacement Warhead Life Extension Program (formerly known as the Interoperable Warhead 1 [IW1]) cost fiscal year 2019 to completion[21]

The Defense Programs ICE models assume a standard 12-year study and development period in advance of the first production unit. The W78 Replacement Warhead LEP is slated to recommence in FY 2019. Estimated Other Program Money is included in the W78 Replacement Warhead budget line for the FYNSP. This estimate does not include the incremental cost to get to a 30-pit-per-year plutonium capability by FY 2026 to support this LEP. These costs are captured as a discrete increment to Plutonium Sustainment in DSW.

Table 4–8. Total estimated cost for W78 Replacement Warhead Life Extension Program

FY 2013-2014, FY 2019-2041 (Dollars in Billions)	NNSA		DOD	
	FY 2018 Dollars	Then-Year Dollars	FY 2018 Dollars	Then-Year Dollars
High Total	11.5	15.1	3.3	4.4
Low Total	7.5	9.9	1.1	1.5
Proposed Budget	NA	12.5	NA	2.9

[21] For the W78 Replacement Warhead, Other Program Money scope and funds are managed by the Federal program office and are included in the FYNSP budget line above.

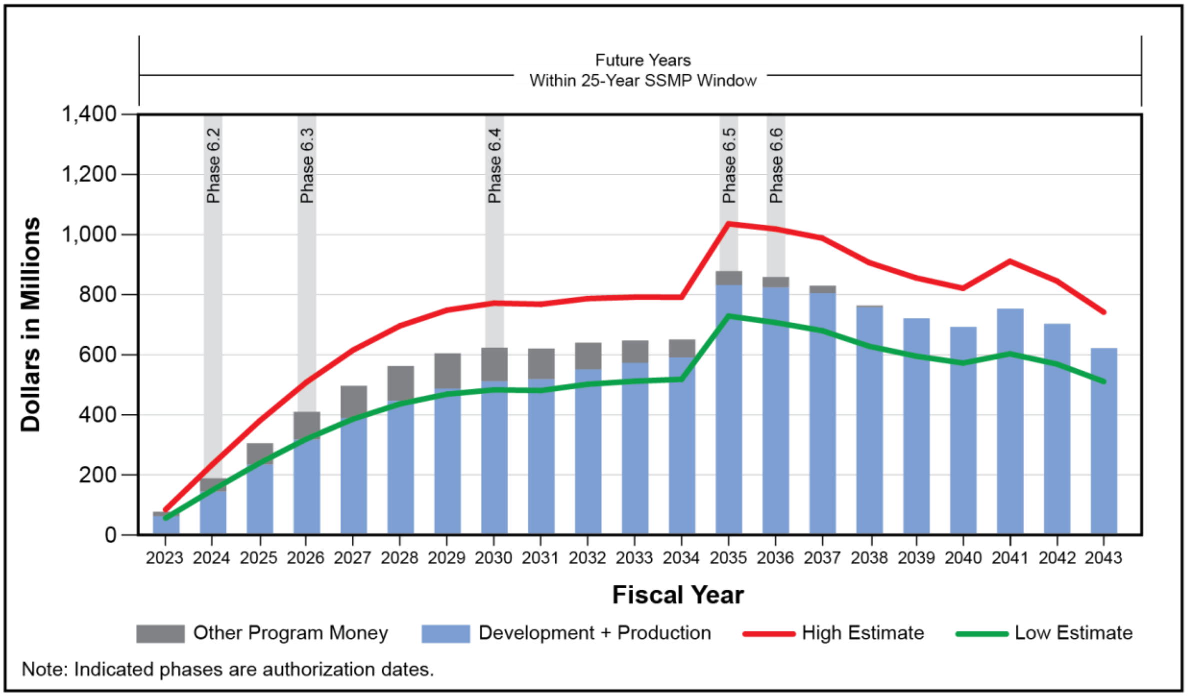

Figure 4–28. Ballistic Missile Warhead (IW or BM-Y) Life Extension Program cost fiscal year 2023 through fiscal year 2043

Table 4–9. Total estimated cost for IW2 Life Extension Program

FY 2023 – FY 2050 (Dollars in Billions)	*NNSA*		*DOD*	
	FY 2018 Dollars	*Then-Year Dollars*	*FY 2018 Dollars*	*Then-Year Dollars*
High Total	12.5	18.9	3.3	5.1
Low Total	8.3	12.7	1.1	1.7
Proposed Budget	NA	15.8	NA	3.4

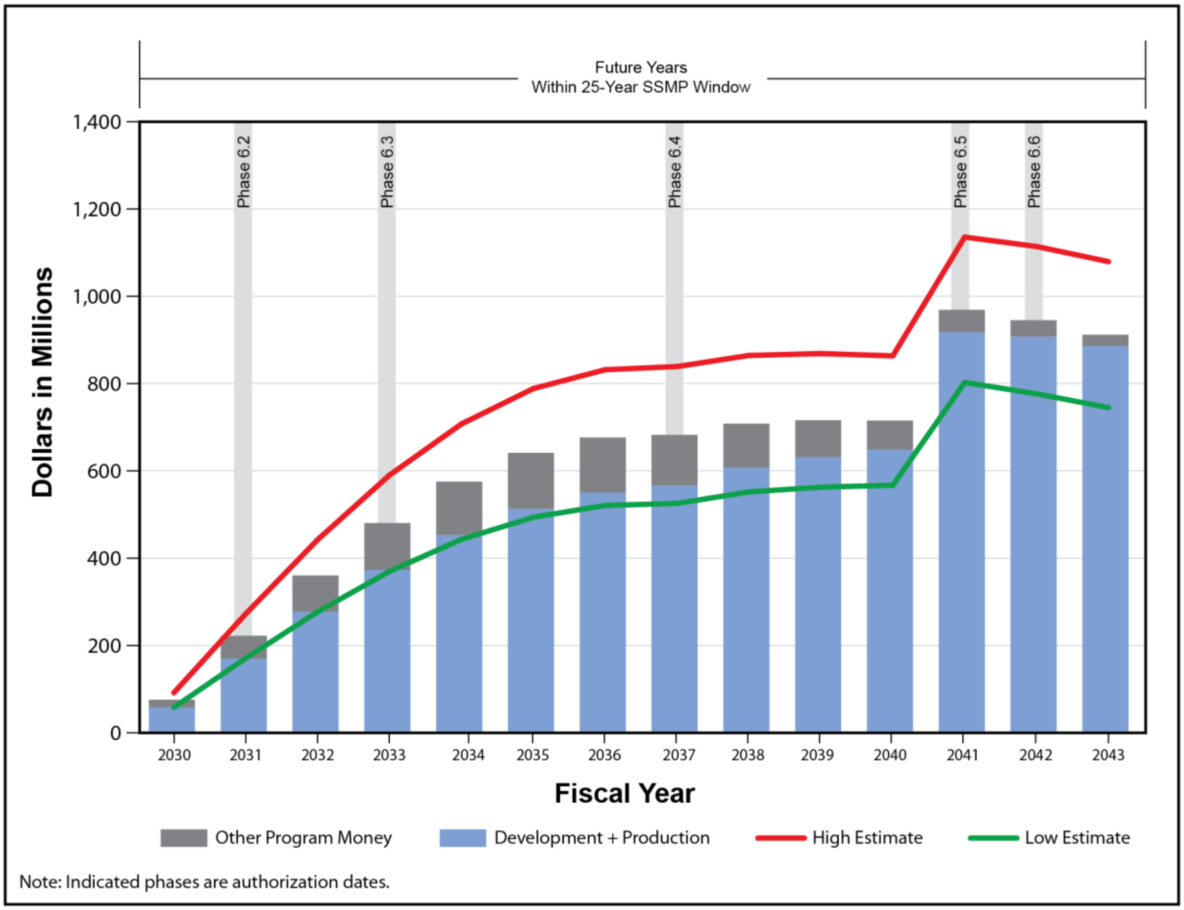

Figure 4–29. Ballistic Missile Warhead (IW or BM-Z) Life Extension Program cost fiscal year 2030 through fiscal year 2043

Table 4–10. Total estimated cost for IW3 Life Extension Program

FY 2030 – FY 2057 (Dollars in Billions)	*NNSA*		*DOD*	
	FY 2018 Dollars	*Then-Year Dollars*	*FY 2018 Dollars*	*Then-Year Dollars*
High Total	11.8	20.6	3.3	5.9
Low Total	8.0	14.2	1.1	2.0
Proposed Budget	NA	17.4	NA	3.9

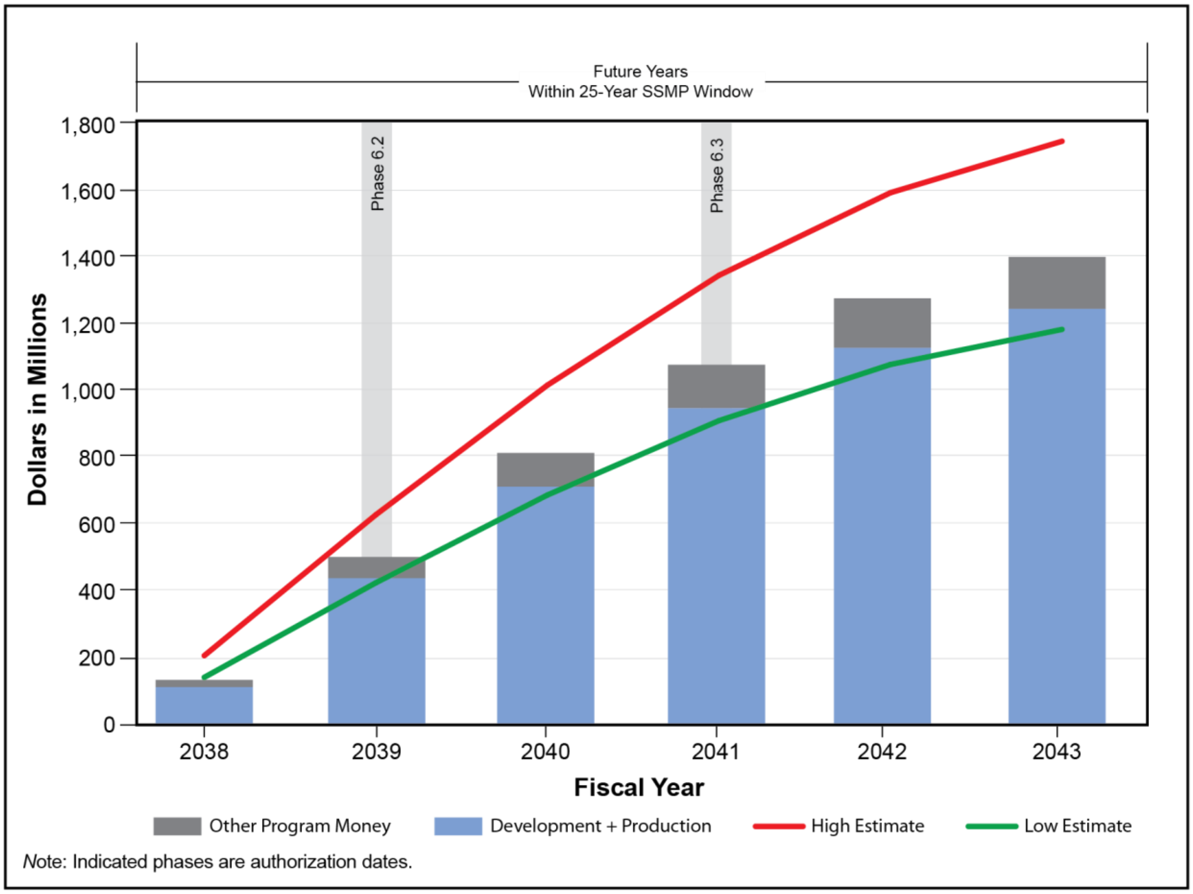

Figure 4–30. Next B61 Life Extension Program cost fiscal year 2038 through fiscal year 2043

Table 4–11. Total estimated cost for next B61 Life Extension Program

FY 2038 – FY 2058 (Dollars in Billions)	NNSA		DOD	
	FY 2018 Dollars	Then-Year Dollars	FY 2018 Dollars	Then-Year Dollars
High Total	13.7	26.3	0.2	0.4
Low Total	9.5	18.3	0.1	0.1
Proposed Budget	NA	22.3	NA	0.3

Figure 4–31 is a one-chart summary of the projected total nuclear weapons life extension costs from FY 2018 through FY 2043, based on the LEP schedule reflected in Chapter 2, Figure 2–3, of this SSMP, and the nominal LEP costs shown in Figures 4–23 through 4–30.[22] The dotted line shows the total projected LEP cost reflected in the FY 2018 SSMP.

[22] Nominal costs are used to allow a comparison of the total LEP costs from SSMP to SSMP. Unless baselined, the cost of any particular LEP should be regarded as a cost range, as shown in the tables accompanying each LEP figure.

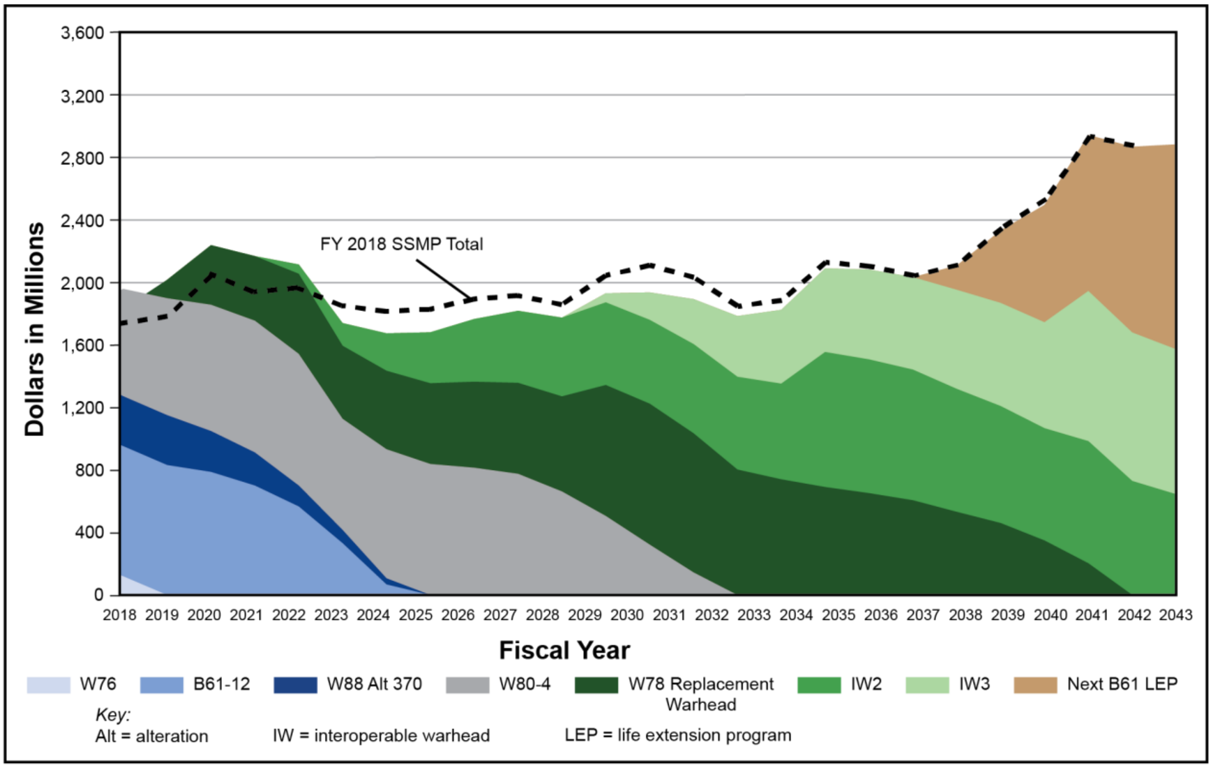

Figure 4–31. Total U.S. projected nuclear weapons life extension costs for fiscal year 2018 through fiscal year 2043 (then-year dollars)

Two adjustments to the LEP Defense Programs independent cost estimate model this year have affected the costs depicted in Figure 4–31. The changes to the cost estimate model have also affected the high and low lines in Figures 4–24 through 4–30:

- For the LEP components that use the B61-12 or the W88 Alt 370 as the reference for the complexity comparison, the Baseline Cost Report scope and cost estimate were used instead of the previous Weapons Design and Cost Report scope and cost estimate. This change generally lowered the estimated cost of development for the LEPs.
- The production model was updated with FY 2018 W76-1 production costs and quantities. This change generally increased the cost of production for the LEPs, particularly for the IWs (also referred to as BM-Y and BM-Z) which have significantly longer production runs.

The principal differences between the FY 2018 and FY 2019 LEP cost estimates are as follows:

- **LEPs that use SAR values.** The W76-1 LEP increased slightly, based on current execution. The slight decreases in the B61-12 LEP and the W88 Alt 370 costs are primarily the result of the model changes described above.
- **LEPs that use Defense Programs ICEs.** The W80-4 program cost reflects additional scope for the secondary than was assumed in the FY 2018 SSMP countered by the model changes described above. The IWs (or BM-Y and BM-Z) reflect an increase in production costs because of the changes in the production model described above.

The total side-by-side differences between this year's and last year's cost estimates are shown in **Figure 4–32**.

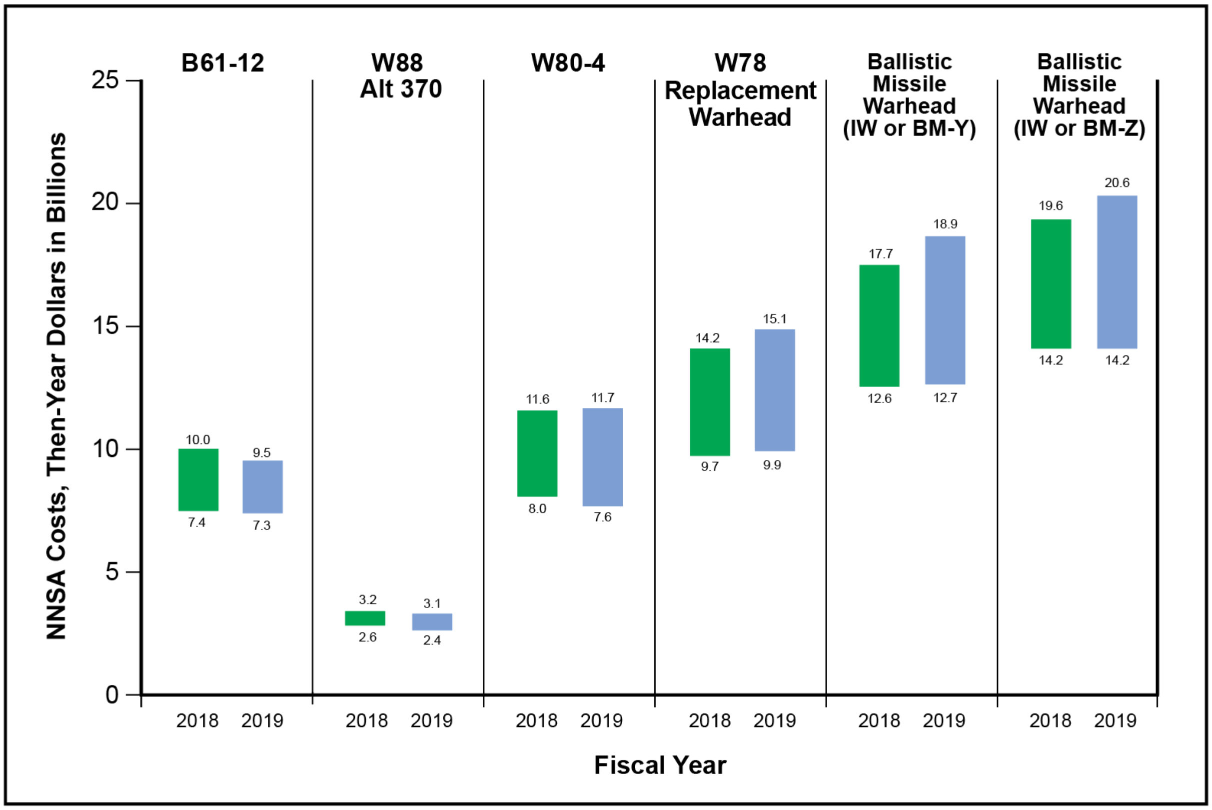

Figure 4–32. Fiscal year 2018 versus fiscal year 2019 SSMP Defense Programs independent cost estimates

4.7.5 Construction

4.7.5.1 Cost Estimates throughout the Capital Acquisition Process

Programmatic Capital Acquisitions account for over 90 percent of the Infrastructure and Operations Construction Budget; the remaining costs are for general construction. In FY 2017, Defense Programs prioritized developing improved programmatic capital acquisition cost and schedule estimates to inform long-term planning.

The capital acquisition process is governed by DOE Order 413.3B and outlines which DOE/NNSA elements are responsible for performing cost estimates throughout the acquisition timeline. Beginning with this FY 2019 SSMP, additional Defense Programs ICEs have been performed for the SSMP.[23] Since these ICEs are performed at a very early pre-acquisition stage (often more than a decade before a project's initial CD-0 milestone), these planning estimates primarily inform the portfolio's long-term cost projections and are supplemental to DOE acquisition requirements.

[23] ICEs are a best practice identified by the GAO and other professional organizations as a tool to objectively compare to program estimates and identify potential issues early.

These Defense Programs ICEs are notably:

- Performed by an independent organization separate from the Federal program office;[24]
- Performed using a top-down parametric method that is consistent with early-stage planning;[25]
- Based on historic NNSA project schedules and costs;
- Time-phased into fiscal year profiles using standard Weibull distributions, which are commonly used in cost estimating;
- Fully unconstrained of future budget availability, which may differ from future budget amounts if programming is constrained; and,
- Based on anticipated project scopes and cost uncertainties at the time, updated annually for the SSMP. Once a project begins the acquisition process, the approved cost estimate ranges at CD-0 (Approve Alternative Selection and Cost Range) supersede previous planning estimates and become the planning basis for resource planning. The project then progresses as described in DOE Order 413.3B (alternative selection and cost range at CD-1, performance baseline at CD-2, etc.).

Since planning estimates begin significantly before the project's acquisition process and years before its feasibility study, DOE/NNSA assumes a high-level scope that is in line with current policy objectives and best known information at the time. However, the scope assumptions for these planning estimates do not predetermine the actual project's acquisition strategy or the outcome of subsequent AoAs, and should be considered notional until the project reaches its performance baseline at CD-2.

4.7.5.2 Fiscal Year 2019 through 2043 Estimates

The budget estimate for capital acquisition in FY 2019 through FY 2023, which is part of the Infrastructure and Operations-Construction total included in Figure 4–21, reflects the DOE/NNSA current program. DOE/NNSA is executing the schedules of multiple ongoing major capital acquisition projects, such as the Uranium Processing Facility and U1a Complex Enhancements projects. In addition, a list of major capital acquisition project proposals have been developed through the efforts of a series of working groups and deep dives with representatives from DOE/NNSA sites and responsible Federal offices. DOE/NNSA reviewed hundreds of project proposals in 2017. The schedule for the highest-priority project proposals is depicted by major capital acquisition projects and project proposals listed in **Figure 4–33.**[26] Projects are color-coded by high-end estimate, as well as status in the capital acquisition process. Projects with a formal Federal acquisition decision are shown with solid colors. Projects that are currently under study and review for a formal Federal acquisition decision are shown with a solid core and transparent ends. Projects that are proposed, but not yet under formal review and study are shown with a transparent line. This planning schedule will be updated annually. Changes will be made based on available funding and programmatic priorities.

[24] Defense Programs ICEs are performed by the Office of Cost Policy and Analysis.

[25] GAO extolls the value of ICEs using a different methodology and the potential benefit to decision-makers in its *GAO Cost Estimating and Assessment Guide*.

[26] Results in Figure 4–33 are accurate as of March 2018 FY 2020 Planning activities. FY 2021 activities are underway and will be reflected in the FY 2020 SSMP.

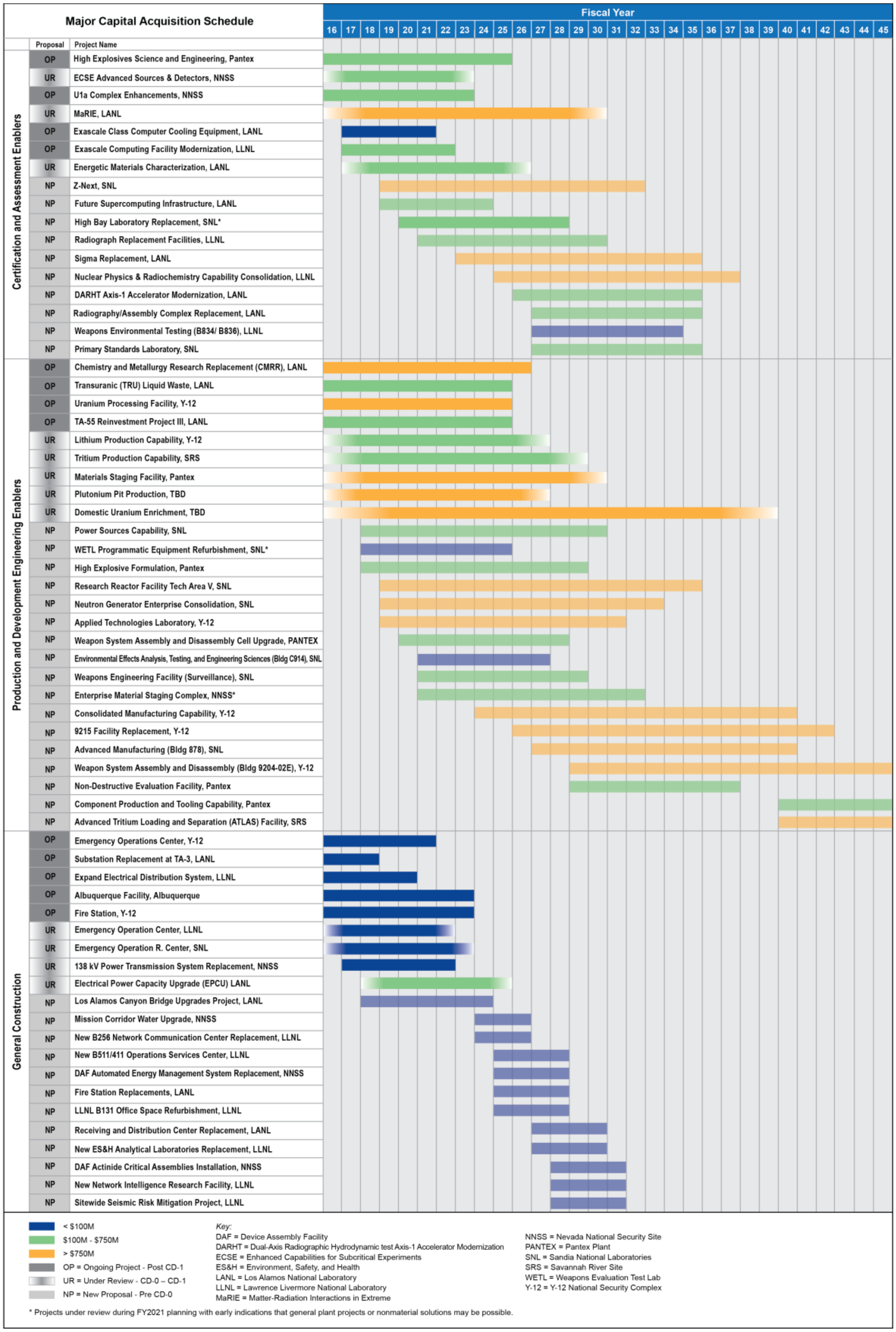

Figure 4–33. DOE/NNSA major capital acquisition projects and project proposals

The current program and the program-vetted project proposals are the basis for the cost estimates. **Table 4–12** lists low and high estimate projections in then-year dollars for Defense Programs capital acquisition projects from FY 2019 through FY 2043. As mentioned in the previous section, several of these projects contain a high degree of scope and cost uncertainties, resulting in a significant cost range. This year's SSMP high estimate benefits from several improvements to prior SSMP projection methodology, including the following:

- Collecting and validating capital acquisition requirements over the full 25-year SSMP timeframe
- Performing a cost estimate for every validated project proposal (either a Defense Programs ICE, as described in the previous section for new construction projects, or site estimates for refurbishment projects)[27] [28]
- Updating the high total to represent the 85th percentile of the confidence range for each project and anticipated future scope [29]
- Expanding the table's time horizon to match the full 25-year SSMP timeframe[30]

It is problematic to make comparisons to previous SSMP estimates, considering the number of significant concurrent updates this year, as these changes collectively result in a substantial increase over last year's published estimates. DOE/NNSA continues to analyze this portfolio's long-term needs, and the next SSMP will include further changes to align it with the recently published 2018 *Nuclear Posture Review*.

Table 4–12. Weapon Activities capital acquisition estimated costs, fiscal years 2019 through 2043

Then-Year Dollars, in Billions	*Low* [a]	*High* [b]
Weapon Activities capital acquisition estimated costs	61.1	90.7

[a] "Low" reflects the Infrastructure and Operations Construction portfolio's FY 2023 estimate in Figure 4-21, with an escalated 2.1 percent inflationary rate.

[b] "High" reflects the program provided Infrastructure and Operations Construction portfolio with the 85th percentile of the Defense Programs independent cost estimates confidence level range, which is based on the underlying scope and cost uncertainties.

[27] The provisional $15 billion high estimate for the Domestic Uranium Enrichment capability in last year's SSMP remains unchanged.

[28] It is also assumed that KCNSC will not require a line-item project to maintain forecast capabilities during the planning period.

[29] Use of the 85th percentile is consistent with DOE Order 413.3B guidance to select an acceptable point estimate from a confidence level range. The new high estimate includes additions to the scope from the FY 2018 SSMP (such as non-nuclear production facility modernization) consistent with the 2018 *Nuclear Posture Review*. Last year's low estimate reflected an even lower amount of new infrastructure scope, including no funds for Plutonium Pit Production or Domestic Uranium Enrichment projects.

[30] The table reflects only the 20-year post-FYNSP planning horizon in last year's SSMP.

Chapter 5
Conclusion

This DOE/NNSA *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Summary* (SSMP), together with the classified Annex, is a key planning document for the nuclear security enterprise. The SSMP represents the 25-year strategic program that is a collection of the plans developed across numerous DOE/NNSA programs and organizations to maintain and modernize the scientific tools, capabilities, and infrastructure to ensure mission success. The DOE/NNSA Federal workforce prepares each SSMP in collaboration with management and operating partners. The plan in the FY 2019 SSMP is also coordinated with DOD through the Nuclear Weapons Council and is consistent with the Nuclear Weapons Council's Strategic Plan for 2017–2042. This SSMP is NNSA's foundation for meeting the nuclear weapons mission tenets laid out in the December 2017 *National Security Strategy* (White House 2017) and the *Nuclear Posture Review* (DOD 2018). As with previous SSMPs, a new version is published each year as DOE/NNSA updates its strategic plans in response to new demands and challenges related to stewardship and management of the stockpile. As such, the FY 2019 SSMP builds on previous SSMPs and updates the costs and resources required for execution of the program based on current mission needs, the strategic environment, and new guidance.

While executing the current plan, DOE/NNSA had an outstanding FY 2017. DOE/NNSA maintained the existing nuclear weapons stockpile, made impressive progress on a number of life extension programs (LEPs), and continued to advance the science and engineering capabilities that underpin the Nation's Stockpile Stewardship Program.

Although many warheads in America's nuclear weapons stockpile have exceeded their original design lives, the Stockpile Stewardship Program continues to maintain the safety, reliability, security, and effectiveness of the nuclear weapons stockpile. This effort harnesses leading-edge science, engineering, high performance computing, and advanced manufacturing to enable the Secretaries of Energy and Defense to annually inform the President regarding the safety, security, and effectiveness of the stockpile without nuclear explosive testing.

The Stockpile Management Program also continued to extend the life of existing U.S. nuclear warheads by replacing nuclear and non-nuclear parts or inserting new parts that use modern technologies. DOE/NNSA's state-of-the-art capabilities for research, development, test, evaluation, and production enabled this critical effort. The scope, budgets, and schedules of the LEPs; infrastructure modernization; and DOD nuclear delivery systems have been fully integrated through coordinated and tightly coupled efforts.

To facilitate future scientific and engineering excellence at the national security laboratories and nuclear weapons production sites, DOE/NNSA has expanded university collaborations and science, technology, engineering, and mathematics educational outreach in applied and technical research supporting technology development. In addition, DOE/NNSA has increased direct mission-specific activities by its Federal, laboratory, and contractor partners.

In the near term, DOE/NNSA began addressing infrastructure challenges and broke ground on construction projects that will provide high-quality workspace for the workforce and serve the nuclear security enterprise for decades to come.

Finally, to meet DOE/NNSA's continued support for the nuclear deterrent into the 2030s and beyond will require significant, sustained investment. Over the past several decades, the U.S. nuclear weapons infrastructure realized the effects of aging and underfunding. All previous Nuclear Posture Reviews highlighted the need to maintain a modern nuclear weapons infrastructure. To achieve this goal, DOE/NNSA has developed a list of major capital acquisition project proposals that will be evaluated against current and future capability needs as resourcing decisions are made.

Highlights of DOE/NNSA's near-term and out-year objectives include the following:

- Advance the innovative experimental platforms, diagnostic equipment, and computational capabilities to ensure stockpile safety, security, reliability, and responsiveness.
- Complete production of the W76-1 warheads by FY 2019.
- Deliver the first production unit of the B61-12 by FY 2020 and complete production by FY 2024.
- Deliver the first production unit of the W88 Alt 370 (with refresh of the conventional high explosive) by FY 2020 and complete alterations by FY 2024.
- Synchronize DOE/NNSA's W80-4 LEP with DOD's Long Range Stand Off program. Achieve a first production unit of the W80-4 by FY 2025 and complete the LEP by 2031.
- Advance the W78 warhead replacement by 1 year to FY 2019 to support fielding of the Ground-Based Strategic Deterrent by FY 2030.
- Sustain the B83-1 until a suitable replacement is identified.
- Explore future ballistic missile warhead requirements.
- Provide an enduring capability and capacity to produce plutonium pits at a rate of no fewer than 80 pits per year in 2030.
- Create an effective, responsive, and resilient nuclear infrastructure that ensures the availability of strategic materials to meet military requirements.
- Phase out mission dependency on Building 9212 at Y-12 and deliver the Uranium Processing Facility for no more than $6.5 billion by the end of 2025.
- Implement the strategy to achieve the strategic priorities laid out in the *Nuclear Posture Review*, as determined by the Nuclear Weapons Council.
- Achieve exascale computing and deliver a capable exascale machine by the early 2020s.
- Ensure an enduring trusted supply of strategic radiation-hardened microsystems beyond 2025.
- Develop an operational enhanced capability (advanced radiography and reactivity measurements) for subcritical experiments by the mid-2020s.
- Implement the Stockpile Responsiveness Program.

The key long-term challenge is balancing near-term commitments with essential nuclear security enterprise capability requirements, given resource constraints. These commitments include meeting the near-term needs of the stockpile, sustaining or recapitalizing the infrastructure, and advancing the understanding of the performance of weapons in the stockpile.

DOE/NNSA has confidence in its ability to execute the program described in the FY 2019 SSMP. The LEPs remain on schedule and, once completed, will extend the service life for the stockpile and improve safety and effectiveness. With Congress' support, the safety, security, effectiveness, and reliability of the current stockpile can be maintained to meet the Nation's national security needs.

Appendix A
Requirements Mapping

A.1 National Nuclear Security Administration Response to Statutory Reporting Requirements and Related Requests

The *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) consolidates a number of statutory reporting requirements and related congressional requests. This appendix maps the statutory and congressional requirements to the respective chapter and section in the FY 2019 SSMP.

A.2 Ongoing Requirements

50 U.S. Code § 2521	*FY 2018 Response*	*FY 2019 Response*
§ 2521. Stockpile stewardship program (a) Establishment The Secretary of Energy, acting through the Administrator for Nuclear Security, shall establish a stewardship program to ensure – (1) the preservation of the core intellectual and technical competencies of the United States in nuclear weapons, including weapons design, system integration, manufacturing, security, use control, reliability assessment, and certification; and (2) that the nuclear weapons stockpile is safe, secure, and reliable without the use of underground nuclear weapons testing.	*Unclassified* All Chapters	*Unclassified* All Chapters
(b) Program elements The program shall include the following:		
(1) An increased level of effort for advanced computational capabilities to enhance the simulation and modeling capabilities of the United States with respect to the performance over time of nuclear weapons.	*Unclassified* Chapter 3, Sections 3.2.2, 3.7, 3.7.1; Appendix C	*Unclassified* Chapter 3, Sections 3.1, 3.2; Appendix B
(2) An increased level of effort for above-ground experimental programs, such as hydrotesting, high-energy lasers, inertial confinement fusion, plasma physics, and materials research.	*Unclassified* Chapter 3, Sections 3.2.1, 3.2.4, 3.7.2; Chapter 8, Sections 8.3.1, 8.3.4	*Unclassified* Chapter 3, Sections 3.4, 3.5, 3.6, 3.8, 3.10, 3.11
(3) Support for new facilities construction projects that contribute to the experimental capabilities of the United States, such as an advanced hydrodynamics facility, the National Ignition Facility, and other facilities for above-ground experiments to assess nuclear weapons effects.	*Unclassified* Chapter 3, Section 3.7.2; Chapter 8, Section 8.3.1	*Unclassified* Chapter 4, Section 4.7.5

50 U.S. Code § 2521	***FY 2018 Response***	***FY 2019 Response***
(4) Support for the use of, and experiments facilitated by, the advanced experimental facilities of the United States, including - (A) the National Ignition Facility at Lawrence Livermore National Laboratory; (B) the Dual Axis Radiographic Hydrodynamic Testing facility at Los Alamos National Laboratory; (C) the Z Machine at Sandia National Laboratories; and (D) the experimental facilities at the Nevada National Security Site.	*Unclassified* Chapter 3, Sections 3.2, 3.2.1, 3.7.2; Chapter 8, Sections 8.3.1, 8.3.4	*Unclassified* Chapter 3, Sections 3.3–3.8, 3.12, 3.14
(5) Support for the sustainment and modernization of facilities with production and manufacturing capabilities that are necessary to ensure the safety, security, and reliability of the nuclear weapons stockpile, including - (A) the nuclear weapons production facilities; and (B) production and manufacturing capabilities resident in the national security laboratories.	*Unclassified* Chapter 2, Sections 2.2.4, 2.2.6, 2.4.1–2.4.6; Chapter 4, Sections 4.2.4, 4.3.3, 4.3.4; Chapter 8, Sections 8.1, 8.3.1, 8.7.5	*Unclassified* Chapter 2, Sections 2.2.4, 2.4.1–2.4.7; Chapter 3, Sections 3.16–3.26
(1) With respect to exascale computing—		
(a) PLAN REQUIRED.—The Administrator for Nuclear Security shall develop and carry out a plan to develop exascale computing and incorporate such computing into the stockpile stewardship program under section 4201 of the Atomic Energy Defense Act (50 U.S.C. 2521) during the 10-year period beginning on the date of the enactment of this Act [Dec. 26, 2013]	*Unclassified* Chapter 3, Sections 3.2.2, 3.7.1; Appendix C	*Unclassified* Appendix B
(b) MILESTONES.—The plan required by subsection (a) shall include major programmatic milestones in— (1) the development of a prototype exascale computer for the stockpile stewardship program; and (2) mitigating disruptions resulting from the transition to exascale computing.	*Unclassified* Chapter 3, Section 3.2.2; Appendix C	*Unclassified* Chapter 4, Section 4.19; Appendix B
(c) COORDINATION WITH OTHER AGENCIES.—In developing the plan required by subsection (a), the Administrator shall coordinate, as appropriate, with the Under Secretary of Energy for Science, the Secretary of Defense, and elements of the intelligence community (as defined in section 3(4) of the National Security Act of 1947 (50 U.S.C. 3003(4))).		
(d) INCLUSION OF COSTS IN FUTURE-YEARS NUCLEAR SECURITY PROGRAM.—The Administrator shall— (1) address, in the estimated expenditures and proposed appropriations reflected in each future-years nuclear security program submitted under section 3253 of the National Nuclear Security Administration Act (50 U.S.C. 2453) during the 10-year period beginning on the date of the enactment of this Act, the costs of— (A) developing exascale computing and incorporating such computing into the stockpile stewardship program; and (B) mitigating potential disruptions resulting from the transition to exascale computing; and (2) include in each such future-years nuclear security program a description of the costs of efforts to develop exascale computing borne by the National Nuclear Security Administration, the Office of Science of the Department of Energy, other Federal agencies, and private industry.	*Unclassified* Chapter 8, Sections 8.1, 8.3.4	*Unclassified* Chapter 4, Section 4.3.4

50 U.S. Code § 2521	*FY 2018 Response*	*FY 2019 Response*
(e) SUBMISSION TO CONGRESS.—The Administrator shall submit the plan required by subsection (a) to the congressional defense committees [Committees on Armed Services and Appropriations of Senate and the House of Representative] with each summary of the plan required by subsection (a) of section 4203 of the Atomic Energy Defense Act (50 U.S.C. 2523) submitted under subsection (b)(1) of that section during the 10-year period beginning on the date of the enactment of this Act.		
(f) EXASCALE COMPUTING DEFINED.—In this section, the term ''exascale computing'' means computing through the use of a computing machine that performs near or above 10 to the 18th power floating point operations per second.		

50 U.S. Code § 2522	*FY 2018 Response*	*FY 2019 Response*
§ 2522. Stockpile stewardship criteria		
(a) Requirement for criteria The Secretary of Energy shall develop clear and specific criteria for judging whether the science-based tools being used by the Department of Energy for determining the safety and reliability of the nuclear weapons stockpile are performing in a manner that will provide an adequate degree of certainty that the stockpile is safe and reliable.	*Unclassified* Chapter 2, Sections 2.2.1, 2.2.2, 2.2.3; Chapter 3, Sections 3.2.2, 3.7.1, 3.7.2; Chapter 8, Sections 8.3.1, 8.3.2, 8.3.3, 8.3.4	*Unclassified* Chapter 2, Sections 2.2, 2.2.1–2.2.4
(b) Coordination with Secretary of Defense The Secretary of Energy, in developing the criteria required by subsection (a), shall coordinate with the Secretary of Defense.		

50 U.S. Code § 2523	*FY 2018 Response*	*FY 2019 Response*
§ 2523. Nuclear weapons stockpile stewardship, management, and responsiveness plan		
(a) Plan requirement The Administrator, in consultation with the Secretary of Defense and other appropriate officials of the departments and agencies of the Federal Government, shall develop and annually update a plan for sustaining the nuclear weapons stockpile. The plan shall cover, at a minimum, stockpile stewardship, stockpile management, stockpile responsiveness, stockpile surveillance, program direction, infrastructure modernization, human capital, and nuclear test readiness. The plan shall be consistent with the programmatic and technical requirements of the most recent annual Nuclear Weapons Stockpile Memorandum.	*Unclassified* All Chapters ——— *Classified Annex*	*Unclassified* All Chapters ——— *Classified Annex*
(b) Submissions to Congress		
(1) In accordance with subsection (c), not later than March 15 of each even-numbered year, the Administrator shall submit to the congressional defense committees a summary of the plan developed under subsection (a).	*N/A*	*Unclassified* All chapters ——— *Classified Annex*
(2) In accordance with subsection (d), not later than March 15 of each odd-numbered year, the Administrator shall submit to the congressional defense committees a detailed report on the plan developed under subsection (a).	*Unclassified* All chapters ——— *Classified Annex*	*N/A*
(3) The summaries and reports required by this subsection shall be submitted in unclassified form, but may include a classified annex.		

50 U.S. Code § 2523	*FY 2018 Response*	*FY 2019 Response*
(c) Elements of biennial plan summary Each summary of the plan submitted under subsection (b)(1) shall include, at a minimum, the following:	*N/A*	
(1) A summary of the status of the nuclear weapons stockpile, including the number and age of warheads (including both active and inactive) for each warhead type.	*N/A*	*Unclassified* Chapter 1, Section 1.4; Chapter 2, Sections 2.2.2, 2.2.3, 2.2.4, 2.3.1 ——— *Classified Annex*
(2) A summary of the status, plans, budgets, and schedules for warhead life extension programs and any other programs to modify, update, or replace warhead types.	*N/A*	*Unclassified* Chapter 2, Section 2.3.1; Chapter 4, Sections 4.1, 4.2, 4.2.1, 4.2.2
(3) A summary of the methods and information used to determine that the nuclear weapons stockpile is safe and reliable, as well as the relationship of science-based tools to the collection and interpretation of such information.	*N/A*	*Unclassified* Chapter 2, Sections 2.2.1, 2.2.2, 2.2.3; Chapter 3, Sections 3.1–3.27
(4) A summary of the status of the nuclear security enterprise, including programs and plans for infrastructure modernization and retention of human capital, as well as associated budgets and schedules.	*N/A*	*Unclassified* Chapter 1, Sections 1.5, 1.8; Chapter 2, Section 2.4; Chapter 3, Sections 3.28–3.31; Chapter 4, Sections 4.2.2, 4.5, 4.5.1–4.5.4, 4.7.5 ——— *Classified Annex*
(5) A summary of the status, plans, and budgets for carrying out the stockpile responsiveness program under section 2538b of this title.	*N/A*	*Unclassified* Chapter 4
(6) A summary of the plan regarding the research and development, deployment, and lifecycle sustainment of technologies described in subsection (d) (7).	*N/A*	*Unclassified* Chapter 3
(7) A summary of the assessment under subsection (d)(8) regarding the execution of programs with current and projected budgets and any associated risks.	*N/A*	*Unclassified* Chapter 4, Section 4.7.1
(8) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*N/A*	*Unclassified* Executive Summary; Chapter 4, Sections 4.2.3, 4.3.1–4.3.5, 4.4.9, 4.5.3, 4.6.2, 4.6.3, 4.7, 4.7.3, 4.7.4, 4.7.5 ——— *Classified Annex*

50 U.S. Code § 2523	*FY 2018 Response*	*FY 2019 Response*
(9) Such other information as the Administrator considers appropriate.	*N/A*	*Unclassified* ——— *Classified Annex*
(d) Elements of biennial detailed report Each detailed report on the plan submitted under subsection (b)(2) shall include, at a minimum, the following:		
(1) With respect to stockpile stewardship, stockpile management, and stockpile responsiveness—		
(A) the status of the nuclear weapons stockpile, including the number and age of warheads (including both active and inactive) for each warhead type;	*Unclassified* Chapter 1, Section 1.4; Chapter 2, Sections 2.2, 2.2.2, 2.3 ——— *Classified Annex*	*N/A*
(B) for each five-year period occurring during the period beginning on the date of the report and ending on the date that is 20 years after the date of the report— (i) the planned number of nuclear warheads (including active and inactive) for each warhead type in the nuclear weapons stockpile; and (ii) the past and projected future total lifecycle cost of each type of nuclear weapon;	*Unclassified* Chapter 8, Sections 8.7.1–8.7.4 ——— *Classified Annex*	*N/A*
(C) the status, plans, budgets, and schedules for warhead life extension programs and any other programs to modify, update, or replace warhead types;	*Unclassified* Chapter 2, Sections 2.3, 2.3.2–2.3.6; Chapter 8, Sections 8.2.4, 8.7.4 ——— *Classified Annex*	*N/A*
(D) a description of the process by which the Administrator assesses the lifetimes, and requirements for life extension or replacement, of the nuclear and non-nuclear components of the warheads (including active and inactive warheads) in the nuclear weapons stockpile;	*Unclassified* Chapter 2, Sections 2.2, 2.2.1, 2.2.2; Chapter 3, Section 3.2.3	*N/A*
(E) a description of the process used in recertifying the safety, security, and reliability of each warhead type in the nuclear weapons stockpile;	*Unclassified* Chapter 2, Sections 2.1, 2.2.1, 2.2.2, 2.2.3, 2.5	*N/A*
(F) any concerns of the Administrator that would affect the ability of the Administrator to recertify the safety, security, or reliability of warheads in the nuclear weapons stockpile (including active and inactive warheads);	*Unclassified* Chapter 2, Section 2.2.3; Chapter 3, Sections 3.5.1–3.5.10 ——— *Classified Annex*	*N/A*
(G) mechanisms to provide for the manufacture, maintenance, and modernization of each warhead type in the nuclear weapons stockpile, as needed;	*Unclassified* Chapter 2; Chapter 3, Section 3.4.2	*N/A*

50 U.S. Code § 2523	***FY 2018 Response***	***FY 2019 Response***
(H) mechanisms to expedite the collection of information necessary for carrying out the stockpile management program required by section 2524 of this title, including information relating to the aging of materials and components, new manufacturing techniques, and the replacement or substitution of materials;	*Unclassified* Chapter 2, Sections 2.2.2, 2.2.3; Chapter 3, Sections 3.2.3, 3.5.3, 3.5.6, 3.5.8, 3.7.2	*N/A*
(I) mechanisms to ensure the appropriate assignment of roles and missions for each national security laboratory and nuclear weapons production facility, including mechanisms for allocation of workload, mechanisms to ensure the carrying out of appropriate modernization activities, and mechanisms to ensure the retention of skilled personnel;	*Unclassified* Chapter 1, Sections 1.3, 1.3.1, 1.3.2, 1.3.3; Chapter 2, Sections 2.2.1, 2.2.4, 2.2.5, 2.3.1–2.3.6; Chapter 7; Appendix E	*N/A*
(J) mechanisms to ensure that each national security laboratory has full and complete access to all weapons data to enable a rigorous peer-review process to support the annual assessment of the condition of the nuclear weapons stockpile required under section 2525 of this title;	*Unclassified* Chapter 2, Section 2.5.2	*N/A*
(K) mechanisms for allocating funds for activities under the stockpile management program required by section 2524 of this title, including allocations of funds by weapon type and facility; and	*Unclassified* Chapter 8, Sections 8.1, 8.2.1, 8.3.1–8.3.3, 8.7.4	*N/A*
(L) for each of the five fiscal years following the fiscal year in which the report is submitted, an identification of the funds needed to carry out the program required under section 2524 of this title;	*Unclassified* Chapter 8, Section 8.1	*N/A*
(M) the status, plans, activities, budgets, and schedules for carrying out the stockpile responsiveness program under section 2538b of this title;	*Unclassified* Chapter 1, Section 1.7.3; Chapter 3, Sections 3.1, 3.2.3; Chapter 8, Section 8.1	*N/A*
(N) for each of the five fiscal years following the fiscal year in which the report is submitted, an identification of the funds needed to carry out the program required under section 2538b of this title; and	*Unclassified* Chapter 8, Section 8.1	*N/A*
(O) as required, when assessing and developing prototype nuclear weapons of foreign countries, a report from the directors of the national security laboratories on the need and plan for such assessment and development that includes separate comments on the plan from the Secretary of Energy and the Director of National Intelligence.		*N/A*
(2) With respect to science-based tools—		
(A) a description of the information needed to determine that the nuclear weapons stockpile is safe and reliable;	*Unclassified* Chapter 2, Sections 2.2.1, 2.2.2, 2.2.3; Chapter 3, Section 3.5.2	*N/A*
(B) for each science-based tool used to collect information described in subparagraph (A), the relationship between such tool and such information and the effectiveness of such tool in providing such information based on the criteria developed pursuant to section 2522(a) of this title; and	*Unclassified* Chapter 3, Section 3.6.2	*N/A*
(C) the criteria developed under section 2522(a) of this title (including any updates to such criteria).		*N/A*

50 U.S. Code § 2523	*FY 2018 Response*	*FY 2019 Response*
(3) An assessment of the stockpile stewardship program under section 2521 (a) of this title by the Administrator, in consultation with the directors of the national security laboratories, which shall set forth—		
(A) an identification and description of— (i) any key technical challenges to the stockpile stewardship program; and (ii) the strategies to address such challenges without the use of nuclear testing;	*Unclassified* Chapter 3, Sections 3.5.1–3.5.10 ——— *Classified Annex*	*N/A*
(B) a strategy for using the science-based tools (including advanced simulation and computing capabilities) of each national security laboratory to ensure that the nuclear weapons stockpile is safe, secure, and reliable without the use of nuclear testing;	*Unclassified* Chapter 3, Sections 3.2, 3.2.1–3.2.4, 3.7, 3.7.1, 3.8	*N/A*
(C) an assessment of the science-based tools (including advanced simulation and computing capabilities) of each national security laboratory that exist at the time of the assessment compared with the science-based tools expected to exist during the period covered by the future-years nuclear security program; and	*Unclassified* Chapter 3, Sections 3.5.1–3.5.10 ——— *Classified Annex*	*N/A*
(D) an assessment of the core scientific and technical competencies required to achieve the objectives of the stockpile stewardship program and other weapons activities and weapons-related activities of the Administration, including—	*Unclassified* Chapter 7, Section 7.5.3	*N/A*
(i) the number of scientists, engineers, and technicians, by discipline, required to maintain such competencies; and	*Unclassified* Chapter 7, Section 7.2; Appendix E	*N/A*
(ii) a description of any shortage of such individuals that exists at the time of the assessment compared with any shortage expected to exist during the period covered by the future-years nuclear security program.	*Unclassified* Chapter 7, Sections 7.6.1, 7.6.2; Appendix E	*N/A*
(4) With respect to the nuclear security infrastructure—		
(A) a description of the modernization and refurbishment measures the Administrator determines necessary to meet the requirements prescribed in—	*Unclassified* Chapter 4, Sections 4.1, 4.2.4, 4.3.3, 4.3.4	*N/A*
(i) the national security strategy of the United States as set forth in the most recent national security strategy report of the President under section 3043 of this title if such strategy has been submitted as of the date of the plan;		
(ii) the most recent quadrennial defense review if such strategy has not been submitted as of the date of the plan; and		
(iii) the most recent Nuclear Posture Review as of the date of the plan;		
(B) a schedule for implementing the measures described under subparagraph (A) during the 10-year period following the date of the plan;	*Unclassified* Chapter 4, Sections 4.2.4, 4.3.4	*N/A*
(C) the estimated levels of annual funds the Administrator determines necessary to carry out the measures described under subparagraph (A), including a discussion of the criteria, evidence, and strategies on which such estimated levels of annual funds are based; and	*Unclassified* Chapter 8, Sections 8.5, 8.5.1, 8.7.1, 8.7.2, 8.7.4	*N/A*

50 U.S. Code § 2523	FY 2018 Response	FY 2019 Response
(D) a description of— (I) the metrics (based on industry best practices) used by the Administrator to determine the infrastructure deferred maintenance and repair needs of the nuclear security enterprise; and (II) the percentage of replacement plant value being spent on maintenance and repair needs of the nuclear security enterprise; and (III) an explanation of whether the annual spending on such needs complies with the recommendation of the National Research Council of the National Academies of Sciences, Engineering, and Medicine that such spending be in an amount equal to four percent of the replacement plant value, and, if not, the reasons for such noncompliance and a plan for how the Administrator will ensure facilities of the nuclear security enterprise are being properly sustained.		
(5) With respect to the nuclear test readiness of the United States—		
(A) an estimate of the period of time that would be necessary for the Administrator to conduct an underground test of a nuclear weapon once directed by the President to conduct such a test;	*Unclassified* Chapter 3, Section 3.8	*N/A*
(B) a description of the level of test readiness that the Administrator, in consultation with the Secretary of Defense, determines to be appropriate;	*Unclassified* Chapter 3, Section 3.8	*N/A*
(C) a list and description of the workforce skills and capabilities that are essential to carrying out an underground nuclear test at the Nevada National Security Site;	*Unclassified* Chapter 3, Section 3.8	*N/A*
(D) a list and description of the infrastructure and physical plants that are essential to carrying out an underground nuclear test at the Nevada National Security Site; and	*Unclassified* Chapter 3, Section 3.8	*N/A*
(E) an assessment of the readiness status of the skills and capabilities described in subparagraph (C) and the infrastructure and physical plants described in subparagraph (D).	*Unclassified* Chapter 3, Section 3.8	*N/A*
(6) A strategy for the integrated management of plutonium for stockpile and stockpile stewardship needs over a 20-year period that includes the following:		
(A) An assessment of the baseline science issues necessary to understand plutonium aging under static and dynamic conditions under manufactured and nonmanufactured plutonium geometries.	*Unclassified* Chapter 3, Sections 3.6.1, 3.6.2 ——— *Classified Annex*	*N/A*
(B) An assessment of scientific and testing instrumentation for plutonium at elemental and bulk conditions.	*Unclassified* Chapter 3, Sections 3.2.1, 3.2.4, 3.4, 3.4.1, 3.7.2 ——— *Classified Annex*	*N/A*
(C) An assessment of manufacturing and handling technology for plutonium and plutonium components.	*Unclassified* Chapter 2, Section 2.4.1	*N/A*
(D) An assessment of computational models of plutonium performance under static and dynamic loading, including manufactured and nonmanufactured conditions.	*Unclassified* Chapter 3, Section 3.2.2 ——— *Classified Annex*	*N/A*

50 U.S. Code § 2523	*FY 2018 Response*	*FY 2019 Response*
(E) An identification of any capability gaps with respect to the assessments described in subparagraphs (A) through (D).	*Unclassified* Chapter 3, Sections 3.5, 3.6.2 ——— *Classified Annex*	*N/A*
(F) An estimate of costs relating to the issues, instrumentation, technology, and models described in subparagraphs (A) through (D) over the period covered by the future-years nuclear security program under section 2453 of this title.	*Unclassified* Chapter 8, Sections 8.2.1, 8.3.1–8.3.4	*N/A*
(G) An estimate of the cost of eliminating the capability gaps identified under subparagraph (E) over the period covered by the future-years nuclear security program.	*Unclassified* Chapter 8, Sections 8.3.1–8.3.4	*N/A*
(H) Such other items as the Administrator considers important for the integrated management of plutonium for stockpile and stockpile stewardship needs.	*Unclassified* Chapter 2, Section 2.4.1	*N/A*
7) A plan for the research and development, deployment, and lifecycle sustainment of the technologies employed within the nuclear security enterprise to address physical and cyber security threats during the five fiscal years following the date of the report, together with—	*N/A*	*N/A*
(A) for each site in the nuclear security enterprise, a description of the technologies deployed to address the physical and cybersecurity threats posed to that site;	*N/A*	*N/A*
(B) for each site and for the nuclear security enterprise, the methods used by the Administration to establish priorities among investments in physical and cybersecurity technologies; and	*N/A*	*N/A*
(C) a detailed description of how the funds identified for each program element specified pursuant to paragraph (1) in the budget for the Administration for each fiscal year during that five-fiscal-year period will help carry out that plan.	*N/A*	*N/A*
(8) An assessment of whether the programs described by the report can be executed with current and projected budgets and any associated risks.	*N/A*	*N/A*
(9) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*Unclassified* Chapter 8	*N/A*

50 U.S. Code § 2523	FY 2018 Response	FY 2019 Response
(e) Nuclear Weapons Council assessment (1) For each detailed report on the plan submitted under subsection (b)(2), the Nuclear Weapons Council shall conduct an assessment that includes the following: (A) An analysis of the plan, including— (i) whether the plan supports the requirements of the national security strategy of the United States or the most recent quadrennial defense review, as applicable under subsection (d)(4)(A), and the Nuclear Posture Review; (ii) whether the modernization and refurbishment measures described under subparagraph (A) of subsection (d)(4) and the schedule described under subparagraph (B) of such subsection are adequate to support such requirements; and (iii) whether the plan supports the stockpile responsiveness program under section 2538b of this title in a manner that meets the objectives of such program and an identification of any improvements that may be made to the plan to better carry out such program. (B) An analysis of whether the plan adequately addresses the requirements for infrastructure recapitalization of the facilities of the nuclear security enterprise. (C) If the Nuclear Weapons Council determines that the plan does not adequately support modernization and refurbishment requirements under subparagraph (A) or the nuclear security enterprise facilities infrastructure recapitalization requirements under subparagraph (B), a risk assessment with respect to— (i) supporting the annual certification of the nuclear weapons stockpile; and (ii) maintaining the long-term safety, security, and reliability of the nuclear weapons stockpile. (2) Not later than 180 days after the date on which the Administrator submits the plan under subsection (b)(2), the Nuclear Weapons Council shall submit to the congressional defense committees a report detailing the assessment required under paragraph (1).	*N/A*	*N/A*
(f) Definitions – In this section: (1) The term "budget", with respect to a fiscal year, means the budget for that fiscal year that is submitted to Congress by the President under section 1105(a) of title 31. (2) The term "future-years nuclear security program" means the program required by section 2453 of this title. (3) The term "nuclear security budget materials", with respect to a fiscal year, means the materials submitted to Congress by the Administrator in support of the budget for that fiscal year. (4) The term "quadrennial defense review" means the review of the defense programs and policies of the United States that is carried out every four years under section 118 of title 10. (5) The term "weapons activities" means each activity within the budget category of weapons activities in the budget of the Administration. (6) The term "weapons-related activities" means each activity under the Department of Energy that involves nuclear weapons, nuclear weapons technology, or fissile or radioactive materials, including activities related to— (A) nuclear nonproliferation; (B) nuclear forensics; (C) nuclear intelligence; (D) nuclear safety; and (E) nuclear incident response.		

50 U.S. Code § 2524	*FY 2018 Response*	*FY 2019 Response*
§ 2524. Stockpile management program		
(a) Program required The Secretary of Energy, acting through the Administrator for Nuclear Security and in consultation with the Secretary of Defense, shall carry out a program, in support of the stockpile stewardship program, to provide for the effective management of the weapons in the nuclear weapons stockpile, including the extension of the effective life of such weapons. The program shall have the following objectives:		
(1) To increase the reliability, safety, and security of the nuclear weapons stockpile of the United States.	*Unclassified* Chapter 2, Sections 2.2.1, 2.2.2, 2.3	*Unclassified* Chapter 2, Sections 2.1, 2.2.1, 2.2.2, 2.2.3
(2) To further reduce the likelihood of the resumption of underground nuclear weapons testing.	*Unclassified* Chapter 3, Sections 3.6, 3.7, 3.7.1, 3.7.2	*Unclassified* Chapter 2, Section 2.2.1; Chapter 3, Sections 3.1–3.14
(3) To achieve reductions in the future size of the nuclear weapons stockpile.	*Unclassified* Chapter 2, Sections 2.2, 2.3, 2.3.1–2.3.6	*Unclassified* Chapter 1, Section 1.7; Chapter 2, Section 2.2.5
(4) To reduce the risk of an accidental detonation of an element of the stockpile.	*Unclassified* Chapter 2, Sections 2.2.1–2.2.5, 2.4.6; Chapter 3, Sections 3.7.1, 3.7.2	*Unclassified* Chapter 2, Sections 2.2.1–2.2.5, 2.4.6
(5) To reduce the risk of an element of the stockpile being used by a person or entity hostile to the United States, its vital interests, or its allies.	*Unclassified* Chapter 5	*Unclassified* Chapter 2, Section 2.1; Chapter 3, Sections 3.15, 3.16
(b) Program limitations In carrying out the stockpile management program under subsection (a), the Secretary of Energy shall ensure that—		
(1) any changes made to the stockpile shall be made to achieve the objectives identified in subsection (a); and		
(2) any such changes made to the stockpile shall— (A) remain consistent with basic design parameters by including, to the maximum extent feasible, components that are well understood or are certifiable without the need to resume underground nuclear weapons testing; and (B) use the design, certification, and production expertise resident in the nuclear security enterprise to fulfill current mission requirements of the existing stockpile.		
(c) Program budget In accordance with the requirements under section 2529 of this title, for each budget submitted by the President to Congress under section 1105 of title 31, the amounts requested for the program under this section shall be clearly identified in the budget justification materials submitted to Congress in support of that budget.		

50 U.S. Code § 2538a	*FY 2018 Response*	*FY 2019 Response*
§2538a. Plutonium pit production capacity (a) Requirement Consistent with the requirements of the Secretary of Defense, the Secretary of Energy shall ensure that the nuclear security enterprise- (1) during 2021, begins production of qualification plutonium pits; (2) during 2024, produces not less than 10 war reserve plutonium pits; (3) during 2025, produces not less than 20 war reserve plutonium pits; (4) during 2026, produces not less than 30 war reserve plutonium pits; and (5) during a pilot period of not less than 90 days during 2027 (subject to subsection (b)), demonstrates the capability to produce war reserve plutonium pits at a rate sufficient to produce 80 pits per year.	*Unclassified* Chapter 2, Section 2.4.1	*Unclassified* Chapter 2, Section 2.4.1
(b) Authorization of two-year delay of demonstration requirement The Secretary of Energy and the Secretary of Defense may jointly delay, for not more than two years, the requirement under subsection (a)(5) if- (1) the Secretary of Defense and the Secretary of Energy jointly submit to the congressional defense committees a report describing- (A) the justification for the proposed delay; (B) the effects of the proposed delay on stockpile stewardship and modernization, life extension programs, future stockpile strategy, and dismantlement efforts; and (C) whether the proposed delay is consistent with national policy regarding creation of a responsive nuclear infrastructure; and (2) the Commander of the United States Strategic Command submits to the congressional defense committees a report containing the assessment of the Commander with respect to the potential risks to national security of the proposed delay in meeting- (A) the nuclear deterrence requirements of the United States Strategic Command; and (B) national requirements related to creation of a responsive nuclear infrastructure.		
(c) Annual certification Not later than March 1, 2015, and each year thereafter through 2027 (or, if the authority under subsection (b) is exercised, 2029), the Secretary of Energy shall certify to the congressional defense committees and the Secretary of Defense that the programs and budget of the Secretary of Energy will enable the nuclear security enterprise to meet the requirements under subsection (a).	*N/A*	*N/A*
(d) Plan If the Secretary of Energy does not make a certification under subsection (c) by March 1 of any year in which a certification is required under that subsection, by not later than May 1 of such year, the Chairman of the Nuclear Weapons Council shall submit to the congressional defense committees a plan to enable the nuclear security enterprise to meet the requirements under subsection (a). Such plan shall include identification of the resources of the Department of Energy that the Chairman determines should be redirected to support the plan to meet such requirements.	*N/A*	*N/A*

50 U.S. Code § 2538b	*FY 2018 Response*	*FY 2019 Response*
§ 2538b. Stockpile responsiveness program (a) Statement of policy It is the policy of the United States to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive.	*Unclassified* All Chapters	*Unclassified* All Chapters
(b) Program required The Secretary of Energy, acting through the Administrator and in consultation with the Secretary of Defense, shall carry out a stockpile responsiveness program, along with the stockpile stewardship program under section 2521 of this title and the stockpile management program under section 2524 of this title, to identify, sustain, enhance, integrate, and continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons.	*Unclassified* Chapter 1, Sections 1.5, 1.7.3; Chapter 3, Sections 3.1, 3.2.3, 3.4.1, 3.4.4; Chapter 8, Section 8.3.2	*Unclassified* Chapter 1, Sections 1.5, 1.7
(c) Objectives The program under subsection (b) shall have the following objectives: (1) Identify, sustain, enhance, integrate, and continually exercise all of the capabilities, infrastructure, tools, and technologies across the science, engineering, design, certification, and manufacturing cycle required to carry out all phases of the joint nuclear weapons life cycle process, with respect to both the nuclear security enterprise and relevant elements of the Department of Defense. (2) Identify, enhance, and transfer knowledge, skills, and direct experience with respect to all phases of the joint nuclear weapons life cycle process from one generation of nuclear weapon designers and engineers to the following generation. (3) Periodically demonstrate stockpile responsiveness throughout the range of capabilities required, including prototypes, flight testing, and development of plans for certification without the need for nuclear explosive testing. (4) Shorten design, certification, and manufacturing cycles and timelines to minimize the amount of time and costs leading to an engineering prototype and production. (5) Continually exercise processes for the integration and coordination of all relevant elements and processes of the Administration and the Department of Defense required to ensure stockpile responsiveness. (6) The retention of the ability, in consultation with the Director of National Intelligence, to assess and develop prototype nuclear weapons of foreign countries and, if necessary, to conduct no-yield testing of those prototypes.	*Unclassified* Chapter 1, Sections 1.1, 1.5, 1.7.3; Chapter 2, Sections 2.2.2, 2.5.3; Chapter 3; Chapter 7, Sections 7.5.4, 7.6.3	*Unclassified* Chapter 3
(d) Joint nuclear weapons life cycle process defined In this section, the term “joint nuclear weapons life cycle process” means the process developed and maintained by the Secretary of Defense and the Secretary of Energy for the development, production, maintenance, and retirement of nuclear weapons.		

A.3 Other Requirements

H.R.244 – Consolidated Appropriations Act, 2017, P.L. 115-31	*FY 2018 Response*	*FY 2019 Response*
SEC. 4. EXPLANATORY STATEMENT. The explanatory statement regarding this Act, printed in the House section of the Congressional Record on or about May 2, 2017, and submitted by the Chairman of the Committee on Appropriations of the House, shall have the same effect with respect to the allocation of funds and implementation of divisions A through L of this Act as if it were a joint explanatory statement of a committee of conference.		
Congressional Record – House, Vol 163, No 76—Book II, page H3753, May 3, 2017 (Explanatory Statement to Accompany the FY 17 Omnibus Appropriations [P.L. 115-31]]		
Life Extension Reporting. – The NNSA is directed to provide to the Committees on Appropriations of both Houses of Congress a classified summary of each ongoing life extension and major refurbishment program that includes explanatory information on the progress and planning for each program beginning with the award of the phase 6.3 milestone and annually thereafter until completion of the program.	*Classified Annex*	*Classified Annex*

Appendix B
Exascale Computing Initiative

The December 2017 *National Security Strategy* mandates that "to maintain our competitive advantage, the United States will prioritize emerging technologies critical to economic growth and security, such as data science, encryption, gene editing, new materials, nanotechnology, advanced computing technologies, and artificial intelligence." In addition, the 2018 *Nuclear Posture Review* states that the Department of Energy's National Nuclear Security Administration (DOE/NNSA) will "maintain and enhance the computational, experimental, and testing capabilities needed to annually assess nuclear weapons." In order to maintain competitive advantage and the capabilities for the annual assessment, the United States must retain primacy in high-performance computing (HPC). HPC will also help ensure national security, economic prosperity, technological strength, and scientific and energy research leadership. Failure to address national security, science, and growing big data needs will open the door to other nations to take the lead, not only in high-end computing, but eventually in science, national defense, and energy innovation, as well as in the commercial computing market.

In 2015 the National Strategic Computing Initiative was established to maximize the benefits of HPC for U.S. economic competitiveness, scientific discovery, and national security. DOE, through a partnership between the DOE Office of Science and NNSA, is responsible for executing the joint Exascale Computing Initiative. This initiative focuses on advanced simulations through an exascale-capable computing program and emphasizes sustained performance and analytic computing to advance DOE/NNSA missions. The objectives and associated scientific challenges define a mission need in the early to mid-2020s for a computing capability of 2 to 10 exaFLOPS (1 exaFLOPS = 10^{18} floating-point operations per second).

B.1 Challenges

To deliver the exascale computing capability for the nuclear security mission within the next decade, while maintaining and modifying the integrated design codes, NNSA will accomplish the following:

- Develop HPC technologies and systems, in close partnership with computer vendors, to provide at least a 25-fold increase in sustained application code performance over the currently largest Advanced Simulation and Computing (ASC) supercomputer, Trinity, which is a 41-petaFLOPS system;
- Address code performance on the next-generation hardware, which is anticipated to incorporate multi-core, heterogeneous computing architectures;
- Develop a tri-laboratory, open-sourced software stack that will run efficiently on the new advanced architecture prototype systems to assess the viability of an alternative HPC architecture path for ASC; and
- Refurbish or construct computing facilities that will be capable of siting exascale platforms with increasing and evolving structural integrity, power, and cooling requirements.

B.2 Approaches and Strategies

To achieve exascale goals, the DOE/NNSA will interact with industry in HPC technology development. Past partnerships between the U.S. Government and industry have led to development of innovative technologies that met both Federal Government and private sector objectives. NNSA will continue its partnership with the DOE Office of Science on the Exascale Computing Initiative, including investments in research and development of software tools and applications with computer vendors, the national laboratories, and universities. In addition, DOE/NNSA are collaborating on the joint April 2018 CORAL-2 (Collaboration of Oak Ridge, Argonne, and Livermore) procurement, which will deliver an exascale-class system to DOE's Office of Science in FY 2021–2022 and another to NNSA in FY 2023. This joint procurement will allow the program offices to share critical non-recurring engineering development costs with the selected vendor(s). The current spend plan in the mid-2020s is shown in **Table B–1**. This spend plan does not support delivery of exascale by 2023.

Table B-1. NNSA Exascale Computing Initiative funding schedule for fiscal years 2018 through 2023

Exascale Computing Initiative Elements (dollars in millions)	*FY 2018*	*FY 2019*	*FY 2020*	*FY 2021*	*FY 2022*	*FY 2023*
Advanced Technology Development and Mitigation	170	95	50	61	56	36
Computational Systems and Software Environment – El Capitan System	1	21	25	46	53	24
Facility Operations and User Support – Construction (Exascale Computing Facility Modernization)	3	23	50			
Facility Operations and User Support – Construction (Exascale Class Computer Cooling Equipment)		24	2			
Total	174	163	127	107	109	60

In addition to hardware and software technology development efforts, exascale systems must meet exacting power usage, reliability, and functionality criteria. Each exascale-class platform will require between 30 and 45 megawatts per year to operate, as well as requisite cooling. Managing a service load of this magnitude, which is over and above existing requirements in ASC facilities, will necessitate major facility modernizations. Currently, ASC is supporting two construction projects in its Exascale Computing Initiative portfolio. At LLNL, the Exascale Computing Facility Modernization (ECFM) project is intended to fill this gap by providing 85 megawatts of power, 18,000 tons of additional water cooling, and structural reinforcement capable of supporting 315 pounds per square foot of rack load by early in calendar year 2022. Critical Decision 0 (CD-0, Approve Mission Need) for the ECFM project was approved in April 2017. CD-1 (Approve Alternative Selection and Cost Range) was approved May 29, 2018. The ECFM is essential for LLNL to site the NNSA exascale system at the beginning of FY 2023. At LANL, the Exascale Class Computer Cooling Equipment Project was approved for CD-2/3 (Approve Performance Baseline/Approve Start of Construction) on April 4, 2018. This project will expand the warm water cooling capacity in Building 2327 to about 9,300 tons, enabling the siting of the Advanced Technology System (ATS)-3 Crossroads supercomputer and future systems at LANL.

B.3 Conclusion

DOE/NNSA, through the ASC Exascale effort, is investing in products and approaches that are directly related to anticipated disruptive changes in the HPC ecosystem. Activities include research and development partnerships with multiple HPC vendors, development of next-generation weapons codes with new simulation capabilities, and procurement of an advanced architecture prototype system with a potential alternative HPC software stack. Cooperation with computer vendors has also led to significant advances in HPC software and hardware technologies. These activities have provided experience and lessons learned and have already delivered a variety of software development tools and libraries on which many ASC applications now rely. To complete this effort, DOE/NNSA must conduct more intensive research, development, and engineering to deploy an exascale capability in the mid-2020s.

Appendix C
Weapons Activities Capabilities

This table represents the breadth of capabilities that delineate critical functions of Weapons Activities in the Department of Energy/National Nuclear Security Administration (DOE/NNSA) nuclear security enterprise. The table includes a definition for each capability as well as the relevant section(s) of the *Fiscal Year 2019 Stockpile Stewardship and Management Plan – Biennial Plan Summary* (SSMP) for each one. These capabilities should not be viewed in isolation or as mutually exclusive, as many overlap and are complementary. They represent the underlying disciplines, activities, and specialized skills required to meet NNSA missions.

Capability	*Definition*	*Relevant Section of FY 2019 SSMP*
Advanced Experimental Diagnostics and Sensors	Advanced diagnostics and sensors are used to measure what is occurring. Standard diagnostics provide less data than required to fully capture the behavior of many tests and experiments; continued development is reducing these limitations. An example of an advanced diagnostic is static or dynamic radiography. Radiography is an imaging technique that uses x-rays or sub-atomic particles (e.g., protons, neutrons) to view the internal structure of an object that is opaque to visible light. Static radiography of a stationary object is used during the post-fabrication inspection process to ensure that components have been fabricated correctly and are free of defects. Dynamic radiography takes multiple images of an object as it is imploding or expanding.	Section 3.7
Advanced Manufacturing	Advanced manufacturing uses innovative techniques from industry, academia, or internal research and development to reduce costs and production time, improve safety, and control waste streams. Examples include additive or digital manufacturing, use of microreactors, microwave casting, and electrorefining.	Section 3.18
Atomic and Plasma Physics	Atomic physics is the study of atoms and the interaction of their electrons with x-rays. Plasma physics is the study of the fourth state of matter, which contains ionized atoms and unbound electrons. The extremely high temperatures in nuclear weapons generate plasma and x-rays.	Section 3.4
Chemistry	Chemistry is the study of the fundamental (or elemental) composition, structure, bonding, and properties of matter. Chemistry is essential for purifying, synthesizing, processing, and fabricating materials. The stability of these materials and how properties and material reactions change with time must be understood to ensure quality, performance, reliability, and safety of the stockpile.	Section 3.9

Capability	***Definition***	***Relevant Section of FY 2019 SSMP***
Environmental Effects Analysis, Testing, and Engineering Sciences	Environmental effects analysis, testing, and engineering sciences use an array of test equipment, tools, and techniques. Examples of environments (normal and abnormal) include shock, vibration, radiation, acceleration, temperature, electrostatics, and pressure. The engineering sciences that support this analysis include thermal and fluid sciences, structural mechanics, dynamics, and aerodynamics.	Section 3.14
Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Material	Hazardous and energetic materials require safe and secure handling, packaging, processing, manufacturing, and inspection. Lithium, beryllium, and mercury have the potential to harm humans, animals, or the environment. Energetic materials (e.g., explosives, propellants) and hazardous materials require special conduct of operations, containment equipment, and facilities to handle, process, or manufacture products containing these materials.	Section 3.20
Handling, Packaging, Processing, and Manufacturing of Special Nuclear Materials	Special conduct of operations, physical security protection, facilities, and equipment are required to handle, package, process, manufacture, and inspect components that contain special nuclear materials (e.g., plutonium, enriched uranium).	Section 3.21
High Energy Density Physics	High energy density physics is the study of matter and radiation under extreme conditions such as those in a nuclear weapon and in experiments at facilities such as the National Ignition Facility, Omega Laser Facility, and the Z pulsed power facility that provide fundamental data for validating computational models.	Section 3.5
High Explosives Science and Engineering	High explosives science and engineering is the study of how energetic materials detonate, how the explosive shock wave propagates through a material, and how to select, synthesize, and manufacture high explosives for specific applications. Knowledge of the performance of high explosives is important to predict the performance of a weapon.	Section 3.10
High Performance Computing	High performance computing requires software, hardware, and facilities of sufficient power to achieve the resolution, dimensionality, and complexity in simulation codes to model the performance of weapon systems and components.	Section 3.2
Hydrodynamic and Subcritical Experiments	A hydrodynamic experiment is performed to understand the dynamics of an implosion. A subcritical experiment contains special nuclear material that never achieves a critical configuration and does not create nuclear yield. Both types of experiments provide data essential to predict the performance of nuclear weapons and validate the multi-physics design codes and the models embedded in these codes.	Section 3.8
Information Technology and Cybersecurity	Information technology and cybersecurity provides infrastructure and protection for all networks and systems to support both classified and unclassified environments. It ensures electronic information and information assets are performing necessary operations and are protected from compromised, unauthorized access and malicious acts that would adversely affect national and economic security.	Section 3.30

Capability	***Definition***	***Relevant Section of FY 2019 SSMP***
Laser, Pulsed Power, and Accelerator Technology	These enhanced technologies provide data at pressure, temperature, and radiation conditions close to those in a nuclear weapon while ensuring safe, reliable, efficient operation of the lasers, pulsed power devices, and accelerators. Lasers and pulsed power devices accumulate energy over long periods and release it very quickly. Accelerators use electromagnetic fields to accelerate charged particles to very high speeds. The charged particles can produce high-energy x-rays to take radiographs or high-energy neutrons for nuclear physics investigations.	Section 3.6
Materials Science and Engineering	Materials science, in the context of stockpile stewardship, is the study of how materials in a nuclear weapon behave under both extreme and moderate conditions of temperature and pressure. Materials engineering involves the evaluation and selection of materials for these environments. Strength, aging, compatibility, viability, and damage mechanisms are among the material characteristics to be evaluated. Materials science and engineering play a key role in resolving stockpile and production issues, validating computational models, and developing new materials (e.g., materials produced through additive manufacturing).	Section 3.11
Metal and Organic Material Fabrication, Processing, and Manufacturing	Although many components in weapons are supplied by U.S. industries, specialized components and materials must be produced within the nuclear security enterprise. This production requires synthesis of organic materials and processing, manufacturing, and inspection of metallic and organic products, based on knowledge of material behavior, compatibility, and aging.	Section 3.23
Non-Nuclear Weapon Component Manufacturing and Assembly	Many non-nuclear weapon components (e.g., microelectronics; gas transfer systems; arming, fuzing, and firing assemblies; environmental sensing devices; radars; neutron generators; batteries) require special manufacturing, assembly, and inspection protocols.	Section 3.24
Nuclear Physics and Radiochemistry	Nuclear physics is the study of atomic nuclei and their interactions, especially fission and fusion. Knowledge is required of the probabilities of interactions of neutrons with fissile material and of light nuclei that can result in fusion. Radiochemistry, the chemistry of radioactive materials, is used to evaluate data from legacy underground tests as well as from experiments at the National Ignition Facility, Omega Laser Facility, and the Z pulsed power facility.	Section 3.3
Physical Security	Physical security protects the Nation's nuclear materials and infrastructure assets and the workforce at NNSA sites involved in Weapon Activities. It protects assets from theft, diversion, sabotage, espionage, unauthorized access, compromise, and other hostile or noncompliant acts that may adversely affect national security, program continuity, and employee security.	Section 3.29
Radiation-Hardened Microelectronics Design and Manufacturing	Design, production, and testing of radiation-hardened microelectronics is required for nuclear weapons to function properly in hostile environments. This capability requires a secure, trusted supply chain, including quality control of materials used in the process and the products.	Section 3.16

Capability	*Definition*	*Relevant Section of FY 2019 SSMP*
Secure Transportation	Protection and movement of nuclear weapons, weapon components, and special nuclear material between facilities includes the design and fabrication or modification of vehicles, design and fabrication of special communication systems, and training of Federal agents.	Section 3.28
Simulation Codes and Models	Advanced computer codes and the models embedded in these codes are developed and used to simulate the behavior of nuclear weapons. NNSA codes operate on computers ranging from desktop machines to the world's largest high performance supercomputers.	Section 3.1
Testing Equipment Design and Fabrication	Design and fabrication of special test equipment to simulate environmental and functional conditions must ensure that products meet specifications. Data from test equipment provide evidence for qualification, certification, reliability, surety, and surveillance.	Section 3.26
Tritium Production, Handling, and Processing	Tritium has a 12-year half-life and must be periodically replenished in gas transfer systems. Production, handling, and processing of tritium includes the recovery, extraction, refinement, storage, filling, and inspection of gas transfer systems.	Section 3.22
Weapon Component and Material Process Development	Process development of weapon components involves small-lot production, precise controls, and a deep understanding of the hazards of working with special nuclear materials and other exotic materials. Component process development is also required whenever process changes are made to reduce cost and production time.	Section 3.19
Weapon Component and System Prototyping	Development, qualification, and manufacture of high-fidelity, full-scale prototype weapon components and systems reduce the cost and life cycle time to develop and qualify new designs and technologies. This capability includes the ability to design, manufacture, and employ mockups with sensors to support laboratory and flight tests that provide evidence that components can function with Department of Defense delivery systems in realistic environments.	Section 3.17
Weapon Component and System Surveillance and Assessment	Surveillance enhances integration across test regimes to demonstrate performance requirements for stockpile systems by inspections, laboratory and flight tests, non-destructive tests, and component and material evaluations. The comparability of data over time provides the ability to predict, detect, assess, and resolve aging trends and anomalous changes in the stockpile, as well as to address or mitigate issues or concerns. Assessment is the analysis, largely through modeling and simulation, of data gathered during surveillance to evaluate the safety, performance, and reliability of weapon systems and the effect of aging on performance, uncertainties, and margins.	Section 3.27
Weapons Engineering Design, Analysis, and Integration	Elements of weapons engineering capability include the following life cycle phases: concept exploration, satisfaction of requirements, conceptual design, detailed design and development, production, and certification and qualification. This capability also includes system integration, which includes understanding and developing the interfaces among the non-nuclear subsystems, between the non-nuclear components and the nuclear explosives package, and between the DOE/NNSA and Department of Defense systems.	Section 3.13

Capability	***Definition***	***Relevant Section of FY 2019 SSMP***
Weapon System Assembly and Disassembly	Weapons system assembly involves the final assembly of the nuclear and non-nuclear components. Assembly requires special conduct of operations, equipment, and facilities. Disassembly, inspection, and storage or disposal of the components require similar special conduct of operations, quality control, equipment, and facilities.	Section 3.25
Weapons Physics Design and Analysis	Design and analysis of the nuclear explosive package is required to maintain existing U.S. nuclear weapons, modernize the stockpile, evaluate possible proliferant nuclear weapons, and respond to emerging threats, unanticipated events, and technological innovation. Elements of design capability include concept exploration, satisfaction of specifications, conceptual design, detailed design and development, production process development, and certification and qualification. Weapons physics analysis includes evaluation of weapons effects.	Section 3.12
Weapons Surety Design, Testing, Analysis, and Manufacturing	Weapons surety design, analysis, integration, and manufacturing employ a variety of safety and use control systems to prevent accidental nuclear detonation and unauthorized use of nuclear weapons to ensure a safe and secure stockpile. This knowledge, infrastructure, and equipment require strict classification control and secure facilities and equipment.	Section 3.15

Appendix D
Glossary

3D printing—Also known as additive manufacturing, which turns digital three-dimensional models into solid objects by building them up in layers.

abnormal environment—An environment as defined in a weapon's stockpile-to-target sequence and military characteristics in which the weapon is not expected to retain full operational reliability, or an environment that is not expected to occur during nuclear explosive operations and associated activities.

additive manufacturing—A manufacturing technique that builds objects, layer by layer, according to precise design specifications, compared to a traditional manufacturing technique, in which objects are carved out of a larger block of material or cast in molds and dies.

advanced manufacturing—Modern technologies necessary to enhance secure manufacturing capabilities and provide timely support for critical needs of the stockpile.

alteration (Alt)—A material change to, or a prescribed inspection of, a nuclear weapon or major assembly that does not alter its operational capability, yet is sufficiently important to the user regarding assembly, maintenance, storage, or test operations to require controlled application and identification.

annual assessment process—The authoritative method to evaluate the safety, reliability, performance, and military effectiveness of the stockpile by subject matter experts based upon new and legacy data, surveillance, and modeling and simulation. It is a principal factor in the Nation's ability to maintain a credible deterrent without nuclear explosive testing. The Directors of the three national security laboratories complete annual assessments of the stockpile, and the Commander of the U.S. Strategic Command provides a separate assessment of military effectiveness. The assessments also determine whether underground nuclear explosive testing must be conducted to resolve any issues. The Secretaries of Energy and Defense submit the reports unaltered to the President, along with any conclusions they deem appropriate.

arming, fuzing, and firing (AF&F) system—The electronic and mechanical functions that ensure a nuclear weapon does not operate when not intended during any part of its manufacture and lifetime, but does ensure that the weapon will operate correctly when a unique signal to do so is properly activated.

B61—An air-delivered gravity bomb.

B61-12 Life Extension Program (LEP)—An LEP to consolidate four families of the B61 bomb into one and improve the safety and security of the oldest weapon system in the U.S. arsenal.

B83—An air-delivered gravity bomb.

Boost—The process that increases the yield of a nuclear weapon's primary stage through fusion reactions.

canned subassembly (CSA)—A component of a nuclear weapon that is hermetically sealed in a metal container. A CSA and the primary make up a weapon's nuclear explosive package.

certification—The process whereby all available information on the performance of a weapon system is considered and the Laboratory Directors responsible for that system certify, before the weapon enters the stockpile, that it will meet, with noted exceptions, the military characteristics within the environments defined by the stockpile-to-target sequence.

co-design—An inclusive process to develop designs that encourages participants to find solutions within the context of the total system rather than based upon individual areas of expertise and interest.

component—An assembly or combination of parts, subassemblies, and assemblies mounted together during manufacture, assembly, maintenance, or rebuild. In a system engineering product hierarchy, the component is the lowest level of shippable and storable entities, which may be raw material, procured parts, or manufactured items.

Continuous Diagnostics and Mitigation (CDM)—A dynamic approach to fortifying the cybersecurity of Government networks and systems. CDM provides Federal departments and agencies with capabilities and tools that identify cybersecurity risks on an ongoing basis, prioritize these risks based upon potential impacts, and enable cybersecurity personnel to mitigate the most significant problems first. Congress established the CDM program to provide adequate, risk-based, and cost-effective cybersecurity and to allocate cybersecurity resources more efficiently.

continuous monitoring—A strategy that enables information security professionals and others to see a continuous stream of near real-time snapshots of the state of risk to their security, data, network, end points, and even cloud devices and applications.

conventional high explosive (CHE)—A high explosive that detonates when given sufficient stimulus via a high-pressure shock. Stimuli from severe accident environments involving impact, fire, or electrical discharge may also initiate a CHE. See also “insensitive high explosive.”

critical decision (CD)—The five levels a DOE project typically progresses through, which serve as major milestones approved by the Chief Executive for Project Management. Each CD marks an authorization to increase the commitment of resources and requires successful completion of the preceding phase. These five phases are CD-0, Approve Mission Need; CD-1, Approve Alternative Selection and Cost Range; CD-2, Approve Performance Baseline; CD-3, Approve Start of Construction/Execution; CD-4, Approve Start of Operations or Project Completion.

cybersecurity—The physical, technical, administrative and management controls for providing the required and appropriate levels of protections of information and information assets against unauthorized disclosure, transfer, modification, or destruction, whether accidental or intentional. Cybersecurity also ensures the required and appropriate level of confidentiality, integrity, availability, and accountability for the information stored, processed, or transmitted on electronic systems and networks.

data loss prevention (DLP)—DLP is a strategy for making sure that end users do not send sensitive or critical information outside the corporate network. DLP also includes software products that aid network administrators in controlling what data end users can transfer.

defense-in-depth—The security approach whereby layers of cybersecurity and information assurance solutions are used to establish an adequate security posture. Implementation of this strategy also is recognized due to the highly interactive nature of the various systems and networks. Cybersecurity defense-in-depth must be considered within the context of the shared risk environment, given that any single system cannot be adequately secured unless all interconnected systems are adequately secured.

design life—The length of time, starting from the date of manufacture, that a nuclear weapon is designed to meet its stated military requirements.

deuterium—An isotope of hydrogen whose nucleus contains one neutron and one proton.

down-select—The process of narrowing the range of design options during the *Phase 6.x Process*, culminating in a final design (normally exercised when moving from Phase 6.1 to 6.2, from Phase 6.2 to 6.2A, and from Phase 6.2A to 6.3) through analysis of the ability to meet military requirements and assessment of schedule, cost, material, and production impacts.

encryption—Technical controls to protect information as it passes throughout a network and resides on computers. These methods protect sensitive information during storage and transmission and provide functionality to reduce the risk of both intentional and accidental data compromise and alteration.

enterprise forensics—The performance of real-time, remote inspections at the binary level of all data on a given system. The inspection includes operating memory, physical storage devices, and virtualization mechanisms on any machine at a given time.

Enterprise Governance, Risk, and Compliance (EGRC)—The official corporate and enterprise program repository used to conduct continuous performance monitoring and reporting of information security program management, operations, and technical controls (e.g., authority-to-operate packages, deviations, incident management reporting).

Enterprise Information System—Systems within NNSA for which the authorization boundary covers multiple sites and multiple local Authorization Official jurisdictions.

exascale computing—Computing systems capable of at least 1 exaFLOPS, or a billion calculations per second. Such capacity represents a thousand-fold increase over the first petascale computer that came into operation in 2008. See also "floating point operations per second (FLOPS)."

firewalls—Systems that can be implemented in hardware and/or software that are designed to prevent unauthorized access to or from private networks connected to the Internet.

first production unit—The first completed component of a nuclear weapon delivered to a user (e.g., the DOD).

fiscal year—The Federal budget and funding year that starts on October 1 and goes to the following September 30.

fission—The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial energy.

floating point operations per second (FLOPS)—The number of arithmetic operations performed on real numbers in a second; used as a measure of the performance of a computer system.

fusion—The process whereby the nuclei of two light elements, especially the isotopes of hydrogen (namely, deuterium and tritium), combine to form the nucleus of a heavier element with the release of substantial energy and a high-energy neutron.

Future Years Nuclear Security Program (FYNSP)—A detailed description of the program elements (and associated projects and activities) for the fiscal year for which the annual budget is submitted and the four succeeding fiscal years.

general purpose infrastructure—The buildings, equipment, utilities, roads, etc., that support operation of the nuclear security enterprise, but are not specifically programmatic-focused.

high explosives (HE)—Materials that detonate, with the chemical reaction components propagating at supersonic speeds. HE are used in the main charge of a weapon primary to compress the fissile material and initiate the chain of events leading to nuclear yield. See also "conventional high explosive" and "insensitive high explosive."

high performance computing (HPC)—The use of supercomputers and parallel processing techniques with multiple computers to perform computational tasks.

ignition—The point at which a nuclear fusion reaction becomes self-sustaining—that is, more energy is produced and retained in the fusion target than the energy used to initiate the nuclear reaction.

Information Assurance Response Center—The NNSA facility that continuously monitors all activity going through the nuclear security enterprise computer firewall system, providing intrusion detection and event forensics.

information system—A combination of information, computer, and telecommunications resources and other information technology and personnel resources that collect, record, process, store, communicate, retrieve, and display information.

information technology (IT)—The equipment or interconnected system or subsystem of equipment used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information. IT includes computers, ancillary equipment, software, firmware, and related procedures, services, and resources.

Information Technology Infrastructure—The shared technology resources that provide the platform for the specific information system applications at a site or NNSA/DOE-wide. It consists of a set of physical devices and software applications that are required to operate the entire nuclear security enterprise.

insensitive high explosive (IHE)—A high explosive substance that is so insensitive that the probability of accidental initiation or transition from burning to detonation is negligible.

integrated design code (IDC)—A simulation code containing multiple physics and engineering models that have been validated experimentally and computationally. An IDC is used to simulate, understand, and predict the behavior of nuclear and non-nuclear components and nuclear weapons under normal, abnormal, and hostile conditions.

interoperable warhead (IW)—A warhead that has a common nuclear explosive package and adaptable non-nuclear components.

intrusion prevention—A network security device that monitors network activities for malicious activities such as security threats or policy violations. The main function of an intrusion prevention system is to identify suspicious activity, log the information, and report it.

Joint Cybersecurity Coordination Center (JC3)—The cybersecurity incident response coordination, reporting, and tracking element for the entire DOE enterprise. JC3 provides computer security support to collect, analyze, and share cybersecurity information for all of DOE, including DOE's Energy Information Administration and Power Marketing Administration, as well as NNSA's national security laboratories, nuclear weapons production facilities, and Nevada National Security Site. JC3 is managed and operated by the DOE Chief Information Officer.

joint test assembly (JTA)—An electronic unit that contains sensors and instrumentation that monitor the weapon hardware performance during flight tests to ensure that the weapon components will function as designed. An NNSA-developed configuration, based on NNSA-DOD requirements, for use in the flight test program.

life cycle—The series of stages through which a component, system, or weapon passes from initial development until it is consumed, disposed of, or altered in order to extend its lifetime.

life extension program (LEP)—A program that refurbishes warheads of a specific weapon type by replacing aged components to extend the service life of a weapon. LEPs are designed to extend the life of a warhead by 20 to 30 years, while increasing safety and security and addressing defects.

lightning arrestor connector—Advanced interconnect nuclear safety devices designed to limit voltage during lightning strikes and other extreme high-voltage, high-temperature environments.

limited life component—A weapon component or subsystem whose performance degrades with age and must be replaced.

manufacturing readiness level (MRL)—A means of communicating the degree to which a component or subsystem is ready to be produced. MRLs represent many attributes of a manufacturing system (e.g., people, manufacturing capability, facilities, conduct of operations, and tooling) and generally are low at the beginning of product development, with the highest of nine levels being steady-state production.

modernization—The changes to nuclear weapons or infrastructure due to aging, unavailability of replacement parts, or the need to enhance safety, security, and operational design features.

modification (Mod)—A modernization program that changes a weapon's operational capabilities. A Mod may enhance the margin against failure, increase safety, improve security, replace limited life components, and/or address identified defects and component obsolescence.

multilayered malware protection—Commercial software that guards against multiple threat vectors such as viruses, spyware, and Trojans. The software searches a hard disk or other media for known threat vectors and removes any that are found.

national security laboratory—Los Alamos National Laboratory, Sandia National Laboratories, or Lawrence Livermore National Laboratory.

national security system—Any telecommunications or information system operated by the U.S. Government, the function, operation, or use of which involves intelligence activities, cryptologic activities related to national security, command and control of military forces, equipment that is an integral part of a weapon or weapons system, or is critical to the direct fulfillment of military or intelligence missions. The term excludes any system used for routine administrative and business applications (including payroll, finance, logistics, and personnel management applications).

network—In relation to information technology and cybersecurity, a network is composed of a communications medium responsible for the transfer of information and all components attached to that medium.

network intrusion detection (NID)—An intrusion detection system inspects all inbound and outbound network activity and identifies suspicious patterns that may indicate an attempt to break in or compromise a system. That NID system (a) monitors all network traffic by inspecting and screening all inbound and outbound information technology network activity for patterns that may indicate an attempt to break in or compromise a system and (b) provides alerts based on predefined rules. These rules or signatures are updated as needed to reflect information learned from exploitation or attack attempts. When triggered, an NID system begins capturing network traffic related to the event in question, and the data are made available to security analysts. Notification is also sent to the Security Information and Event Management tool.

network monitoring—The use of a system that constantly monitors a computer network, providing vulnerability management and policy compliance tools; operating system, database, and application logs; and compilation of external threat data. A key focus is to monitor and manage user and service privileges, directory services, and other system configuration changes. Network monitoring also provides log auditing and review of incident responses.

NNSA Information Technology System—An information system that is owned and/or operated by NNSA or by contractors on behalf of NNSA to accomplish a Federal function. Regardless of whether NNSA Federal employees have access, this does not include information systems operated by management and operating contractors unless such systems' primary purpose is to accomplish a Federal function.

non-nuclear components—The parts or assemblies designed for use in nuclear weapons or in nuclear weapons training that do not contain special nuclear material; such components (e.g., radiation-hardened electronic circuits or arming, fuzing, and firing components) are not available commercially.

nuclear explosive package (NEP)—An assembly containing fissionable and/or fusionable materials, as well as the main charge high-explosive parts or propellants capable of producing a nuclear detonation.

nuclear forensics—The investigation of nuclear materials to find evidence for the source, trafficking, and enrichment of the material.

nuclear security enterprise—The physical infrastructure, technology, and workforce at the national security laboratories, the nuclear weapons production sites, and the Nevada National Security Site.

Nuclear Weapons Council—The joint DOE/DOD Council composed of senior officials from both departments who recommend the stockpile options and research priorities that shape national policies and budgets to develop, produce, surveil, and retire nuclear warheads and weapon delivery platforms and who consider the safety, security, and control issues for existing and proposed weapons programs.

nuclear weapons production site —The Kansas City National Security Campus, Pantex Plant, Y-12 National Security Complex, or Savannah River Site. Los Alamos National Laboratory and Sandia National Laboratories also perform some specific weapons production activities.

Other Program Money—Funding that is found outside of a life extension program (LEP) funding line (in other program lines), but is directly (uniquely) attributed to an LEP. Such funding would not be needed were it not for the LEP, although the activity or effort might still be done at some future point along a different timeline.

out-years—The years that follow the 5-year period of the Future Years Nuclear Security Program.

Phase 6.x Process—A time and organizational framework to manage the existing nuclear weapon systems that are undergoing evaluation and implementation of refurbishment options to extend the stockpile life or to enhance system capabilities. The *Phase 6.x Process* consists of sub-phases, which basically correspond to Phases 1 through 6 of the nuclear weapons lifecycle.

physical security—The application of physical or technical methods that protect personnel; prevent or detect unauthorized access to facilities, material, and documents; protect against espionage, sabotage, damage, and theft; and respond to any such acts that occur.

pit—The critical core component in the primary of a nuclear weapon that contains fissile material.

Predictive Capability Framework (PCF)—A framework that defines high-level research, development, test, and evaluation activities to be executed by Defense Programs. The PCF identifies the complex set of interlinked analytical, computational, and experimental activities needed for stockpile assessment, the evaluation of some surveillance data, and the coordination of related efforts.

primary—The first stage of a two-stage nuclear weapon.

programmatic infrastructure—Specialized experimental facilities, computers, diagnostic instruments, processes, and capabilities that allow the nuclear security enterprise to carry out research, testing, production, sustainment, and other direct programmatic activities to meet national security missions.

Protected Distribution Systems—Wireline or fiber-optic distribution systems used to transmit and protect unencrypted classified signal and data lines that exit secure areas and traverse through areas of lesser classification or security control.

quantification of margins and uncertainties—The methodology used in the post-nuclear-testing era to facilitate analysis and communicate confidence in assessing and certifying that stockpile weapons will perform safely, securely, and reliably. Scientific judgment of experts at the national security laboratories plays a crucial role in this determination, which is based on metrics that use experimental data, physical models, and numerical simulations.

quantum computing—The area of study focused on developing computer technology based on the principles of quantum-mechanical theory, which explains the nature and behavior of energy and matter on the atomic and subatomic level.

radiation case—A vessel that confines the radiation generated in a staged nuclear weapon.

reservoir—A vessel containing deuterium and tritium that permits its transfer as a gas in a nuclear weapon.

Retrofit Evaluation System Test—A test program conducted during retrofit of an NNSA weapon system on randomly selected, newly retrofitted weapons to determine the effect of the retrofit on the weapon system's reliability and to verify that the purpose of the retrofit is fully achieved. The program may consist of flight testing and/or laboratory testing.

Safeguards Transporter (SGT)—A highly specialized trailer designed to safeguard nuclear weapons and special nuclear materials while in transit.

secondary—The second stage of a two-stage nuclear weapon that provides additional energy release in the form of fusion and is activated by energy from the primary.

security—An integrated system of activities, systems, programs, facilities, and policies to protect classified matter, unclassified controlled information, nuclear materials, nuclear weapons, nuclear weapon components, and DOE's and its contractors' facilities, property, and equipment.

security area—A defined area containing safeguards and security interests that requires physical protection measures. The types of security areas used by DOE/NNSA include property protection areas, limited areas, exclusion areas, protected areas, material access areas, and functionally specialized security areas such as sensitive compartmented information facilities, classified computer facilities, and secure communications centers.

security system—The combination of personnel, equipment, hardware and software, structures, plans and procedures, etc., used to protect safeguards and security interests.

service life—The duration of time that a nuclear weapon is maintained in the stockpile from Phase 5/6.5 (First Production) to Phase 7 (Retirement, Dismantlement, and Disposition). The terms "stockpile life," "deployed life," and "useful life" are subsumed by service life.

significant finding investigation (SFI)—A formal investigation by a committee, chaired by an employee of a national security laboratory, to determine the cause and impact of a reported anomaly and to recommend corrective actions as appropriate.

special nuclear material (SNM)—Plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. The Nuclear Regulatory Commission defines three categories of quantities of SNM according to the risk and potential for its use in the creation of a fissile explosive. Category I is the category of the greatest quantity and associated risk; Category II is moderate; Category III is the lowest.

stockpile-to-target sequence—A document that defines the logistical and employment concepts and related physical environments involved in delivering a nuclear weapon from storage and assembly, testing it, transporting it, and delivering the weapon to a target.

subcritical experiment—An experiment specifically designed to obtain data on nuclear weapons for which less than a critical mass of fissionable material is present and, hence, no self-sustaining nuclear fission chain reaction can occur, consistent with the Comprehensive Nuclear Test-Ban Treaty.

supply chain risk management (SCRM)—The coordinated efforts of an organization to help identify, monitor, detect, and mitigate threats to supply chain continuity. Threats to the supply chain include cost volatility, material shortages, supplier financial issues and failures, and natural and manmade disasters. SCRM strategies and software help an organization foresee potential issues and adapt to both those risks and unforeseeable supply chain disruptions as quickly and efficiently as possible.

surety—The assurance that a nuclear weapon will operate safely, securely, and reliably if deliberately activated and that no accidents, incidents, or unauthorized detonations will occur. Factors contributing to that assurance include model validation for weapon performance based on experiments and simulations, material (e.g., military equipment and supplies), personnel, and execution of procedures.

surveillance—Activities that provide data for evaluation of the stockpile, giving confidence in the Nation's deterrent by demonstrating mission readiness and assessment of safety, security, and reliability standards. These activities may include laboratory and flight testing of systems, subsystems, and components (including those of weapons in the existing stockpile, newly produced weapons, or weapons being disassembled); inspection for unexpected wear or signs of material aging; and destructive or nondestructive testing.

sustainment—A program to modify and maintain a set of nuclear weapon systems.

technology maturation—Advancing laboratory-developed technology to the point at which it can be adopted and used by U.S. industry.

technology readiness level (TRL)—A measurement system to assess the maturity level of a particular technology that includes nine levels, where TRL 1 is the lowest (the associated scientific research is beginning) and TRL 9 is the highest (a technology has been proven through successful operation).

test readiness—The preparedness to conduct underground nuclear explosive testing if required to ensure the safety and effectiveness of the stockpile or if directed by the President for policy reasons.

threat information—Any information related to a threat that might help an organization protect itself against a threat or detect the activities of an actor. Major types of threat information include indicators; tactics, techniques, and procedures; security alerts; threat intelligence reports; and tool configurations.

tractor—A modified and armored vehicle to transport the Safeguards Transporter trailer.

tritium—A radioactive isotope of hydrogen whose nucleus contains two neutrons and one proton and is produced in nuclear reactors by the action of neutrons on lithium nuclei.

virtual desktop infrastructure—Software technology that separates the desktop environment and associated application software from the physical client device used to access it.

vulnerability scanning—The application of software that seeks out security flaws based on a database of known flaws, testing systems for the occurrence of these flaws, and generation of a report of the findings that can be used to tighten a networks security.

W76-1 Life Extension Program (LEP)—An LEP for the W76 submarine-launched ballistic missile warhead, delivered by a Navy Trident II.

W78—An intercontinental ballistic missile warhead, delivered by an Air Force Minute Man III LGM-30.

W80-4 Life Extension Program (LEP)—An LEP for the W80 warhead aboard a cruise missile, delivered by the Air Force B-52 bomber and future launch platforms.

W88—A submarine-launched ballistic missile warhead delivered by a Navy Trident II.

W88 Alt 370—An alteration of the W88 warhead to replace the arming, fuzing, and firing components and to refresh the conventional high explosive main charge.

warhead—The part of a missile, projectile, torpedo, rocket, or other munitions that contains either the nuclear or thermonuclear system intended to inflict damage.

wireless security (WISEC)—Security solution designed to test and evaluate the impact of mobile and fixed wireless communication devices used in or near classified and sensitive unclassified activity areas for the purpose of determining risks and countermeasures.

Appendix E
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Appendix F
Acronyms and Abbreviations

3D	three-dimensional
AF&F	arming, fuzing, and firing
Alt	alteration
AoA	Analysis of Alternatives
ASC	Advanced Simulation and Computing
ASIC	application-specific integrated circuit
ATS	Advanced Technology System
CCRI	Command Cyber Readiness Inspections
CD	Critical Decision
CHAMP	Cooling and Heating Asset Management Program
CHE	conventional high explosive
CMRR	Chemistry and Metallurgy Research Replacement
CoLOSSIS	Confined Large Optical Scintillator Screen and Imaging System
CSTART	Center for Security Technology, Analysis, Response, and Testing
CTA	common tester architecture
CUAS	Counter-Unmanned Aircraft System
DARHT	Dual-Axis Radiographic Hydrodynamic Test
DHS	Department of Homeland Security
DNS	Office of Defense Nuclear Security
DOD	Department of Defense
DOE	Department of Energy
DSW	Directed Stockpile Work
DUF_4	depleted uranium tetrafluoride
DUF_6	depleted uranium hexafluoride
ECFM	Exascale Computing Facility Modernization
ECSE	Enhanced Capabilities for Subcritical Experiments
EMETL	Enterprise Mission Essential Task List
EOS	equations of state
ESSPAP	Enterprise Safeguards and Security Planning and Analysis Program
FFRDC	Federally Funded Research and Development Center
FICAM	Federal Identity, Credential, and Access Management
FISMA	*Federal Information Security Management Act*
FY	Fiscal Year
FYNSP	Future Years Nuclear Security Program
GAO	Government Accountability Office

GTS	gas transfer system
HE	high explosives
HED	high energy density
HEU	highly enriched uranium
HOT SHOT	High Operational Tempo Sounding Rocket Flight Test
HPC	high performance computing
HVAC	heating, ventilation, and air conditioning
IARC	Information Assurance Response Center
ICE	independent cost estimate
ICF	Inertial Confinement Fusion Ignition and High Yield
IDC	integrated design code
IDS	Intrusion Detection Systems
IHE	insensitive high explosive
IT	information technology
IW	interoperable warhead
JASPER	Joint Actinide Shock Physics Experimental Research
JILS	Joint Integrated Lifecycle Surety
JODE	Joint Development Environment
JTA	joint test assembly
KCNSC	Kansas City National Security Campus
LANL	Los Alamos National Laboratory
LANSCE	Los Alamos Neutron Science Center
LEED	Leadership in Energy and Environmental Design
LEP	life extension program
LLC	limited life component
LLNL	Lawrence Livermore National Laboratory
LRSO	Long Range Stand Off
M&O	management and operating
MagLIF	magnetized liner inertial fusion
MAP	Master Asset Plan
MAR	material-at-risk
Mbar	megabar
MESA	Microsystems and Engineering Science Applications
MGT	Mobile Guardian Transporter
MicroFab	Microsystems Fabrication facility
Mod	modification
MRR	Material Recycle and Recovery
NDAA	*National Defense Authorization Act*
NEP	nuclear explosive package
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
OCIO	Office of the Chief Information Officer

OMB	Office of Management and Budget
Omega	Omega Laser Facility
PACS	Physical Access Controls
Pantex	Pantex Plant
PCF	Predictive Capability Framework
petaFLOPS	quadrillion floating point operations per second
PF-4	Plutonium Facility
PIDAS	Perimeter Intrusion Detection and Assessment System
PPI	Process Prove-In
QE	Qualification Evaluation
R&D	research and development
RAMP	Roof Asset Management Program
RDT&E	research, development, test, and evaluation
SAR	Selected Acquisition Report
SFI	significant finding investigation
SGT	Safeguards Transporter
SiFab	Silicon Fabrication facility
SMIP	Security Management Improvement Program
SNL	Sandia National Laboratories
SNM	special nuclear material
SRS	Savannah River Site
SSMP	Stockpile Stewardship and Management Plan
ST&E	science, technology, and engineering
STA	Secure Transportation Asset
STS	stockpile-to-target sequence
TA	Technical Area
TPBARs	tritium-producing burnable absorber rods
TRU	transuranic
U.S.	United States
U.S.C.	United States Code
U1a	U1a Complex
UAS	unmanned aircraft systems
UK	United Kingdom
USSTRATCOM	U.S. Strategic Command
WIPP	Waste Isolation Pilot Plant
Y-12	Y-12 National Security Complex
Z	Z pulsed power facility

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