U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

Fiscal Year 2018

Stockpile Stewardship and Management Plan

Report to Congress

November 2017

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

Message from the Administrator

The Department of Energy's National Nuclear Security Administration (NNSA) *Fiscal Year 2018 Stockpile Stewardship and Management Plan* (SSMP) describes NNSA's plans to ensure the safety, security, and effectiveness of the U.S. nuclear 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 mission to reduce the threats of nuclear proliferation and nuclear terrorism. In keeping with our commitment to transparency, updated versions of these reports are published each year.

The U.S. nuclear deterrent has been the cornerstone of the United States' strategy to keep the American people safe and secure for more than 70 years, as well as a significant contributor to global stability. NNSA, in partnership with the Department of Defense, ensures that the deterrent is modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st century threats and to reassure our allies and partners.

The uncertain global security environment reaffirms the need to maintain a credible nuclear deterrent. Russia is presently undertaking a wholesale modernization of its nuclear arsenal and enhancing the role of nuclear weapons in its security strategy. China is upgrading and expanding its strategic deterrent in pursuit of an "assured retaliation" capability against the United States. North Korea is developing the means to conduct nuclear attacks against U.S. allies in East Asia, Guam, and the American homeland. Each of these developments underscores the enduring salience of the U.S. nuclear stockpile to deter our adversaries, assure our allies and partners, and maintain strategic stability.

This year's SSMP describes the substantial level of activity being performed within NNSA and DOE's national laboratories and production plants to ensure the continued credibility of our nuclear deterrent. This includes three warhead life extension programs (LEPs) and one major warhead alteration (Alt). In particular, this report describes the path to complete production of W76-1 warheads by Fiscal Year (FY) 2019; deliver the first production unit of the B61-12 gravity bomb by FY 2020; deliver the first production unit of the W88 Alt 370 by FY 2020; and achieve a first production unit of the W80-4 warhead by FY 2025.

NNSA is also stepping up actions to repair and recapitalize its aging infrastructure, much of which dates to the Eisenhower era. These infrastructure investments are crucial to ensuring the long-term availability of strategic materials associated with nuclear weapons, including completion of the Uranium Processing Facility by 2025 and reaching the capacity to produce 50 to 80 War Reserve plutonium pits per year by 2030. Providing quality workspace to NNSA's workforce is also 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.

Adequate resources are absolutely essential to execute all of these vital missions and achieve the President's objectives as described in the National Security Presidential Memorandum, "Rebuilding the U.S. Armed Forces." The annual budget request for NNSA's Weapons Activities has increased for all but one of the past 8 years, resulting in a total increase of approximately 60 percent since 2010. If adopted by Congress, the FY 2018 budget request will increase funding by $996 million (about 10.8 percent) from the FY 2017 request. A significant portion of the increase would fund the research for multiple LEPs, support the programs in Directed Stockpile Work, and modernize the physical infrastructure of the nuclear security enterprise. As described in this report, significantly increased investment will be needed in FY 2019 and beyond.

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

The Honorable Thad Cochran
Chairman, Senate Committee on Appropriations

The Honorable Patrick Leahy
Vice Chairman, Senate Committee on Appropriations

The Honorable John McCain
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 William "Mac" Thornberry
Chairman, House Committee on Armed Services

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

The Honorable Michael 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,

Frank G. Klotz

Frank G. Klotz

This page left blank intentionally

Message from the Secretary

National security is a fundamental mission of the Department of Energy (DOE). While there are significant security implications in the Department's wide-ranging energy portfolio, it also performs a range of explicitly defense-oriented work that directly contributes to the safety and security of the American people. The stewardship of the U.S. nuclear stockpile, chiefly performed through the work of DOE's National Nuclear Security Administration (NNSA), accounts for more than a quarter of the Department's budget. Other activities include preventing the spread of nuclear weapons; countering nuclear terrorism; responding to nuclear and radiological incidents; and designing, developing, and deploying nuclear propulsion systems for the United States Navy.

The work of the science-based Stockpile Stewardship Program has allowed the Departments of Energy and Defense to certify to the President for the 21st consecutive year that the U.S. nuclear weapons stockpile remains safe, secure, and reliable. State-of-the-art diagnostic tools, high performance computing platforms, and – most importantly – NNSA's world-class scientists, engineers, and technicians make this impressive scientific achievement possible each year. The knowledge gained from investments in this program provides confidence in the nuclear weapons stockpile.

Stockpile stewardship and management require a resilient infrastructure that is appropriately tailored to meet the challenges of a dynamic global security environment and unanticipated technical challenges. As described in this report, NNSA's current research, development, and production facilities require major investments to continue to meet the Nation's evolving nuclear security requirements; keep the nuclear deterrent safe, secure, and effective; and enhance worker and public safety. More than half of NNSA's facilities are over 40 years old and the current and increasing demands of four simultaneous major modernization programs have pushed our facilities to their limit.

The recapitalization and modernization efforts laid out here will require sustained and predictable funding over many years. Investments in infrastructure, science, and people have not kept pace with the needs of an aging enterprise and its growing workload. As described in this report and the associated classified Annex, significant investments are necessary in Fiscal Year 2019 to ramp up the W80-4 life extension program and begin major recapitalization efforts to support plutonium pit production, trusted microsystems fabrication, and strategic materials sustainment.

In one of his very first decisions, the President directed the Department of Defense, along with DOE and other national security agencies, to conduct a 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. DOE remains committed to protecting and modernizing the Nation's nuclear stockpile and stands ready to implement the guidance resulting from the Nuclear Posture Review.

Sincerely,

Rick Perry

Rick Perry

This page left blank intentionally

Executive Summary

This *Fiscal Year 2018 Stockpile Stewardship and Management Plan* (SSMP), including its classified Annex, is the Department of Energy's (DOE) National Nuclear Security Administration's (NNSA) strategic program for maintaining the safety, security, and effectiveness of the nuclear stockpile over the next 25 years. The SSMP is published annually either in full report form or as a summary, in response to statutory requirements, to support the President's Budget request to Congress for Weapons Activities. The Fiscal Year (FY) 2018 SSMP is a full report. This annual plan provides a single, integrated picture of current and future nuclear security enterprise activities 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 FY 2017–2042.

To achieve mission success, highlights of near-term and out-year objectives include:

- Advance the innovative experimental platforms, diagnostic equipment, and computational capabilities necessary 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.
- Deliver the first production unit of the W88 Alteration (Alt) 370 (with refresh of the conventional high explosive) by FY 2020.
- Achieve a first production unit of the W80-4 by FY 2025.
- Produce not less than 10 War Reserve pits in 2024, not less than 20 War Reserve pits in 2025, and not less than 30 War Reserve pits in 2026.
- Create a modern, responsive nuclear infrastructure that includes the capability and capacity to produce 50 to 80 pits per year by 2030.
- Cease enriched uranium programmatic operations in Building 9212 at the Y-12 National Security Complex and deliver the Uranium Processing Facility for no more than $6.5 billion by 2025.
- Implement the "3+2 Strategy" for a smaller stockpile with upgraded safety and security and interoperable nuclear explosive packages for the missile warheads.
- Achieve exascale computing and deliver an exascale machine by the early 2020s.
- Ensure a trusted supply of strategic radiation-hardened microsystems by 2025.
- Develop an operational enhanced capability for subcritical experiments by the mid 2020s.

While executing the current plan, DOE/NNSA had an outstanding FY 2016. 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.

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 scope, budgets, and schedules of the LEPs, infrastructure modernization, and the nuclear delivery systems of the Department of Defense have been fully integrated and coordinated.

Life Extension Program Highlights include:

- The Air Force and NNSA completed the first development flight test of the B61-12 guided nuclear bomb at the Tonopah Test Range in 2017. NNSA formally authorized the production engineering phase of the B61-12 LEP in 2016. This LEP remains on track for a first production unit in FY 2020. When the LEP is finished, it will add at least 20 years to the life of the system and will consolidate four versions of the B61 into a single variant.
- NNSA completed the fourth qualification flight test for the W88 Alt 370 (with conventional high explosive refresh), along with a critical test of the arming, fuzing, and firing assembly in 2016. The program remains on schedule for delivery of the first production unit in FY 2020.
- In 2017 NNSA passed the 80 percent mark in production of W76-1s to be delivered to the Navy for the submarine-launched ballistic missile fleet. These warheads will add an additional 30 years of service life.
- NNSA made significant progress on the W80-4 LEP that supports the Long Range Stand Off program—the Air Force's approach to replacing the current air-launched cruise missile. The first production unit is on track for FY 2025.

NNSA also addressed long-term infrastructure challenges and broke ground on construction projects that will provide high quality workspace and serve the nuclear security enterprise for decades to come. Finally, NNSA used its experimental facilities and high performance computing capabilities at the three national security laboratories and other sites to obtain key data and results to support science-based stockpile stewardship priorities. These facilities include the National Ignition Facility (NIF), the Dual Axis Radiographic Hydrodynamic Test (DARHT), the Los Alamos Neutron Science Center (LANSCE), the Joint Actinide Shock Physics Experimental Research (JASPER) gas gun, the Z pulsed power facility, and the Microsystems and Engineering Sciences Applications complex.

Research and Experimental Highlights include:

- Recently NNSA performed a record-breaking experimental shot at NIF, located at Lawrence Livermore National Laboratory (LLNL). The experiment created a fusion reaction that produced 45 kilojoules of energy—not ignition but the highest fusion yield from any experiment at NIF and nearly double the previous record. The experiment also produced the highest neutron yield in the facility's history and indicates directions that may ultimately lead to achieving fusion ignition. In September 2016, NIF performed its 400th experiment, thereby meeting the FY 2016 goal several weeks early and leading to a record 417 total shots for the year. This record number represents a more than 110 percent increase from FY 2014 to FY 2016, allowing a greater number of high energy density and inertial confinement fusion experiments to support the Stockpile Stewardship Program, as well as shots that support other national security applications and discovery science.
- NNSA completed seven integrated hydrodynamic experiments during calendar year 2017 at the Los Alamos National Laboratory (LANL) DARHT facility, including three from February through April, 2017. The experiments supported the B61-12 LEP, Annual Assessment for the existing stockpile, stockpile options, and global security.
- NNSA executed an experiment in FY 2016 at Sandia National Laboratories (SNL) Z pulsed power facility, with collaboration from LANL, to support certification of the B61 LEP. The resulting data

will be used to characterize the material property differences between new and aged plutonium. A second Z experiment, also conducted in collaboration with LANL, used a recently developed shock ramp platform to provide plutonium data at higher pressures than were previously accessible with this device.

- Using JASPER at the Nevada National Security Site, NNSA completed 11 experiments in FY 2016, including 2 to validate projectile velocity and gun performance, 4 to test the integration of the new seven-channel pyrometer, and 5 performed on encapsulated alpha plutonium targets. Data from JASPER experiments are used to determine material equation-of-state properties and to validate computer models of material response for weapons applications.
- NNSA's Microsystems and Engineering Sciences Applications complexat SNL met all FY 2016 nuclear weapons mission deliverables on schedule and under budget. It also received three R&D 100 Awards for the design and fabrication of sensors for ultra-fast x-ray imagers.

High Performance Computing

NNSA completed installation of the Trinity high performance computing system at LANL. Trinity, one of the most advanced computers in the world, initially has at least seven times better performance than LANL's former supercomputer (Cielo). When fully built out, Trinity will have a speed of 41 petaFLOPS[1] to ensure robust modeling and simulation capabilities.

SSMP Structure

To ensure some of the highest demand information is easier to find, this SSMP includes *Information at a Glance* on page xi. The overview in Chapter 1 gives background information useful for understanding the entire document. The remainder of the SSMP is organized programmatically and functionally. The appendices include additional information to aid in understanding the material covered, along with detailed information about each of NNSA's national security laboratories, nuclear weapons production facilities, and the Nevada National Security Site.

NNSA's current program and its achievements are possible because of the specialized, unique capabilities of the nuclear security enterprise and the efforts of the extraordinary people who ensure the success of NNSA's enduring missions. Those missions include conducting world-class science, technology, and engineering; modernizing the physical infrastructure; and effectively managing the operations. These crosscutting missions of the nuclear security enterprise are key components of the nuclear deterrent. Additional information about NNSA's achievements in stockpile stewardship and management and its future plans to enable the nuclear deterrent are included in the chapters that follow.

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

This page left blank intentionally

Information at a Glance

This page left blank intentionally

Fiscal Year 2018 Stockpile Stewardship and Management Plan
Table of Contents

This page left blank intentionally

Legislative Language

Title 50 of United States Code Section 2523 (50 U.S. Code § 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, NNSA has submitted reports on the plan to Congress annually since 1998, with the exception of 2012.[2] 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 2018 Stockpile Stewardship and Management Plan* (SSMP) is a full report 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 has been prepared. That Annex contains supporting details concerning the U.S. nuclear stockpile and stockpile management.

[2] In 2012, a *Fiscal Year 2013 Stockpile Stewardship and Management Plan* was not submitted to Congress because analytic work conducted by the Department of Defense and NNSA to evaluate the out-year needs for nuclear modernization activities across the nuclear security enterprise was ongoing and not yet finalized.

Chapter 1
Overview

The Department of Energy's National Nuclear Security Administration (DOE/NNSA) is tasked with carrying out DOE's national security responsibilities. That mission and authority is drawn from the *Atomic Energy Act* (42 United States Code [U.S. Code] § 2011 *et seq.*) and, more specifically, the *National Nuclear Security Administration Act* (50 U.S. Code § 2401 *et seq.*), which establishes DOE/NNSA's core mission pillars of 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 (**Figure 1–1**).[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 advancing world-class science, technology, and engineering (ST&E); support for the people and modernization of the infrastructure that make up the DOE/NNSA nuclear security enterprise; and maintenance of a management culture that operates a safe and secure enterprise in an efficient manner.[2]

These mission pillars and cross-cutting capabilities are realized within the nuclear security enterprise, including the national security laboratories, the nuclear weapon production facilities, the Nevada National

[1] DOE Order 452.3 addresses the prioritization among these pillars.
[2] Additional details are available in the *DOE/NNSA Enterprise Strategic Vision*, August 2015.

Security Site, and the larger DOE national laboratory system. The Nuclear Weapons Stockpile mission pillar can be further broken down into Weapons Activities mission areas and capabilities (**Figure 1–2**).

Figure 1–2. Weapons Activities mission areas

Achieving success in the Weapons Activities' mission areas requires unique capabilities to maintain the stockpile while ensuring the ability to adapt and respond to a dynamic security environment and to geopolitical and technological surprises. Capabilities that address critical functions of weapons activities are shown in **Figure 1–3**. Each of these capabilities contributes to the nuclear security enterprise and should not be viewed in isolation, as each capability is complementary and supports multiple pillars. Continued investment in these capabilities is necessary to sustain and modernize nuclear weapons, improve the understanding of nuclear weapons performance, maintain confidence in the aging and evolving stockpile, and ensure that the nuclear security enterprise remains responsive. These capabilities are resource constrained, but their achievement occurs at appropriate levels as defined by both the Nuclear Weapons Council and the interagency process that weighs and prioritizes missions and resources. Chapter 8 contains the current resource prioritizations. Definitions for each of these capabilities can be found in Appendix B, "Weapons Activities Capabilities," while information on the specialized capabilities of each of the seven management and operating (M&O) partners can be found in Appendix E, "Workforce and Site-Specific Information."

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

Crosscutting capabilities: science, technology, and engineering; people, equipment, and infrastructure; and management and operations

Figure 1–3. Weapons activities capabilities

This *Fiscal Year 2018 Stockpile Stewardship and Management Plan* (SSMP) is NNSA's 25-year strategic program of record and is developed to be fully consistent with the Nuclear Weapons Council's strategic plan for fiscal year (FY) 2017–2042. The annual SSMP has two primary purposes. First, the SSMP documents NNSA's plans to maintain and extend the life of the nuclear stockpile, enhance the understanding of internal nuclear weapons function through science-based stockpile stewardship, modernize the supporting infrastructure, and sustain DOE/NNSA's highly skilled workforce. Second, the SSMP provides NNSA's formal response to multiple statutory reporting requirements, a full listing of which can be found in Appendix A, "Requirements Mapping." The FY 2018 SSMP includes detailed budget information for the FY 2018 Future Years Nuclear Security Program (FYNSP), along with life extension program (LEP) schedules, construction resource planning lists, and estimates through FY 2042 as a means to describe the long-term NNSA strategy for ensuring the Nation's nuclear deterrent to Congress and to the Department of Defense (DOD).[3]

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

1.1 Policy Framework Summary

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

NNSA is also directed by Presidential and DOE policy documents that provide additional direction on accomplishing the DOE/NNSA nuclear weapons mission. The 2017 National Security Presidential Memorandum on Rebuilding the U.S. Armed Forces (NSPM-1) directs a "new Nuclear Posture Review to ensure that the U.S. nuclear deterrent is modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st-century threats and reassure our allies."[4] The policy laid out in NSPM-1 is intended "to pursue peace through strength" and "give the President and the Secretary [of Defense] maximum strategic flexibility."

Until officially superseded, several other important policy documents serve as partial guidance for the FY 2018 SSMP, to include: the *Nuclear Posture Review Report* (DOD 2010), the 2013 Presidential Policy Directive on the Nuclear Weapons Employment Strategy of the United States (PPD 24), and the *National Security Strategy* (2015). DOE/NNSA's program of record for maintaining the nuclear weapons stockpile will be updated as these documents are replaced by finalized policy documents over the coming months and years.

1.2 Summary of Strategic Environment for Nuclear Security

The challenges of today's global security environment are compounded by the proliferation of advanced technologies and the destabilizing behavior of other nations, some of which are investing in long-term military modernization programs, including capabilities that pose a threat to the United States and its allies. While the United States has significantly reduced its nuclear weapons stockpile since the end of the Cold War, other countries have not reduced stockpiles and thousands of nuclear weapons and large amounts of weapons-usable nuclear materials remain globally. Countries such as Russia and China are modernizing, expanding, and diversifying their nuclear arsenals. North Korea has developed a nuclear program, and other foreign state and non-state actors continue to pursue nuclear and radiological capabilities. This environment requires that the United States maintain a credible deterrent appropriate for responding to advanced foreign military competitors and regional states willing to acquire and use weapons of mass destruction. The United States nuclear triad, which includes capabilities *via* sea, land, or air, provides a robust deterrent capability for this ever-changing security environment. The nuclear triad provides independently viable weapon systems and platforms that present adversaries with a complex, multi-faceted challenge. The triad also simultaneously hedges against a technological surprise in any one leg of the triad. **Figure 1–4** shows the U.S. nuclear weapons and delivery platforms.

---

[4] 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.

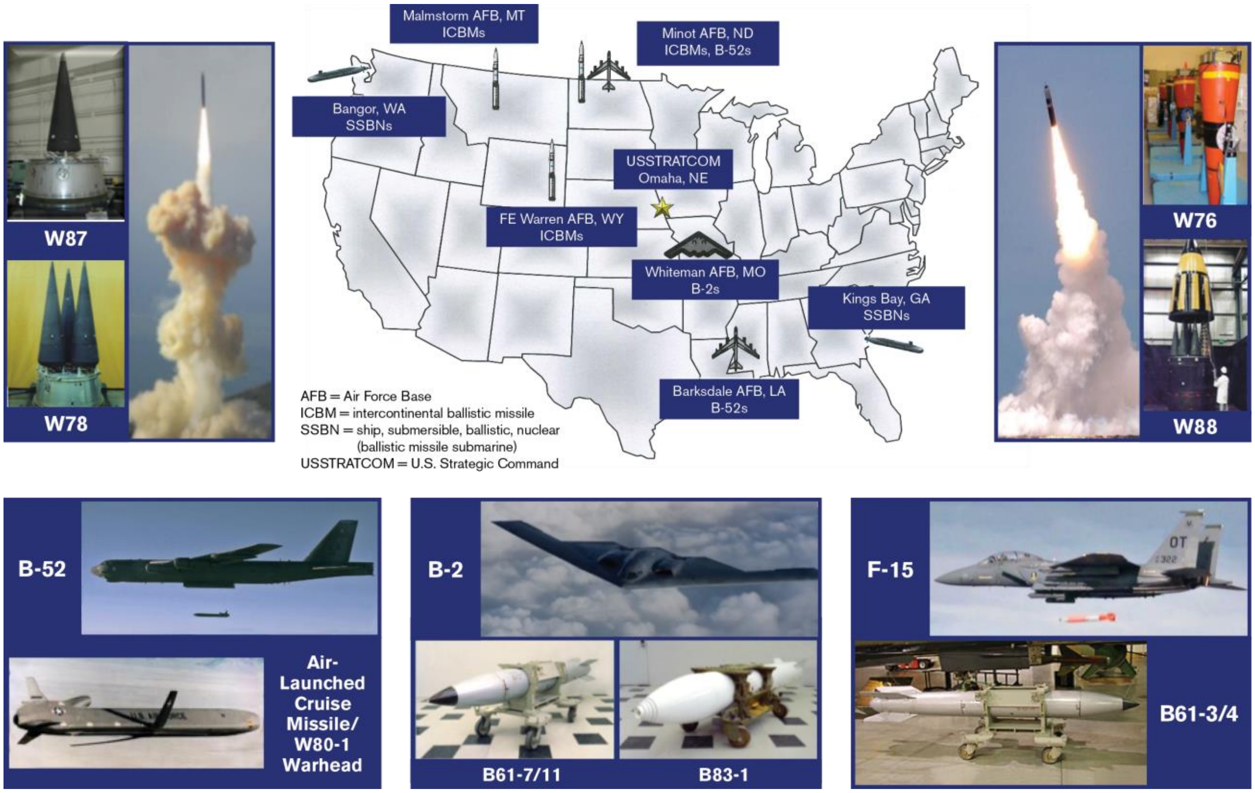


Figure 1–4. U.S. nuclear weapons and delivery systems

The U.S. nuclear deterrent maintains strategic stability across the globe and benefits nonproliferation goals by removing incentives for other nations to develop indigenous nuclear capabilities. For as long as this deterrent is necessary, NNSA will continue to ensure that the stockpile remains safe, secure, and effective.

1.3 The Nuclear Security Enterprise

DOE/NNSA's nuclear security enterprise 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 facilities, and the Nevada National Security Site (see **Figure 1–5**). The highly trained workforce consists of approximately 39,000 Federal civilian employees, contractor employees at NNSA's M&O partners, and assigned members of the military.[5] (Chapter 7, "Sustaining the Workforce," Appendix D, "Federal Workforce," and Appendix E, "Workforce and Site-Specific Information," include a more detailed description of the workforce and each of the M&O sites). NNSA Headquarters implements the overall nuclear weapons strategy in collaboration with its M&O partners and oversees and coordinates activities to ensure these are accomplished in an efficient, fiscally responsible manner.

[5] These numbers do not include Naval Reactors or the Office of Secure Transportation.

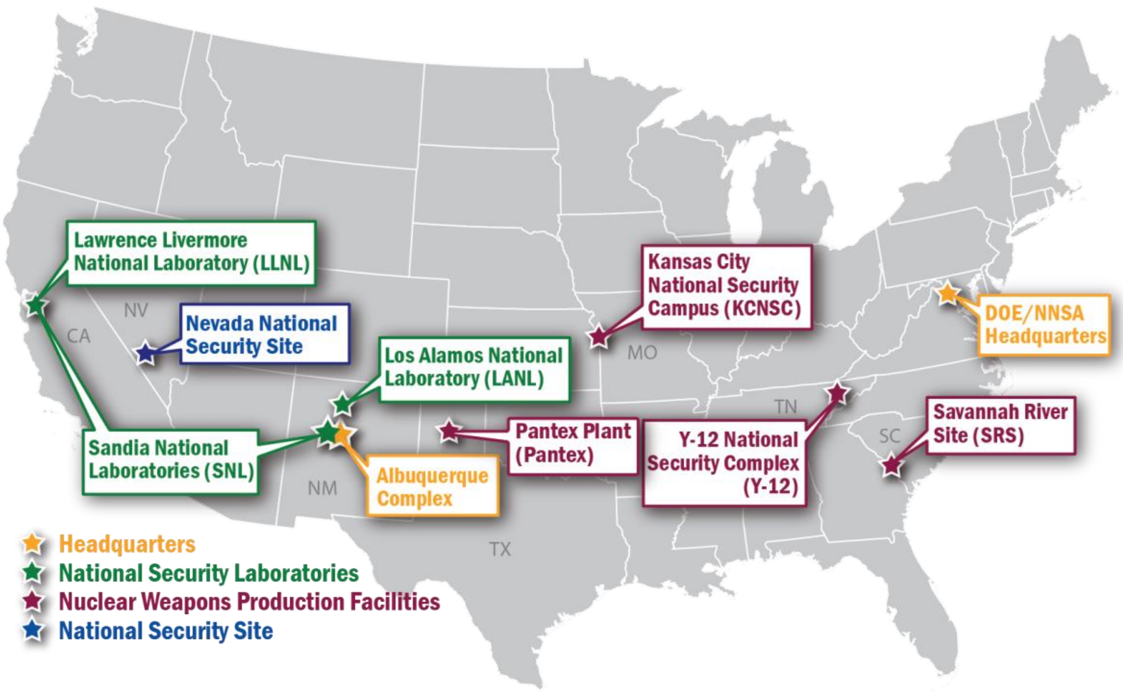


Figure 1–5. The nuclear security enterprise

Information is available in other chapters about other functions funded by the Weapons Activities account. See Chapter 4, "Physical Infrastructure," Chapter 5, "Secure Transportation Asset," and Chapter 6, "Physical and Cyber Security."

1.3.1 National Security Laboratories

The primary mission of DOE/NNSA's 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); they engage in long-term research, development, test, and evaluation (RDT&E) activities for respective primary nuclear weapon missions and also apply science, engineering, and technology to solve other national challenges. Other DOE national laboratories also support the Weapons Activities and Defense Nuclear Nonproliferation programs.[6]

The three national security laboratories are 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.[7] All three laboratories support nuclear counterterrorism and counterproliferation.

[6] Federally Funded Research and Development Centers (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. Often government-owned and contractor-operated, FFRDCs are characterized by their commitment to the public interest, objectivity, independence, and long-term focus.

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

Lawrence Livermore National Laboratory. LLNL is one of two national security laboratories that design nuclear components of weapons. Its mission is to develop and sustain design, simulation, modeling, and experimental capabilities and competencies to ensure stockpile confidence without nuclear testing. LLNL is responsible for nuclear design activities for the B83, W80, and W87 legacy systems and for the IW1 and the W80-4 cruise missile warhead LEPs. Other LLNL core capabilities include high performance computing (HPC), high energy density (HED) physics, plutonium research and development (R&D), hydrodynamic and weapons engineering environmental tests, advanced manufacturing and materials science, tritium target development and fabrication, and high explosives (HE) R&D.

Lawrence Livermore National Laboratory

Livermore, CA

- Nuclear design/physics lab
- High explosives research and development Center of Excellence
- Design agency for the W80, W87, and B83

Los Alamos National Laboratory. LANL is the other national security laboratory that designs the nuclear components of weapons. Its mission is to develop and sustain design, simulation, modeling, and experimental capabilities and competencies to ensure stockpile confidence without nuclear testing. LANL is responsible for the nuclear design and engineering of the B61, W76, W78, and W88 legacy systems, as well as for the W76-1 and B61-12 LEPs, and the W88 Alteration (Alt) 370. LANL also provides plutonium operations for R&D and pit manufacturing capabilities within the nuclear security enterprise. LANL's other core missions include advanced radiography, tritium and HE R&D; detonator, radioisotope thermoelectric generator power supply, and other non-nuclear component production and testing; and special nuclear material (SNM) accountability, storage, protection, handling, and disposition.

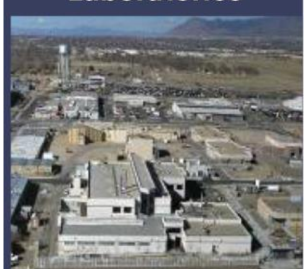
Los Alamos National Laboratory

Los Alamos, NM

- Nuclear design/physics lab
- Pit, radioisotope thermoelectric generators, and detonator production
- Plutonium Center of Excellence
- Design agency for the B61, W76, W78, and W88

Sandia National Laboratories. SNL is the national security laboratory responsible for systems engineering and integration of nuclear weapons and for designing, developing, qualifying, sustaining, and retiring the non-nuclear components of nuclear weapons, which correspond to the vast bulk of the identified components. SNL's other core missions include neutron generators, radiation-hardened microelectronics, and other non-nuclear component production as well as engineering, design, and technical systems integration for the NNSA Office of Secure Transportation.

Sandia National Laboratories



Albuquerque, NM

- Warhead system engineering and integration
- Design, development, and qualification of non-nuclear components
- Production of non-nuclear components (neutron generators, microelectronics, thermal battery back-up, and other trusted specialty components)
- Development and application of science and technology to solve other national security challenges

1.3.2 Nuclear Weapons Production Facilities

The four nuclear weapons production facilities conduct a range of stockpile management activities.[8] The Kansas City National Security Campus (KCNSC) in Kansas City, Missouri, produces non-nuclear components. The Pantex Plant (Pantex) in Amarillo, Texas, manufactures and tests HE components and assembles, 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 (SRS) in Aiken, South Carolina, extracts, recycles, and loads tritium into gas transfer systems (GTSs). In addition, the nuclear weapons production facilities process uranium and plutonium to meet DOE/NNSA's nonproliferation goals and counterterrorism activities.

Kansas City National Security Campus. KCNSC is the main site for developing manufacturing processes and producing non-nuclear weapon components. It manufactures and procures many of NNSA's most intricate and technically demanding components, including radar systems, mechanisms, programmers, reservoirs and valves for GTSs, joint test assemblies, engineered materials, and mechanical cases. These components make up about 85 percent of the elements that constitute a nuclear weapon.

Pantex Plant. Pantex manufactures and tests HE components; assembles, disassembles, refurbishes, repairs, maintains, and surveils stockpile weapons and components; fabricates joint test assemblies and performs postmortems; assembles and disassembles test beds; conducts interim staging and storage of components from dismantled weapons; and performs pit requalification, reuse, surveillance, and packaging.

Savannah River Site. SRS is NNSA's Tritium Center of Excellence—the primary location for NNSA's tritium operations. The tritium facilities use unique separation and extraction systems, developed by the Savannah River National Laboratory, to supply the radioactive hydrogen gas for nuclear weapons. That activity, which is an integral part of the Nation's nuclear defense, has been central to the SRS mission for more than 60 years. SRS's primary mission activities include extracting tritium from irradiated target rods, separating and recycling the gas from field returns, managing the tritium inventory for the stockpile, loading tritium and deuterium into the GTSs, performing surveillance of GTSs to support stockpile certification, and recovering helium-3.

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

Y-12 National Security Complex. Y-12 is the Uranium Center of Excellence for the nuclear security enterprise. Y-12 manufactures uranium components for nuclear weapons, cases, and other weapons components and evaluates and tests these components for surveillance purposes. Y-12 is also the main storage facility for Category I/II quantities of HEU; conducts dismantlement, storage, and disposition of HEU; and supplies HEU for naval reactors.

1.3.3 Nevada National Security Site

The Nevada National Security Site provides facilities, infrastructure, and personnel to the national security laboratories to conduct unique nuclear and non-nuclear experiments essential to maintaining the stockpile. It is the primary location where experiments with radiological 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 SNM. Other missions include developing and deploying state-of-the-art diagnostics and instruments, analyzing data, storing programmatic materials, conducting criticality experiments, and supporting nuclear counterterrorism and counterproliferation activities.

1.4 Introduction to the Nuclear Weapons Stockpile

The size and composition of the nuclear stockpile has evolved as a consequence of the global security environment and the needs of U.S. national security. As of 1967, the stockpile peaked at 31,255 weapons; by the end of 2016, the stockpile consisted of 4,018 weapons—the smallest since the Eisenhower Administration. In accordance with New START (New Strategic Arms Reduction Treaty) between the United States and Russia, which entered into force on February 5, 2011, the operationally deployed stockpile will be reduced even further.

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 condition, perform routine maintenance to ensure weapon operability, and extend lifetimes.

The current stockpile consists of active weapons, which are maintained to meet military requirements, and inactive weapons, which augment or replace warheads in the active stockpile as necessary. Retired weapons are not included in the count of stockpile weapons. The evolution in the size and age of the nuclear weapons stockpile is illustrated in **Figure 1–6**. **Table 1–1** reflects the major characteristics of the Nation's current stockpile, which is composed of two types of submarine-launched ballistic missile (SLBM) warheads, two types of intercontinental ballistic missile (ICBM) warheads, several types of bombs, and a cruise missile warhead delivered by aircraft.

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

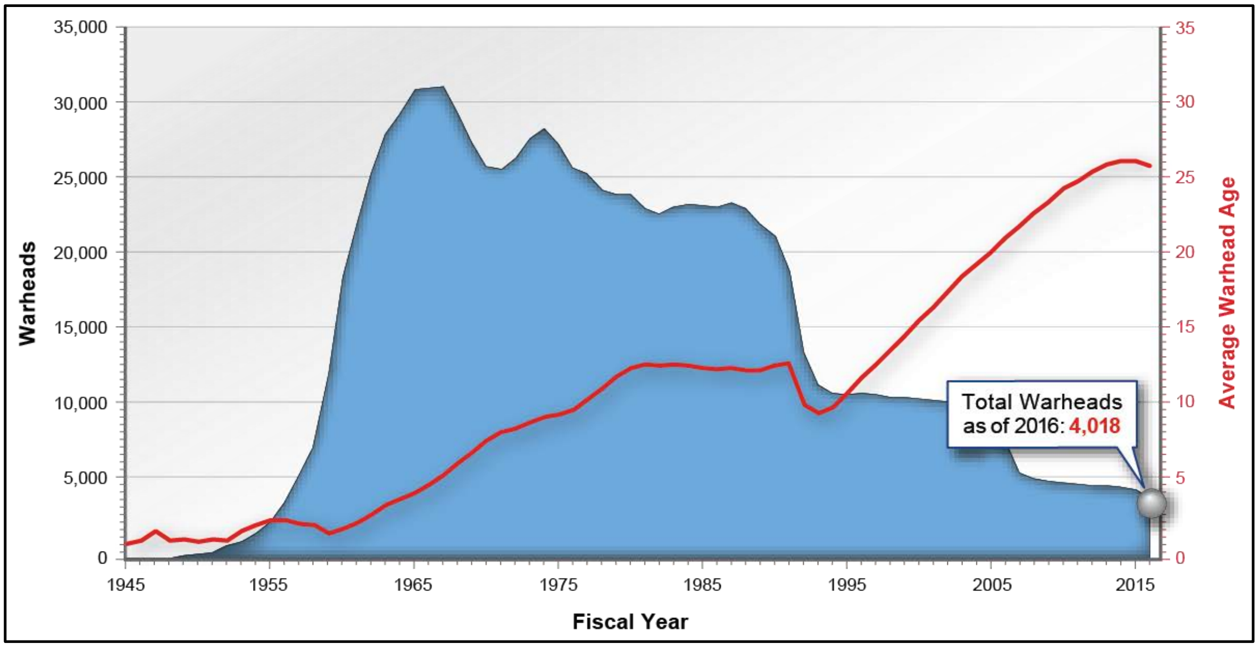


Figure 1–6. Size and age of the U.S. nuclear weapons stockpile, 1945–2016

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

Warheads—Strategic Ballistic Missile Platforms					
Type [a]	***Description***	***Delivery System***	***Laboratories***	***Mission***	***Military***
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					
B61-3/4/10	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 DOD implement the Nation's objectives to maintain strategic stability with other major nuclear powers, deter potential adversaries, and reassure allies and partners as to 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 in the near and long term.

The major strategies for sustaining and maintaining the stockpile are as follows.

- 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 and incorporating new knowledge into models and advanced performance computing.
- Address aging infrastructure and equipment obsolescence by improving the processes to plan and prioritize investments. DOE/NNSA have partnered with the eight M&O sites to make additional facilities and infrastructure investments, target reduction of deferred maintenance, and designate funds to decontaminate and remove excess facilities.
- Augment the Stockpile Stewardship and Stockpile Management Programs with an effective Stockpile Responsiveness Program to provide a greater breadth of opportunities to exercise key capabilities and skills. Exercising these capabilities also provides a mechanism to preserve and transfer knowledge across the workforce.

Major Goals of Weapons Activities

- *Complete W76-1 production by 2019.*
- *Cease programmatic operations at the Chemistry and Metallurgy Research facility at LANL.*
- *Complete B61-12 first production unit by March 2020.*
- *Complete W88 Alteration 370 first production unit (with refreshed conventional high explosive) by 2020.*
- *Complete W80-4 first production unit by 2025.*
- *Demonstrate the capability and capacity to produce 50 to 80 pits per year by 2030.*
- *Cease enriched uranium programmatic operations in Building 9212 at Y-12 by 2025.*
- *Provide experimental and computational capabilities to support assessment and certification of the stockpile.*
- *Enhance the predictive modeling capability to certify and assess via experimental data and implementation of advanced scientific tools.*

Additional activities to sustain and maintain the stockpile are as follows.

- To assess the potential for advanced manufacturing, 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 as well as greater in-house production of nuclear weapon components.
- To better assure supply chain protection and viability, NNSA has implemented several initiatives in the Nuclear Enterprise Assurance (NEA) program to address threats to critical products and processes. The program will focus on restricting information; enhancing and protecting 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.

- NNSA and DOE are also investing in exascale computing to advance the timeframe over which these capabilities can be applied to stockpile stewardship and ensure that the computing needs of the nuclear security enterprise will be addressed by 2021 rather than 2025.

1.6 Partnership with the Department of Defense

NNSA and DOD work collaboratively to maintain and modernize the stockpile and delivery systems. 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 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. Code § 179 to facilitate cooperation and coordination, reach consensus, and establish priorities between the two Departments in fulfilling dual-agency responsibilities for stockpile management. The Council is also the focal point for interagency activities to maintain the U.S. nuclear weapons stockpile.

1.6.1 3+2 Stockpile Strategy

The 3+2 Strategy preserves confidence in the stockpile's operational reliability and effectiveness, while mitigating risk and uncertainty.

The Nuclear Weapons Council's strategic plan for FY 2017–2042 supports the 3+2 Strategy for the stockpile, a strategy established formally in 2013. Specifically, the 3+2 Strategy aligns weapon system modernization plans with delivery system and platform schedules, and outlines investments for recapitalizing the nuclear security enterprise infrastructure. The strategy meets current policy objectives that will be adjusted with the upcoming Nuclear Posture Review. The 3+2 Strategy underlies the NNSA FY 2018 program of record in this report and includes the following.

- Three types of ballistic missile interoperable nuclear explosive packages (NEPs) with adaptable non-nuclear components. These systems are the "3" in the "3+2" Strategy. Each of the three types will be deployed on both Air Force and Navy delivery systems, with the aeroshells being service-specific. These ballistic missile warheads are referred to as interoperable warheads (IWs). Full implementation of the 3+2 Strategy will extend beyond 2060.
- Two air-delivered systems, the B61-12 gravity bomb and the long range stand off (LRSO) cruise missile, which will include the W80-4 warhead. These systems represent the "2" in the "3+2" Strategy.

Over time, as each of the 11 warhead or bomb variants within the deployed warhead families enters an LEP, the 3+2 Strategy would transition the stockpile as shown in **Figure 1–7**.

U.S. nuclear weapon triad

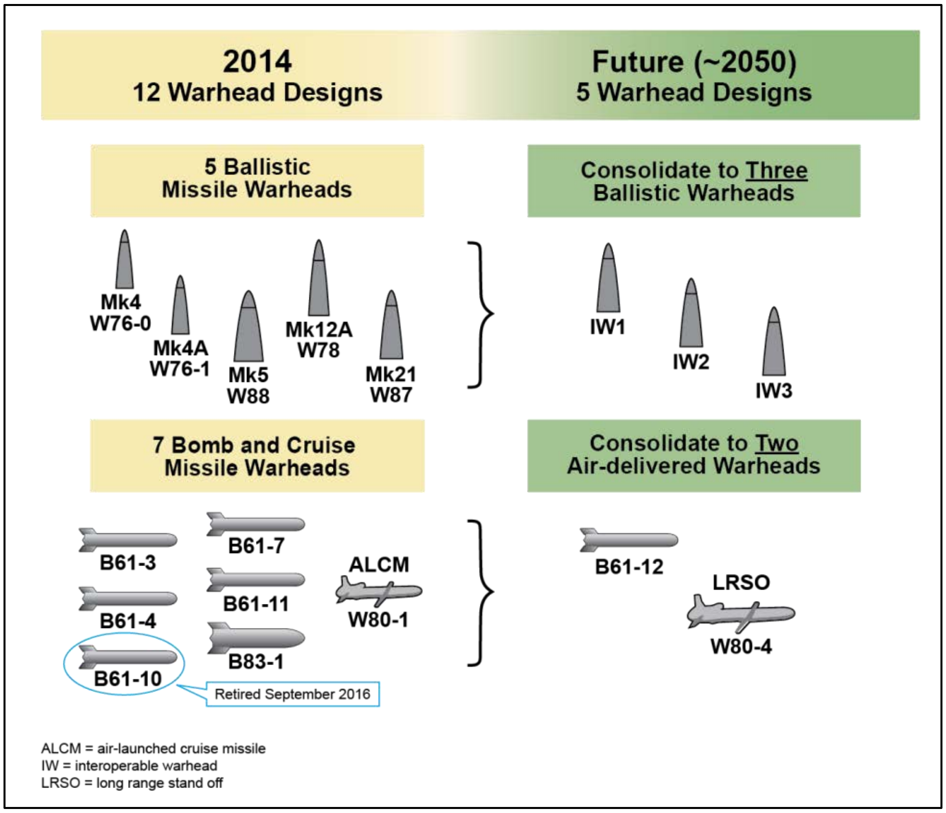


Figure 1–7. The 3+2 Strategy

1.6.2 Implementing the 3+2 Strategy

Implementation of the 3+2 Strategy will take 30 or more years, beginning with the B61-12 LEP. The B61-12 LEP, in the first year of Production Engineering, is critical to modernize this gravity weapon and ensure sustainment of the Nation's strategic and non-strategic air-delivered deterrent capability. The B61-12 LEP will refurbish nuclear and non-nuclear components and allow the replacement of four B61 strategic and non-strategic weapon designs and the retirement of the B83—the last megaton-class weapon in America's arsenal.

An F-15E drops a B61-12 test unit during a development flight test.

The W80-4 LEP will modernize the cruise missile warhead to correspond with DOD's replacement of the air-launched cruise missile (ALCM) by a new LRSO missile. The ALCM, first launched in 1982, has far exceeded its planned service life and is being sustained by a series of service LEPs. The W80-4 warhead will be a life-extended version of the W80-1, with additional surety features.

Sandia National Laboratories performing electromagnetic qualification measurements on the air-launched cruise missile.

The Nuclear Weapons Council's objective for the IWs is an interoperable NEP, with adaptable non-nuclear components on SLBMs and ICBMs. The first IW option is designated the IW1; initial production is planned for ICBM deployment. Two additional IWs, the IW2 and the IW3, are also planned. Final designs of NEPs for the IW1, IW2, and IW3 warheads are yet to be determined. IWs, together with the B61-12 and the Air Force cruise missile warhead, would lead to a reduction in both the overall stockpile numbers and the number of warhead types.

Figure 1–8 illustrates the evolution of the size and composition of the stockpile. In execution of the 3+2 Strategy, NNSA expects to sustain a highly specialized technical workforce and to develop and sustain the capabilities, facilities, and physical infrastructure essential to meet stockpile requirements.

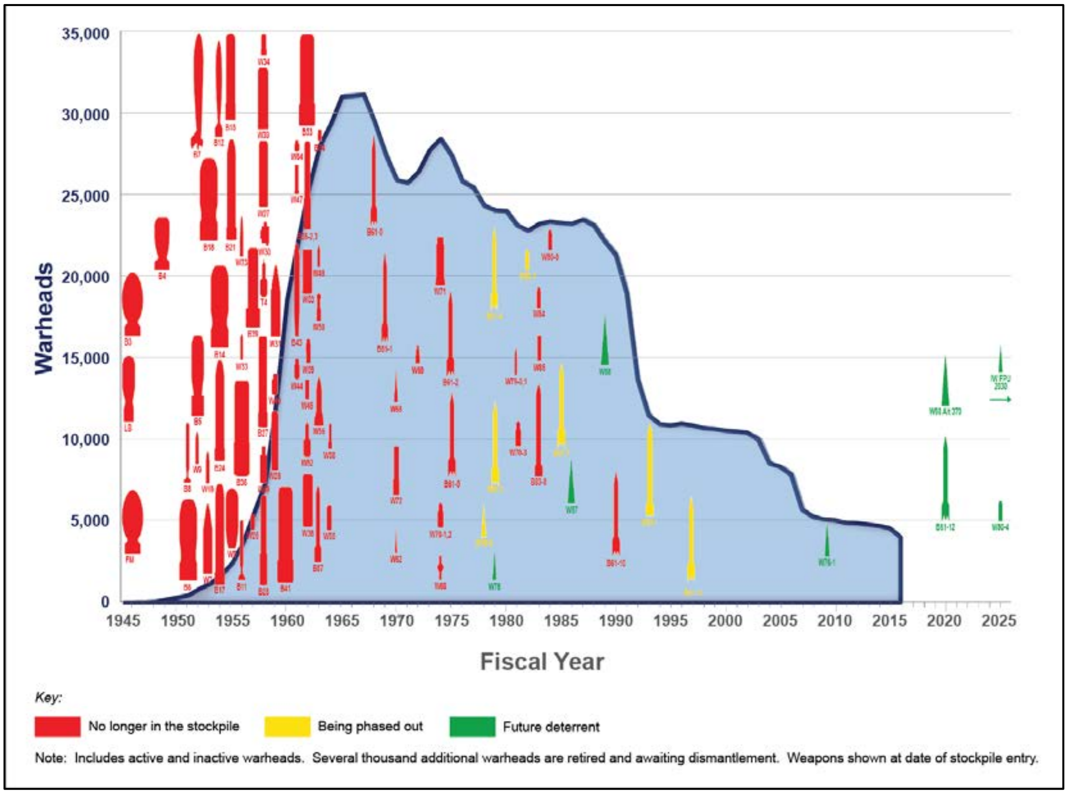


Figure 1–8. Size and composition of the U.S. nuclear weapons stockpile

See Chapter 2, "Stockpile Management," and the SSMP classified Annex for additional details.

1.7 Overview of Stockpile Stewardship, Management, and Responsiveness

Before 1992, developing and maintaining the nuclear deterrent was accomplished by a cycle of weapon design, weapon testing, and incorporation of lessons learned as weapon changes were implemented. One constant in this process was underground nuclear explosive tests. From 1945 through 1992, the United States conducted 1,054 nuclear explosive tests, the majority of which tested design concepts, physics, and engineering details such as safety and radiation effects. These explosive tests also exercised the designers, engineers, "manufacturing plants" (now called nuclear weapons production facilities), and the entire nuclear infrastructure in carrying out the mission.

Since 1992, the moratorium on underground nuclear explosive testing has increased the importance of science-based tools and methods to provide the necessary data to ensure the warheads are safe, secure, and reliable. In the future, geopolitical strategic changes and technological advances may lower barriers to nuclear proliferation and enable rapid development and deployment of advanced offensive and defensive capabilities. In addition, the threat of cyber warfare, supply chain subversion, and other asymmetric attacks is increasing. These developments introduce evolving cross-domain technological threats that will drive the need for a more modern, robust, flexible, resilient, ready, and appropriately tailored deterrent and its supporting nuclear security enterprise.

1.7.1 Stockpile Stewardship

NNSA uses a suite of innovative experimental platforms, materials science and engineering capabilities, computational tools, diagnostic equipment, and supercomputers that build on past test data to simulate the internal dynamics of nuclear weapons. DOE/NNSA use capabilities to assess the health of the nuclear weapons stockpile and certify that it remains safe, secure, and effective, as well as provide the technical basis for current and future warhead LEPs.

1.7.2 Stockpile Management

Stockpile management sustains weapons in the stockpile through surveillance, maintenance, and modernization efforts such as LEPs, Alts, and modifications (Mods). The Stockpile Management Program includes the following elements.

- **Assessments.** Assessments determine warhead performance, safety, and reliability based on physics and engineering analyses, experiments, and computer simulations. Specific assessments may also evaluate changes in performance caused by aging and quantify performance thresholds, uncertainties, and margins.
- **Surveillance.** Surveillance is the process whereby individual weapons undergo inspections, including inspections and tests of components and materials to determine whether performance expectations are met and to acquire a deeper understanding of material degradation mechanisms. Data collected during surveillance are used to support the assessment process and inform life extension decisions.
- **Maintenance.** This process includes limited life component exchanges, which are periodic exchanges of components as they reach the end of their lives. GTSs, neutron generators, and power sources are limited life components that are replaced on a regular schedule.
- **Significant finding investigations**. Significant finding investigations (SFIs) are evaluations and investigations of anomalies identified by experiments, assessments, surveillance, or other activities. Each SFI is evaluated to determine the impact of the anomaly on weapon performance, reliability, security, and safety, with recommendations for corrective actions as required.
- **Modernization through alterations, modifications, and life extension programs.**
  - **Alts** are limited-scope changes that typically affect assembly, testing, maintenance, and/or storage of weapons. An Alt may address identified defects and component obsolescence, but does not change a weapon’s operational capabilities.
  - **Mods** are more comprehensive modernization programs that change the operational capabilities of weapons. A Mod may enhance the margins against failure, increase safety, improve security, extend limited life component life cycles, and/or address identified defects and component obsolescence.
  - **LEPs** refurbish warheads by replacing aged components with the intent of extending the service life of the weapon. An LEP can extend the life of a warhead by 20 to 30 years, while increasing safety, improving security, and addressing defects.
- **Dismantlement and disposition**. This is the process whereby the major components are disassembled and earmarked for reuse, storage, recycling, surveillance, or disposal.

Activities that directly support stockpile management are described in detail in Chapter 2, "Stockpile Management" and Chapter 3, "Stockpile Stewardship Science, Technology, and Engineering."

1.7.3 Stockpile Responsiveness

Section 3112 of the FY 2016 *National Defense Authorization Act* (NDAA) established that "[i]t 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." Section 3112 then created the Stockpile Responsiveness Program to achieve this policy in coordination with the already existing Stockpile Stewardship and Stockpile Management Programs.

DOE/NNSA's report to Congress, *Stockpile Responsiveness,* provides preliminary information on the proposed plan to augment the Stockpile Stewardship and Stockpile Management Programs with the Stockpile Responsiveness Program.

1.8 Challenges in Executing the Stockpile Stewardship and Management Plan

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. More than 75 percent of the W76-1 warheads have already been provided to the Navy, and NNSA authorized the national security laboratories and nuclear weapons production facilities to enter Phase 6.4 (Production Engineering) for the B61-12 LEP. In addition, planning activities for the W88 conventional high explosive (CHE) refresh were accelerated and combined with replacement of the weapon's arming, fuzing, and firing (AF&F) systems and with safety enhancements. This has 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), has completed Phase 6.1 (Concept Study) and received Nuclear Weapons Council approval to enter Phase 6.2 (Feasibility Study). Major investments in infrastructure are currently underway to address a number of critical capabilities identified in the 2010 *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 (CMRR) Project.

Notwithstanding these accomplishments, the 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. The NNSA mission depends on many specialized facilities, infrastructure, and equipment. NNSA is long overdue to build a more modern enterprise 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 current demands of the LEPs, along with the demands of the Stockpile Stewardship Program, have increased the loads on the aging NNSA infrastructure. Without infrastructure modernization, the risk to NNSA's mission will increase.

Investments in infrastructure and science have not kept pace with the needs of an aging enterprise with a growing workload. In lieu of changing the business model as the Government Accountability Office

(GAO) has suggested over a number of years,[9] or managing for significant efficiencies as the DOD has suggested,[10] additional investment is necessary to decrease a number of risks. Risks from lack of adequate investment include cost growth and schedule slippage in ongoing LEPs, failure to re-establish the capability to produce strategic material for the stockpile, and inability to maintain long-term stockpile stewardship without underground nuclear explosive testing. These additional investments will reduce maintenance, operating, and associated security costs and will also reduce NNSA's footprint.

Other key considerations include the following.

- The nuclear weapons stockpile contains many obsolete technologies that must be replaced as the service lives of the warheads are extended. This will require significant investment in new processes, technologies, and tools to produce and certify warheads and deliver 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 deal with the potential for sabotage, malicious introduction of an unwanted function, or subversion of a function without detection. NNSA's radiation-hardened silicon microelectronics facility, Microsystems and Engineering Sciences Applications (MESA) at SNL, now relies on tools and capabilities that are no longer supported by manufacturers. MESA's obsolescence, size and weight limitations, coupled with enhanced performance needs, have driven NNSA to study options for a trusted microsystem capability to ensure future needs can continue to be met.
- At most NNSA sites, the number of retirement-eligible employees is large (see **Figure 1–9**); aggressive programs are required to recruit and retain high-quality individuals and provide new personnel with opportunities to acquire the experience and expert judgment to sustain the stockpile. Retaining early-career staff in certain specialties and disciplines is challenging and made even more difficult by the fact that facilities have not yet been modernized or replaced.

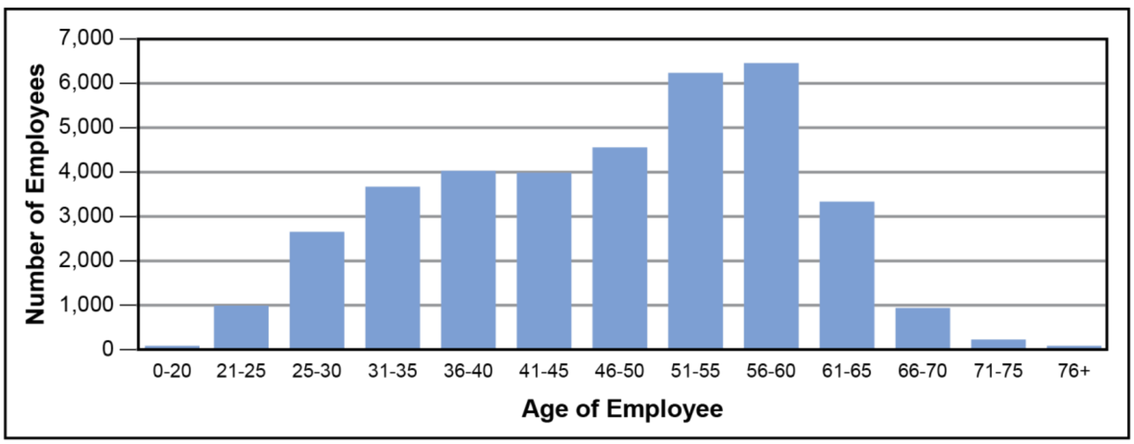


Figure 1–9. Management and operating partners headcount distribution by age

[9] See for instance GAO-15-662T and GAO-17-317. Persistent resistance to recommendations made by the GAO and others has been noted by the Congressional Advisory Panel on the Governance of the Nuclear Security Enterprise, Final Report, December 2014. This report is often known by the last names of its co-chairmen, that is, the Augustine-Mies Report.

[10] DOD report to Congress, *FY 2012 Annual Report on Cost Assessment Activities*, April 2013. In its May 2014 report to Congress, *Notification of National Nuclear Security Administration (NNSA) Efficiencies in FY 2014*, NNSA noted "NNSA explored whether $320 million in savings could be identified in the President's FY 2014 budget request in consultation with DOD/Cost Assessment and Program Evaluation (CAPE)," but ultimately noted in its August 2014 final report that only $139.5 million could be found in excess overhead and other accounts.

Chapter 2 Stockpile Management

Stockpile management encompasses the activities of the Directed Stockpile Work (DSW) Program along with technology maturation programs, and activities that support the stockpile. These activities include surveillance, assessment, and maintenance of stockpile weapons; implementation of minor and major Alts, Mods, and LEPs; dismantlement and disposition of retired weapons; and preservation and enhancement of capabilities necessary to continue stockpile management activities in the future. (Note, the box immediately to the right with "accomplishments" is repeated in many chapters to follow. In general, if unspecified, the accomplishments described occurred after October 2015 (the start of FY 2016).

Stockpile Management Accomplishments

- *Passed the 75 percent point for the W76-1 in total refurbished warheads scheduled for delivery to the Navy.*
- *Received approval for the B61-12 to enter into Phase 6.4, Production Engineering.*
- *Conducted the fourth successful qualification flight test for the W88 Alteration 370.*
- *Reconstituted capabilities to manufacture radioisotope thermoelectric generators and detonator cable assemblies.*
- *Executed the safety surveillance requirements for the W84 weapon.*

2.1 Stockpile Management Overview and Nuclear Enterprise Assurance

The stockpile management cycle incorporates several complex and interrelated processes. The nuclear weapon stockpile undergoes annual assessments, while surveillance and maintenance occur on a scheduled basis throughout the lifetime of a weapon.

In the course of conducting surveillance, assessment, or maintenance, an article of interest may arise and give cause to conduct an SFI. The results of the investigation might lead to an engineering corrective action, an Alt or Mod to a weapon system, or may be resolved without any changes to the stockpile. As the stockpile ages and policies change to meet the needs of an evolving threat environment, the Nuclear Weapons Council may also initiate major Alts, Mods, LEPs, or weapon retirements as necessary. All systems, subsystems, and components undergo certification and assessment before a weapon is reintroduced into the active stockpile.

Recycled and recovered material from dismantled weapons also provides some of the strategic material used to maintain the nuclear weapons stockpile. Since not all of this material can come from dismantled weapons, NNSA also manages the procurement and production of strategic materials to support the stockpile. In addition, NNSA develops processes to ensure a safe and reliable supply of all other materials and components necessary for stockpile management.

To address the security challenges associated with these efforts, NNSA established the Nuclear Enterprise Assurance (NEA) program. NEA identifies and mitigates the consequences of the current and dynamic spectrum of threats to the nuclear security enterprise and incorporates both the item-focused Supply Chain Risk Management and design-focused Weapons Trust Assurance initiatives. The focus for the NEA is the design, development, production, and maintenance of weapons with enhanced trust features that are resilient to subversion and counterfeiting attempts. Since its establishment, NEA has led to the development of program protection plans for the current LEPs and major Alts for weapon system functionality and operability.

Effective stockpile management requires comprehensive planning to ensure that all stockpile activities fit cohesively into an integrated system. These activities are:

- managing limited life component exchanges;
- planning and executing LEPs;
- assessing the stockpile and certifying weapons and components before their addition to the stockpile;
- addressing urgent and emerging issues that affect the performance or reliability of the stockpile;
- retaining core capabilities and essential skill sets;
- managing strategic nuclear and non-nuclear materials;
- implementing improved safety, security, and use-control features where certifiable and cost effective;
- managing the dismantlement and disposition of weapons and materials; and
- developing components and manufacturing processes for the future stockpile.

2.2 Status of the Stockpile

The status of the stockpile is measured through continuous, multi-layered assessments of the safety, security and reliability of U.S. nuclear weapons currently in the stockpile. These assessments are based primarily on information from surveillance, experiments and modeling, SFIs, and other information as appropriate. The national security laboratory directors and the Commander of U.S. Strategic Command (USSTRATCOM) prepare annual assessment letters, based on the most current assessment information available. These annual assessment letters are included in the congressionally mandated Report on Stockpile Assessment, which is signed by both the Secretaries of Energy and Defense and delivered to the President.

2.2.1 Weapon Assessment, Reliability, and Certification and Predicting Performance

The assessment and certification processes rely on assembling a body of evidence—based on experiments, physical and environmental tests, destructive and nondestructive evaluations, and modeling and simulation—and then making an assessment at the part, component, subsystem, and system levels to determine whether all the required performance characteristics are met. Both processes are quantitative and combine data and theory with simulations of nuclear weapons to arrive at a conclusion based on expert judgment.

2.2.1.1 Annual Assessment

> *Each year since the reporting process began, the Laboratory Directors have concluded there is no current requirement to conduct an underground nuclear test to maintain certification of any nuclear warhead.*

As part of the annual assessment review, the directors of the three national security laboratories and the Commander, USSTRATCOM provide written assessment on the state of each warhead in the nuclear weapons stockpile. The annual stockpile assessment review process is not an annual re-certification of the warheads in the stockpile. It is an assessment of each warhead's existing certification basis in light of information generated by the Stockpile Stewardship Program in the past year. Each annual assessment builds on continuing experience with each weapon system and incorporates new information from stockpile maintenance, surveillance, experiments, simulations, and other sources to enhance the technical basis of each weapon type.

The annual stockpile assessment process evaluates the safety, performance, and reliability of weapons based on physics and engineering analyses, experiments, and computer simulations. Assessments may also evaluate the effect of aging on performance and quantify performance thresholds, uncertainties, and margins. These evaluations rely on all available sources of information on each weapon type, including surveillance, non-nuclear hydrodynamic tests, subcritical experiments, materials evaluation, modeling and simulation, and enhanced surveillance techniques.

The overall assessment philosophy and approach involves quantification of weapon characteristics and the rigorous review of the results and certification basis by teams of weapons scientists and engineers. The laboratory teams responsible for each weapon type and its assessment include individuals with extensive weapons experience and access to both historical and new data. The assessments and conclusions in the Annual Assessment Reports are reviewed by independent peers, Red Teams (subject matter experts appointed by each laboratory's director), program managers, senior laboratory management, and the Laboratory Directors. Specific results related to the stockpile systems are in the latest *Report on Stockpile Assessments*.

2.2.1.2 Weapon Reliability

The stockpile also undergoes an annual weapon reliability assessment, which is compiled into a report called the Weapon Reliability Report, which concerns the military effectiveness of the stockpile. Nuclear weapon reliability is the probability that a designated weapon can deliver the specified nuclear yield at the target. The Weapon Reliability Report is the principal NNSA report on reliability for USSTRATCOM. USSTRATCOM uses the Weapon Reliability Report 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 any noted exceptions, the 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 Predicting Weapon Performance

NNSA relies on a combination of experiments and integrated design codes (IDCs) to predict weapon performance. To provide a predictive capability, NNSA must know how accurately the code simulations can describe a real weapon—that is, knowing the 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, as well as data from the nearly 40 years of U.S. underground 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.

Modern simulations with the IDCs can approximate the physics of interest and provide information that contributes to predicting the performance of a weapon. Stockpile stewardship scientists have broken down the operation of a weapon into a sequence of individual steps, analyzed those steps through computational models and experiments, and then reintegrated the steps through large-scale weapon simulation codes and computational tools. That process requires new experimental facilities that can approach the densities, pressures, velocities, temperatures, and timescales relevant in a nuclear detonation; development of high-fidelity weapon simulation codes; development and acquisition of high performance computers; and detailed data to validate and calibrate the models in the codes. New approaches are also necessary to qualify the nuclear and non-nuclear components against hostile nuclear attack using improved experimental tools and simulation codes. Although NNSA has made significant progress in eliminating phenomenological models, much computational and experimental research remains to be performed.

2.2.1.5 Developing Accurate Models of Weapon Systems and Components

Understanding the full-system behavior of a weapon from knowledge of its component subsystems is one of the most difficult aspects of modeling a nuclear weapon. The physical processes that the weapon undergoes extend from the microscale to the macroscale in both time and length. The processes that must be modeled at these widely disparate scales include material damage, mixing of fluids, and detonation of HE. Moreover, a full-system numerical simulation of the weapon depends upon 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 regimes experienced by the weapon. As a specific example, to inform decisions on developing replacements for particular materials and components and on when LEPs, Mods, and Alts ought to occur, NNSA is improving models for the long-term aging behavior of materials and components by using advanced diagnostics, simulations, and technologies and applying new evaluation techniques as part of Enhanced Surveillance.

2.2.1.6 Quantification of Margins and Uncertainties

Using predictive capabilities to assess and certify the performance of a weapon is a tremendous challenge. This challenge is addressed through the quantification of margins and uncertainties methodology, which evaluates the confidence of 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 in a prediction is numerically represented as a confidence factor—that is, as the ratio of margin (M) over uncertainty (U), or M/U. The 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 values that are measured (*via* experiments) and the values that are calculated (*via* databases for physical quantities, physical models, and numerical simulations). An analogy can be drawn between the quantification of margins and uncertainties methodology and the process to approve a new aircraft by the Federal Aviation Administration (as described in the text box to the right).

Analogy between "Quantification of Margins and Uncertainties"
Methodology and Aircraft Safety and Reliability

NNSA requires positive evidence that a nuclear weapon will work; the absence of evidence that the weapon does not perform safely, securely, and reliably is not sufficient. When an airplane is developed, the Federal Aviation Administration requires documentation of its safety and reliability under various conditions, with sufficient safety margins to ensure confidence. Similarly, NNSA requires documentation of the effects of aging and obsolescence of components on the behavior of a weapon and how it performs under specific conditions.

A confidence factor, M/U, 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 limited life component replacements. Decreasing the uncertainty can be done by focusing R&D resources on areas, such as the specific characteristics of strategic materials to which weapon performance is sensitive (like uncertainty in cross sections), or by improving the fidelity of models used to simulate the operation of the warhead. Both approaches are pursued by the RDT&E programs.

2.2.2 Stockpile Surveillance

NNSA's surveillance activities provides data to evaluate the condition of the stockpile in support of the 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 the following 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 surveillance data.
- Calculate margins between design requirements and performance at the component and material levels.
- Identify aging-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 annual *Weapon Reliability Report* and the annual *Report on Stockpile Assessments*.

The Surveillance program consists of the Stockpile Evaluation program and Enhanced Surveillance (see Chapter 3, Section 3.2.3, Engineering, Stockpile Assessments, and Responsiveness). The Stockpile Evaluation program conducts surveillance evaluations of both the existing stockpile (*i.e.*, stockpile returns) and new production (*i.e.*, Retrofit Evaluation System Test units). The Enhanced Surveillance subprogram provides the diagnostics, processes, and other tools to 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 or Navy. Newly produced weapons or ones returned from the stockpile are disassembled, and their non-nuclear components, along with surrogate parts for their nuclear components, are used to build a joint test assembly (JTA), which is delivered to the DOD for flight testing. Some JTAs contain extensive telemetry instrumentation, while others contain high-fidelity mock nuclear assemblies to recreate, as closely as possible, the mass properties of War Reserve weapons. These JTAs are flown on the respective DOD delivery platform to gather the requisite 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 conducted 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, electronic, optical, 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.

The following provides a more detailed description of the stockpile evaluation elements.

- **Disassembly and inspection**. Weapons sampled from the production lines or returned from the DOD are inspected during disassembly. Weapon disassembly is conducted in a controlled manner to identify any abnormal conditions and preserve the components for subsequent evaluations. Visual inspections (of, for instance, color changes, cracking, or flaking) during dismantlement can also provide state-of-health information.

- **Stockpile flight testing.** After disassembly and inspection, selected weapons are reconfigured into JTA configurations and rebuilt to represent the original build to the extent possible. Plutonium and HEU are replaced with either surrogate materials and/or instrumentation. The JTA units are flown by the DOD operational command responsible for the system. JTA configurations vary from high-fidelity units that have essentially no onboard diagnostics to fully instrumented units that provide detailed information on component and subsystem performance.

- **Stockpile laboratory testing.** After disassembly and inspection, selected weapons are reconfigured into test bed configurations, using parent unit parts, to enable prescribed function testing of single parts or subsystems.

- **Component testing and material evaluation.** Components and materials from the disassembly and inspection process undergo further evaluations to assess component functionality, performance margins and trends, material behavior, and aging characteristics. The testing can involve both nondestructive evaluation techniques (*e.g.*, radiography, ultrasonic testing, electrical testing, and dimensional measurements) and destructive evaluation techniques (*e.g.*, tests of material strength and explosive performance, as well as chemical assessments).

- **Test equipment.** System-level testers are complex systems that perform two key functions. First, they provide the mechanical, electrical, and radio frequency stimuli to the system in a specified sequence to simulate a weapon employment scenario. Second, the testers simultaneously collect data on the performance of components, subsystems, and system as a whole. The data collected is used to assess and certify the performance of the weapon system.

The number of disassembly and inspections and major component tests completed in FY 2016 and FY 2017 are shown in **Table 2–1**.

Table 2–1. Fiscal years 2016 and 2017 core Directed Stockpile Work Program stockpile evaluation activities (as of October 12, 2017)

	D&Is		*JTA Flights*		*Test Bed Evals*		*Pit NDE*		*Pit D-Tests* [a]		*CSA NDE*		*CSA D-Tests*		*GTS Tests*		*HE D-Tests*		*DCA Tests*		*Program Totals*	
	Fiscal Year																					
Warheads	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*	*16*	*17*
B61	7	11	6	5	6	4	12	20	0	0	4	8	2	2	4	14	1	0	10	14	52	78
W76-0	4	4	4	0	4	0	16	4	0	0	6	4	0	2	14	12	3	4	1	4	52	34
W76-1	22	20	3	1	14	24	24	31	1	0	5	25	0	3	7	13	0	5	0	22	76	144
W78	10	8	1	3	0	0	22	22	1	1	7	18	1	1	6	10	1	4	9	0	58	67
W80-1	11	0	5	4	0	8	43	29	0	0	1	1	1	1	9	6	4	4	0	8	74	61
B83	2	2	1	1	2	1	11	13	1	0	1	1	1	1	8	5	1	1	0	9	28	34
W84	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5
W87	9	8	3	3	6	8	17	14	0	0	0	1	1	1	8	11	1	1	4	3	49	50
W88	9	6	4	4	0	12	18	24	0	0	1	0	1	1	6	13	2	1	0	7	41	68
Totals	**75**	**64**	**27**	**21**	**32**	**57**	**163**	**157**	**3**	**1**	**25**	**58**	**7**	**12**	**62**	**84**	**13**	**20**	**24**	**67**	**431**	**541**

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

[a] A pause in plutonium operations in the Plutonium Facility (PF-4) caused postponement of most FY 2016 pit D-test requirements.
Note: Totals are preliminary counts as of October 12, 2017.

LANL restarted pit surveillance activities in late 2015 after pausing plutonium operations at the Plutonium Facility (PF-4) in 2013. **Table 2–2** reflects pit tests including the recovery schedule for pit destructive tests not done earlier due to the work-stoppage between 2013 and 2015 at PF-4 across the FYNSP. NNSA and the Navy agreed to conclude joint flight tests for the W76-0 in FY 2016, with the last production unit of the W76-1 scheduled for completion in FY 2019. Moreover, in anticipation of completing the B61-12 LEP and gaining confidence in the B61-12's performance, in FY 2016 Nuclear Weapons Council members agreed on surveillance test reductions of 50 percent for the B83 and the four B61 variants that are to be replaced by the B61-12 (-3, -4, -7, and -10) to partially offset the added cost of replacing the CHE in the W88. The decrease in total tests between FY 2017 and FY 2018 is predominantly the result of the pending decrease in weapon variants after the B61-12 LEP is completed. Weapon Alts implemented across the FYNSP will require additional surveillance tests during the phase-in periods.

Table 2–2 also shows surveillance requirements for the FYNSP as compared to the actual FY 2016 and FY 2017 surveillance evaluations.

Table 2–2. Major surveillance evaluations completed in fiscal years 2016 and 2017, and planned for the Future Years Nuclear Security Program (fiscal year 2018 through 2022) (as of October 12, 2017)

Major Activity	FY 2016 Actual	FY 2017 Actual	FYNSP (FY 2018 through FY 2022)					
			FY 2018 Requirements	FY 2019 Requirements	FY 2020 Requirements	FY 2021 Requirements	FY 2022 Requirements	FYNSP Total [a]
D&Is	75	64	85	76	77	85	76	399
JTA Flights	27	21	25	20	31	29	29	134
Test Bed Evaluations	32	57	47	36	57	55	42	237
Pit NDEs	163	157	155	191	213	147	140	846
Pit D-Tests	3	1	12	24	19	13	12	80
CSA NDEs	25	58	35	41	54	48	45	223
CSA D-Tests	7	12	13	15	15	17	16	76
GTS Tests	62	84	87	83	65	67	52	354
HE D-Tests	13	20	21	13	41	36	35	146
DCA Tests	24	67	125	73	131	107	108	544
TOTALS	431	541	605	572	703	604	555	3,039

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

[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 October 12, 2017.

Surveillance requirements, as determined by the national security laboratories for the weapon systems in conjunction with the Air Force and Navy for joint testing, result in defined experiments to acquire the data that support the Stockpile Surveillance program. The national security laboratories, in conjunction with NNSA and the nuclear weapons production facilities, continually refine these requirements, based on new surveillance information, annual assessment findings, and analysis (or reanalysis) of historical information using modern assessment methodologies and computational tools. An agile and continuous cycle of surveillance, as depicted in **Figure 2–1**, provides the flexibility for adjusting program priorities to address critical issues. Key outcomes of this process include:

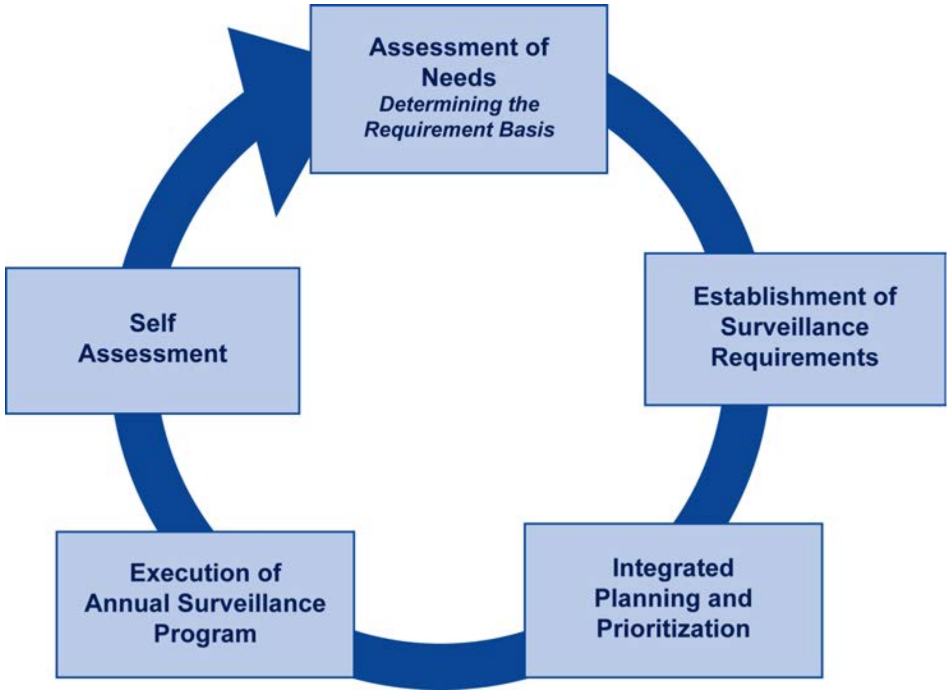


Figure 2–1. Continuous cycle of Surveillance program activities[11]

- collections of data to quantify performance margins;
- identification of knowledge gaps in NNSA's understanding of stockpile health;
- technology updates;
- establishment of priorities among competing surveillance activities;
- continuous improvement of surveillance processes;
- identification of malicious acts; and
- technical bases and evidence for confidence statements made by the Laboratory Directors and NNSA in Annual Assessment Reports.

NNSA's nuclear weapons surveillance governance model ensures rigor in planning and execution. Under this governance model, a Senior Technical Advisor for Surveillance manages and integrates all elements of the Surveillance program and reports directly to the Director of the Office of Nuclear Weapon Stockpile. The Senior Technical Advisor for Surveillance is responsible for ensuring that:

- key activities are coordinated so that the most appropriate diagnostics are developed and used for surveillance evaluations;
- system-specific surveillance requirements are up to date and achieve a balance in priorities; and
- all systems requirements are integrated into an executable plan.

This approach forms an annual surveillance schedule and ensures that requirements are defined and communicated to the nuclear security enterprise and that appropriate resources are available. The plan includes proposed schedules and funding throughout the FYNSP. The integration of all surveillance

[11] "Self Assessment" means that onboard sensors continuously monitor weapon characteristics and flag anomalies.

elements ensures that emerging issues and aging characterization will be addressed using the most cost-efficient and effective diagnostics.

NNSA continues to improve the current Stockpile Evaluation program by implementing changes in both strategy and execution to build and sustain stockpile confidence in the 21st century. As the Stockpile Surveillance program shifts its surveillance activities to meet the diverse needs of a changing stockpile, concepts that enable a flexible, tailorable, and more responsive Stockpile Evaluation program are emerging and being developed. The following are key priority elements needed for the 21st century Stockpile Surveillance program:

- Risk-based strategies that appropriately focus on detecting defects and/or aging in the stockpile
- Forecasting potential technical risks that could impact safety, security, and/or effectiveness of the stockpile
- Agility to support a sustainable assurance case for fielded weapon systems while responding to emerging questions and issues
- Innovative science and engineering approaches to diagnose and analyze both the current state and the aging trajectory of systems' state of health
- Advanced innovative approaches to determine, with the highest fidelity configurations possible, that the weapon system will function as a system and deliver yield on target throughout operational requirements
- An agile, sustainable foundation (people, infrastructure, equipment, information management, and R&D capability) to support the surveillance program of record and be responsive to directional change

Other near-term surveillance activities include the development of a long-term strategy for the Enhanced Surveillance program that meets outcome-oriented strategic goals, addresses management challenges, and identifies the necessary resources.

2.2.3 Significant Finding Investigations

SFIs are conducted when anomalies arise that can significantly 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. A tracking and reporting system monitors progress from the discovery of an anomaly through its closure report, as well as the status of any corrective actions. The closure report identifies the assessed impacts, if any, and provides recommendations for follow-on activities. A prioritization process also ensures that the most serious and oldest SFIs receive appropriate resources. Depending on its nature, an SFI may be resolved solely as part of Stockpile Management, or a broader evaluation scope may be required that includes experiments, advanced code analysis, and other resources from Stockpile Stewardship. Most SFIs are closed without effect to the stockpile. Some impacts involve only a subpopulation of a particular stockpile system, which may result in a minor, acceptable reduction in reliability. If the finding has a significant impact, however, it can result in a change to the reported reliability (*e.g.*, the issuance of an exception to the Major Assembly Release until an appropriate remedial action has occurred, such as an Alt, Mod, or LEP, as indicated by the historical data in **Figure 2–2**).

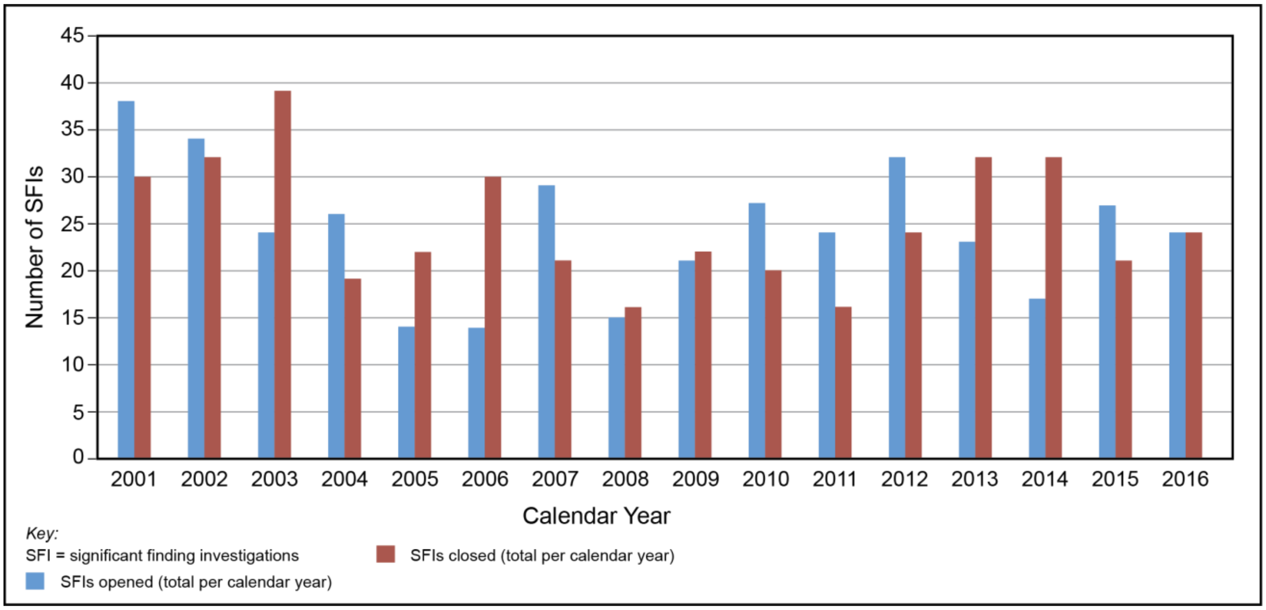


Figure 2–2. Historical number of significant finding investigations opened and closed in calendar years 2001 to 2016

The threshold for the initial assessment of an anomaly is set intentionally low to ensure that any issue that may affect system performance, safety, security, or reliability is identified. Once an anomaly is identified by the nuclear weapons production facility, the national security laboratory with responsibility for the affected weapon has a short timeline to resolve the anomaly or article of interest.

2.2.4 Stockpile Maintenance

Weapons contain limited life components, such as GTSs, power sources, and neutron generators, which require periodic replacement to sustain system functionality. NNSA produces limited life components, while NNSA and DOD jointly manage component delivery and installation of replacements before warhead performance or personnel safety is adversely affected.

In addition to limited life component exchanges, maintenance includes certain minor Alts, such as replacing a limited life component with a different type, to stockpile weapons to address specific concerns that do not rise to the level of a system Mod or an LEP activity. These minor Alts respond to an emerging issue and are addressed on a priority basis, depending on the stockpile impact. Unlike limited life component activities, Alts are scheduled on an as-needed basis.

2.2.4.1 Gas Transfer Systems

NNSA delivers tritium-filled GTSs (limited life components) to DOD for the nuclear weapon stockpile. GTSs are designed, produced, filled, and delivered for existing and future weapon systems. SNL and LANL have the design agency role while KCNSC manufactures the components. Modern GTS designs have extended limited life component intervals and increased weapon performance margin. This has resulted in improved efficiency for DOD and NNSA in weapon maintenance while also ensuring weapon safety and reliability. LANL conducts function testing of preproduction development hardware at the Weapon Engineering Tritium Facility to validate performance characteristics. At SRS, the Savannah River National Laboratory works closely with SNL and LANL to evaluate new GTS designs and verify that these GTSs can be loaded in the production facilities and meet performance characteristics of the weapon systems. In parallel with these R&D efforts, SRS also maintains production facilities for conducting tritium-loading operations, GTS surveillance, and recovering tritium from GTSs at the end of their service lives. The tritium to fill reservoirs is discussed further in the Tritium section (Section 2.4.3).

Gas Transfer System Challenges

Formal risk analyses (taking into account the current status of facilities and programmatic equipment, and the current and projected workload) indicate that, without focused facilities and equipment investments, SRS's ability to maintain its continuity of operations, and deliveries to the stockpile may degrade to an unacceptable level. To limit these risks the following mitigations are being implemented:

- In part due to new Environmental Protection Agency regulations, some of the process and support equipment in the tritium gas processing facility must be replaced within the FYNSP period.
- Infrastructure needs in a high-hazard area need to be addressed without interrupting mission schedule while adapting for multiple, more complex operations.
- NNSA is planning for additional staff (now being determined but about 70 FTEs) during the FYNSP period to meet future GTS demands because of the concurrent production of multiple weapon systems, the additional complexity of modern GTSs, and the tritium R&D that must be conducted to support legacy and LEP programs.

Gas Transfer Systems Long-term Sustainment Strategy

SRS will maintain both production and R&D capabilities through a three-pronged strategy that will: (1) plan and construct (in conjunction with NNSA) new and more capable R&D facilities that are separate from the production infrastructure, (2) recapitalize existing process equipment, and (3) fully replace some production facilities through line-item construction.

Revitalization of the SRS infrastructure is foundational to maintaining a reliable and responsive capability to meet the Stockpile Maintenance mission. SRS is implementing the Tritium Responsive Infrastructure Modifications (TRIM) program to right-size and relocate production processes into more modern facilities. The TRIM program is NNSA's primary strategy for mitigating infrastructure and programmatic risks associated with the remaining legacy production facilities at SRS. In FY 2016, NNSA initiated the formal Analysis of Alternatives (AoA) process for the TRIM program's Tritium Production Capability line-item project. The effort to achieve Critical Decision-1 (CD-1, Approve Alternative Selection and Cost Range) continued in FY 2017.

To address the capacity issue, the Savannah River Tritium Enterprise (SRTE) will modify process and infrastructure equipment in multiple facilities by FY 2020 and evaluate alternative staffing options for some production areas. SRTE started a project in FY 2016 to recover and recycle tritium from newer LEP GTSs returned from the field. Evaluations are ongoing to determine if other critical systems need to be refurbished to establish sufficient capacity in the modern facilities to accommodate the increased mission workload.

2.2.4.2 Power Source

All legacy, LEPs, and future planned nuclear weapons require compact, high-powered, highly variable power sources that are reliable for multi-decadal lifetimes. Requirements for size, weight, active life, responsiveness, and output are unique to nuclear weapon applications. In general, such devices are not available via commercial venders. This capability to produce these devices also supports other national security missions that require advanced power sources with similarly stringent requirements. Including needs for prototyping and parts development, the capability includes the full life-cycle requirements of power source components—from early stage R&D and modeling, to technology maturation, design, and development, and, finally, to production, surveillance, and disassembly.

Power Source Challenges

- At SNL, the facility that houses the power sources capability is 66 years old, was originally designed as a shipping and receiving warehouse, and has been re-purposed many times to meet evolving mission needs. It does not meet modern building code requirements and was not designed or planned to be the long-term solution to house the power sources capability, but instead tactically addresses the immediate gap to meet mission needs. The building and associated infrastructure have far exceeded their design life. The additional corrective measures and modifications needed to further extend safe and stable operational use are not deemed cost-effective, resulting in the need for a different solution.
- SNL's research, design, realization, and surveillance capabilities are highly specialized. New facilities and infrastructure are required to meet the full life-cycle requirements of power source components. Instabilities in the supplier base put the primary production capability at risk, and facility inadequacies put SNL's RDT&E and production capabilities at elevated risk of not meeting the mission.

Power Sources Long-term Sustainment Strategy

- Relocate the power sources capability to a robust, modern facility with tooling capacity to execute mission work.
- The Weapons Engineering Facility was originally planned as a multi-purpose facility to address the power sources and other essential capabilities (*e.g.*, surveillance testers) with similar challenges *via* a single line-item construction project. However, NNSA is considering other options to address these growing challenges that may be more affordable and achievable within shorter timelines.

2.2.4.3 Neutron Generators

Nuclear weapons require a highly reliable source of neutrons to function properly. Neutron generators are highly complex limited life components that provide neutrons at specific timing and rates to initiate weapon function. SNL's Neutron Generator Enterprise, which is an integrated design and production agency, supports NNSA's neutron generator design and production commitments by managing the entire life cycle of the neutron generators, from scientific understanding through design, development, qualification, production, surveillance, dismantlement, and disposal.

Neutron Generator Challenges

Aging facilities, infrastructure, and equipment are the biggest challenges for neutron generator production sustainment. Near-term investments will focus on sustainment by ongoing recapitalization of existing facilities, infrastructure, and equipment and by making incremental improvements in process efficiency and cleanliness.

Long-term Sustainment Strategy for Neutron Generators

SNL's Neutron Generator Enterprise is conducting ongoing formal planning for long-term capabilities to ensure that mission deliverables are met and to allow consolidation, increased flexibility, and expanded capabilities. These capabilities 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 Administration, through the Nuclear Weapons Council, continually adjusts quantity and makeup of the nuclear stockpile. When weapons are no longer required in the stockpile they move into retirement status.[12] The Weapons Dismantlement and Disposition Program takes those retired weapons and disassembles them into their major components. Those components are then assigned for reuse, storage, recycling, surveillance, or disposal. The dismantlement and disposition process of a retired weapon is illustrated in **Figure 2–3**.

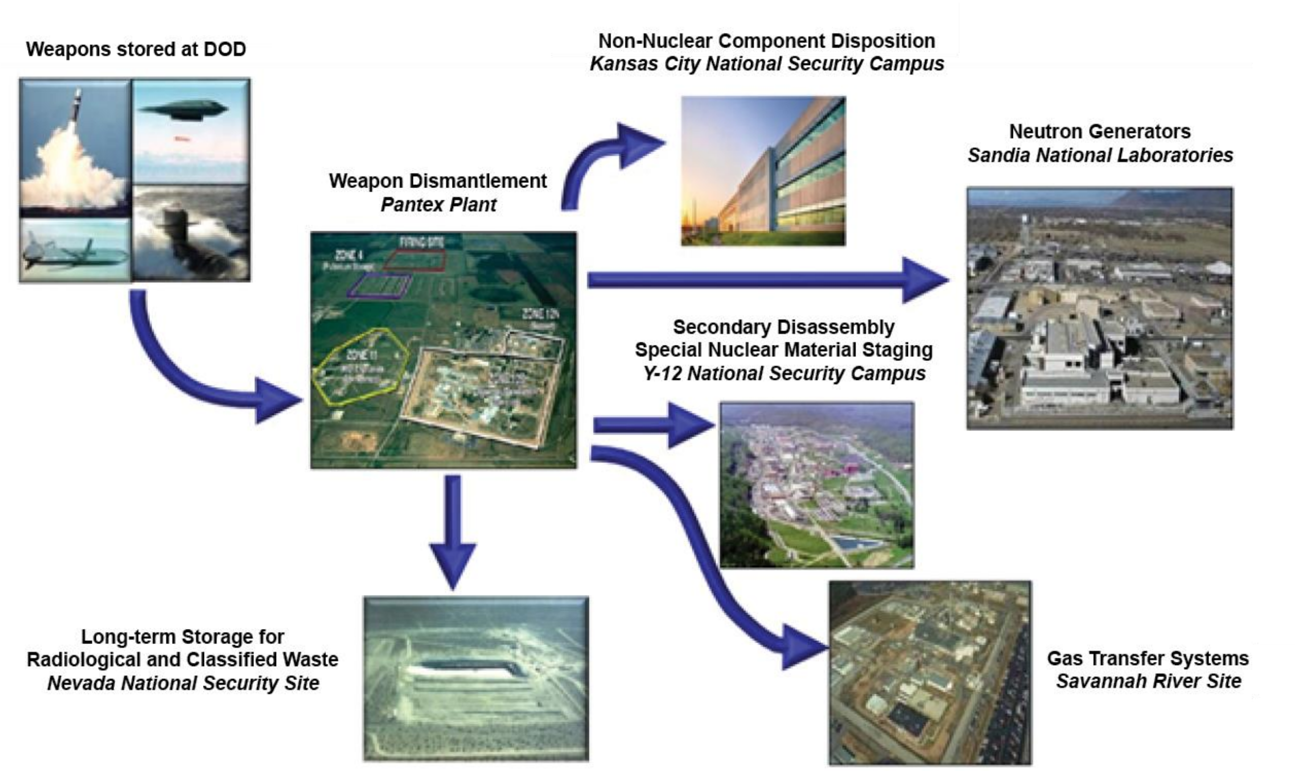


Figure 2–3. Weapons dismantlement and disposition workflow

Many factors affect dismantlement rates, including funding, shipping, logistics, congressional authorization, weapon system complexity, and availability of qualified personnel, equipment, and facilities. NNSA's current SSMP dismantlement plan balances these constraints. For FY 2016, Pantex exceeded its required weapon dismantlements and Y-12 also exceeded its required canned subassembly (CSA) dismantlements.

Dismantlement of retired nuclear weapons are scheduled to provide material and components required for the stockpile (including LEPs) and external customers, to maintain proficiency of technicians, and to balance the work scope at the production plants. In addition, dismantlement rates adhere to the restrictions in the NDAA for FY 2017 (Pub. Law 114-328), that stated:

> *… none of the funds authorized to be appropriated by this Act or otherwise made available for any of fiscal years 2017 through 2021 for the National Nuclear Security Administration may be obligated or expended to accelerate the nuclear weapons dismantlement activities of the United States to a rate that exceeds the rate described in the Stockpile Stewardship and Management Plan* [specifically

[12] Some weapons are retired when they undergo dismantlement and the components are destructively evaluated.

identified as the FY 2016 SSMP] *schedule.* (Section 3125. Limitation on Availability of Funds for Acceleration of Nuclear Weapons Dismantlement)

The funding limits imposed by the NDAA language and increased cost estimates for dismantlement activities may impact NNSA's dismantlement schedule.

The Weapons Dismantlement and Disposition Program focuses on the safe, secure dismantlement of excess nuclear weapons and components in four key areas:

- Disassembly of weapons and CSAs to supply material for future nuclear weapons production
- Identification of waste streams for the permanent disposition of weapon components
- Studies to ensure weapons in the stockpile awaiting dismantlement remain safe while in DOD's custody
- Characterization of all hazards associated with individual weapon components

Longer-term and ongoing activities include the following elements:

- Reducing the legacy part inventories at the national security laboratories and nuclear weapons production facilities
- Supporting nonproliferation and surveillance needs
- Providing components for reuse in the stockpile and LEPs
- Providing recycled special materials for the stockpile, LEPs, naval reactors, and other uses (*e.g.*, lithium bridging strategy)

2.2.6 Technology Maturation

Technology maturation is the technological progression of basic R&D concepts into multi-system use components and processes that engineering design teams can refine for insertion into the stockpile. The program invests in multi-system technology development and advanced manufacturing capabilities to reduce the technological risks and life-cycle costs of maintaining the stockpile. The program enables innovative solutions to the challenges of sustaining a safe, secure, and effective nuclear deterrent in a world without nuclear explosive testing.

Technology maturation for nuclear weapon applications, given the challenging environments and need for qualification, typically requires several years of development before transition to the end user for final development and deployment. Technology maturation relies upon and supports the crosscutting capability of advanced science, technology, and engineering that underpins the nuclear weapons stockpile. Technology maturation also prepares for the future by ensuring a nuclear posture that is agile, flexible, and responsive to change.

Technology maturation converts scientific research into applied R&D, from Technology Readiness Level 1 (TRL 1), basic principles observed and reported, through the integration of technologies tested in a relevant (actual) environment (TRL 5). During the proof-of-concept validation (TRL 3), the Manufacturing Readiness Level 1 (MRL 1) begins with the identification of design, process, materials, manufacturing options, needs, and risks. Down-selection of technologies for insertion into an LEP occurs at the end of Phase 6.2A in the *Phase 6.x Process*. Optimally, technologies down-selected for insertion have progressed to TRL 5/MRL 4 (component/subsystem proof-of-concept validation) to minimize the programmatic risk to the LEP.

Technology maturation includes continued efforts to enhance the security and resilience of the nuclear weapons supply chain through NEA activities, to improve transport security through final development and transition of the Integrated Surety Architectures, when approved by the Nuclear Weapons Council, to a weapon-specific program for refinement, and to increase stockpile responsiveness and risk reduction collaboration efforts through the Joint Technology Demonstrator (JTD).

Technology Manufacturing Challenges

- Steady development of new technologies must be sustained so they are available for stockpile modernization, while simultaneously responding to stockpile maintenance challenges.
- Infrequent insertion opportunities require deliberate and close coordination with LEP, Alt, and Mod programs in order to ensure technologies are developed sufficiently by Phase 6.2A in the *Phase 6.x Process*.
- Although the innovative technologies developed provide significant cost and schedule risk reductions, qualification of new technologies or processes has to clear a necessarily high bar, requiring additional time and resources.

Technology Manufacturing Strategy

- Develop and mature technologies that improve the ability of NNSA to perform life extensions, Alts, or Mods to the stockpile.
- Develop and mature technologies that improve the safety and security of the stockpile.
- Improve the ability to maintain the stockpile.
- Improve the agility of the nuclear security enterprise to better respond to emerging threats.
- Increase confidence in system-unspecified components and subsystems by demonstration in potentially relevant environments.

2.2.6.1 Research and Development Support

The Research and Development Support Program provides the administrative and organizational infrastructure to support R&D capabilities and activities for multiple systems in the stockpile. Research and Development Support also enables the national security laboratories to support the nuclear weapons production facilities in addressing stockpile stewardship and management issues.

The Research and Development Support Program is responsible for:

- providing support for flight tests for multiple weapon systems;
- providing development, diagnostics, and qualifications for HE surveillance;
- archiving historical weapons data;
- upgrading computer hardware and software to remain current with evolving technologies;
- providing the technical skills and knowledge to conduct the core base of tests and experiments;
- implementing quality control, procedures, methods, instructions, certifications, calibrations, and process for R&D activities;
- supporting Joint Integrated Lifecycle Surety multi-agency activities that uniquely deliver surety risk analysis for the nuclear security enterprise; and
- supporting NEA activities that uniquely deliver methodologies for supply chain assurance against the consequences of the current and dynamic spectrum of threats to the nuclear security enterprise.

Research and Development Accomplishment

The Research and Development Support Program conducted a Joint Integrated Lifecycle Surety analysis as well as coordinated the restructuring of the Technical Basis for Stockpile Transformation Planning document.

2.2.6.2 Research and Development Certification and Safety

The Research and Development Certification and Safety (RDCS) Program encompasses weapon component development activities. These R&D activities include primary and secondary modeling, subcritical experiments (utilizing plutonium and surrogates), some hydrodynamic experiments and diagnostic development, non-nuclear component development, weapons effects and system analysis studies, engineering and information infrastructure support, and production liaison and oversight. These activities provide the core capabilities for R&D efforts attributable to multiple weapon systems.

The RDCS Program addresses limited life component issues and sunset technologies that may jeopardize operations and safety if neglected. These technologies include the following elements.

- **Arming, Fuzing, and Firing.** The AF&F subsystem incorporates the electrical and mechanical signaling that initiates the nuclear explosive chain. AF&F scope supports early-stage exploration of technologies that are applicable to multiple stockpile systems, such as microelectronics, foundation bus, and batteries.
- **Nuclear Explosive Package.** The NEP is the central element of a thermonuclear weapon. NEP scope supports technologies to ensure full nuclear design performance of previously fielded NEPs. These include replacement of select components; qualification of new materials, including new formulations of insensitive high explosive (IHE); and advanced diagnostics to detect age-related defects and identify acceptable components for reuse. Multiple science and engineering disciplines are included in this category to ensure overall system performance and component certification.
- **Neutron Generators.** Neutron generators deliver the neutrons at the initiation of the nuclear chain reaction. As a part of stockpile maintenance, neutron generators must be inspected and replaced or refurbished in a timely or periodic manner. The RDCS Program conducts R&D to improve aging and obsolescence issues, as well as potential compatibility challenges when integrated with evolving technology. Tests are also conducted to ensure that the neutron generator performance meets the space and environmental requirements for future stockpile systems.
- **Gas Transfer Systems.** These systems enable reliable weapon functionality. As limited life components, these technologies are replaced periodically to address aging issues as a part of stockpile management. The RDCS Program conducts R&D to improve aging and obsolescence issues, as well as potential compatibility challenges when integrated with evolving technology. Moreover, RDCS engineering endeavors focus on ensuring GTS performance meets the size and environmental requirements for future stockpile systems.
- **Energetics (Power Sources and Explosives).** Thermal batteries are used extensively throughout the stockpile to support numerous weapon functions. RDCS is conducting research to develop a material to support continuing weapon system needs while meeting existing design constraints.

Other Research and Development Certification and Safety efforts include the following:

- Integrated Surety Architectures focuses on improving NNSA transportation surety by integrating nuclear weapon shipping configurations with elements of physical security. This risk mitigation approach was endorsed by the 2010 JASON Surety Study and subsequently validated by the 2013

Joint Integrated Lifecycle Surety baseline assessment. This program has made significant progress in development and is transitioning to the appropriate DSW elements for final development and deployment.

- Surety Engineering consolidates multiple science and engineering disciplines and ensures emerging technologies meet the specified design requirements. Activities focus on development of future safety mechanisms and next-generation use control technologies.
- While Enhanced Surety is not a component of RDCS, its work is coordinated with the two RDCS surety efforts. Enhanced Surety received its funding through the Engineering Program budget line. Enhanced Surety develops state-of-the-art technologies to incorporate into stockpile weapon systems for advanced safety, security, use control, and integrated surety and explores visionary leading-edge technologies for these purposes.
- R&D and engineering studies and experiments are conducted in support of safe nuclear explosive operations.
- Non-warhead-specific R&D studies, assessments, and analyses are conducted to support development of alternative weapon architectures and to support weapon qualification and certification and safety processes.
- Hydrodynamic and subcritical plutonium experiments driven by HE are conducted.

Research and Development Certification and Safety Accomplishments

- Completed the development of the Code Management System for the B61-12.
- Completed the GTS prototype build and associated fit-check on the targeted system's transportation configuration *via* Integrated Surety Architectures.
- Completed a study of CHE and IHE for weapon response.
- Completed the final year of work on maturing and transitioning non-nuclear technologies to the W80-4 LEP.
- Completed planning phase for JTD and obtained approval to begin execution phase.
- Developed NEA capabilities.
- Invested in preliminary development of a new small, reconfigurable radiation-hardened electronic neutron generator.
- Collaborated with the Atomic Weapons Establishment on advanced safety technologies.
- Advanced the physics design capabilities for high-confidence performance and modeling sufficiently to enable application of some common modeling methods to the Annual Assessment and Independent Weapon Assessment processes, thereby increasing confidence in certification.

2.2.6.3 Demonstrator Initiative

NNSA is starting technology development activities to develop a series of system agnostic integrated solutions in a systems context. Development of these demonstrators is independent of a specific weapon requirement while still providing a system-level perspective that integrates two or more components. This demonstrator initiative will provide a balance of requirements pull and technology push with alignment to future deterrence objectives (*e.g.*, the 3+2 Strategy). These demonstrators are test bed activities for maturation of system architectures, subsystems, and/or components through the TRLs and MRLs for insertion into the next *Phase 6.x* with acceptable risk. The initiative focuses on the entire technical maturation spectrum from science and technology activities through alignment to DOD requirements. These technology development activities, combined with annual assessments, will strengthen NNSA's weapon certification to determine whether all the required performance characteristics are met.

A significant part of the overall demonstrator initiative is the JTD collaboration with the United Kingdom (UK). The JTD is a strategic collaboration between the United States and UK dedicated to the research of a series of joint integrated, and system agnostic, demonstrations. The mission needs statement for the project defines early technology development that may have applicability for future systems. The JTD collaboration will challenge and help develop a cadre of subject matter experts across the United States and UK nuclear security enterprises. The JTD will also buy down risk in preparation for future systems work by exercising the capability to design, develop, produce, and certify nuclear weapon components. The JTD collaboration will conduct joint systems engineering and integration of all subsystems and components into a reference design.

The technologies and certification strategies explored through the JTD collaboration are intended to provide options to ensure and enhance the long-term safety and security of the stockpiles of both nations.

2.2.6.4 Radiation-Hardened Microelectronics

Nuclear warheads include electronics that must function reliably in a range of operational environments. These environments include radiation sources ranging from cosmic rays to intrinsic radiation within the weapon and from hostile sources. NNSA requires a trusted supply of these strategic radiation-hardened advanced microelectronics (broadly defined), including R&D capabilities to maintain the safety, security, and effectiveness of the Nation's nuclear deterrent in a diverse threat environment. The MESA fabrication facilities at SNL produce custom, strategic, radiation-hardened microelectronics for nuclear weapons.

Radiation-Hardened Microelectronics Challenges

- The competing requirements among the three Alt/LEP programs must be balanced while continuing the development and sustainment of the engineering and science-based microelectronics capabilities required to accomplish the Nation's nuclear weapon missions.
- The MESA microsystems fabrication (MicroFab) facility capabilities, which deliver strategic radiation-hardened semiconductor devices, need to be sustained over the next decade to meet nuclear weapon requirements.
- The fragility and capability limits of the MESA facility infrastructure places considerable risk on NNSA design and production efforts.
- Silicon fabrication (SiFab) capabilities are inadequate for War Reserve microelectronics needs beyond 2025.

Radiation-Hardened Microelectronics Long-term Sustainment Strategy

A strategy has been developed to assure a long-term supply of microelectronics for NNSA by:

- prioritizing LEP support and microelectronics fabrication capabilities to achieve investment balance to enable delivery of the program of record;
- addressing the highest risk process tool and infrastructure/safety system requirements to enable a transition from processing 6-inch wafers to 8-inch wafers, including the requalification of processes for War Reserve production;
- sustaining the equipment and infrastructure in both the SiFab and MicroFab capabilities through 2025; and

- addressing long-term SiFab and MicroFab capabilities in the interagency consortium that is addressing multiple agency needs for a trusted foundry (or foundries) in a common framework (see Chapter 3, Section 3.7.2.4).[13]

2.3 Stockpile Sustainment and Modernization through the 3+2 Strategy

As weapons systems age, or when 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.

- **Life Extension Program**. An LEP is designed to evaluate an entire weapon system and refurbish, reuse, or replace components with the intent to extend the service life of a warhead while increasing safety and improving security. LEPs require routine *Selected Acquisition Reports* (SARs) to Congress.
- **Alteration**. 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 and less costly changes that are performed on a priority basis, while major Alts are governed by the *Phase 6.x Process* (see **Figure 2–4**) and require a SAR to Congress.
- **Modification**. A Mod is a change to a major assembly that alters the nuclear weapon's operational capabilities. This kind of 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.

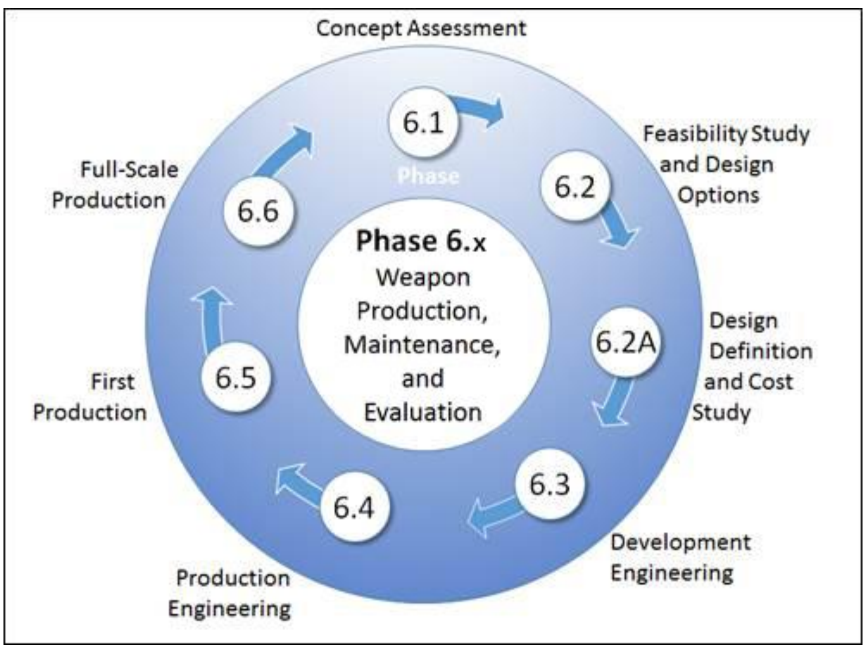


Figure 2–4. *Phase 6.x Process*, adapted from the *Nuclear Matters Handbook*

[13] The trusted microsystems capability is addressing NNSA's long-term supply requirements and R&D capabilities for all microsystems. That acquisition program is not limited to the types of microsystems currently supplied by the SiFab.

NNSA activities for LEPs and major Alts of specific weapon types are illustrated in **Figure 2–5**. The Baseline Life Extension Plan shown in that figure has been approved by the Nuclear Weapons Council and was developed in coordination with DOD; any changes to that plan are coordinated with DOD. The need to anticipate and mitigate manufacturing challenges is an essential part of the planning and management responsibility and could also result in changes to the Baseline Life Extension Plan. The Enterprise Modeling and Analysis Consortium (EMAC)[14] assists Federal program managers within NNSA in understanding and evaluating various alternative pathways to meeting the Nation's nuclear deterrence objectives. In particular, EMAC provides information from the nuclear weapons production facilities that helps decision makers assess the feasibility of proposed changes to the Baseline Life Extension Plan.

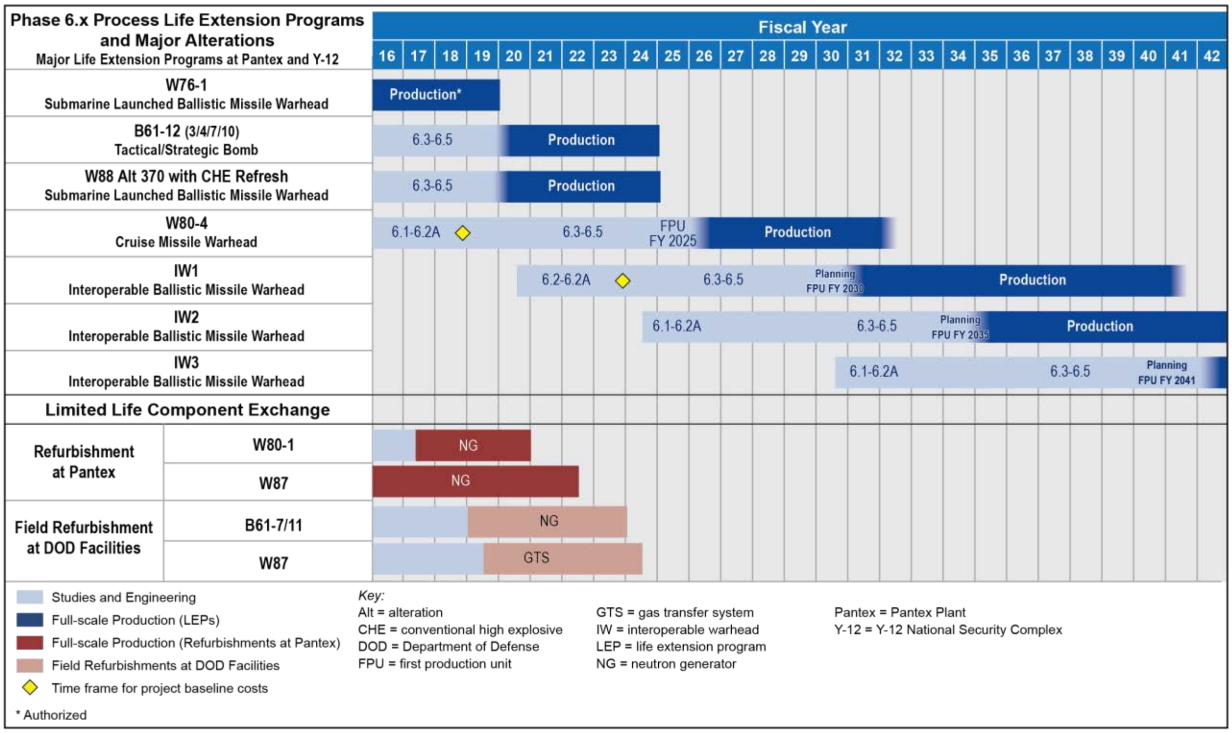


Figure 2–5. National Nuclear Security Administration warhead activities

Moreover, EMAC provides a broad range of decision-making support by analyzing the capabilities, capacities, and infrastructure life-cycle planning of the nuclear security enterprise that are associated with stockpile management alternatives. **Figures 2–6** to **2–9** illustrate examples of the tools that NNSA uses for capacity and resource planning. Figure 2–6 relates to the capacity for weapon assembly and disassembly at Pantex, Figure 2–7 to the capacity for CSA production at Y-12, Figure 2–8 to the capacity for AF&F and associated electronics production at KCNSC, and Figure 2–9 to the capacity for neutron generation production at SNL. These four figures depict the planning for the projected workloads of various product lines before any mitigation strategies are applied. Note also that the projected workload capacity for these weapon component systems can be affected by LEPs and major Alts that have overlapping production schedules. Such data are used in the development of mitigation strategies for optimal site and nuclear security enterprise output with respect to both LEPs and major Alts.

[14] The Enterprise Modeling and Analysis Consortium (EMAC) is composed of M&O partners from each NNSA site to create, maintain, and integrate site component models with other sites' component models.

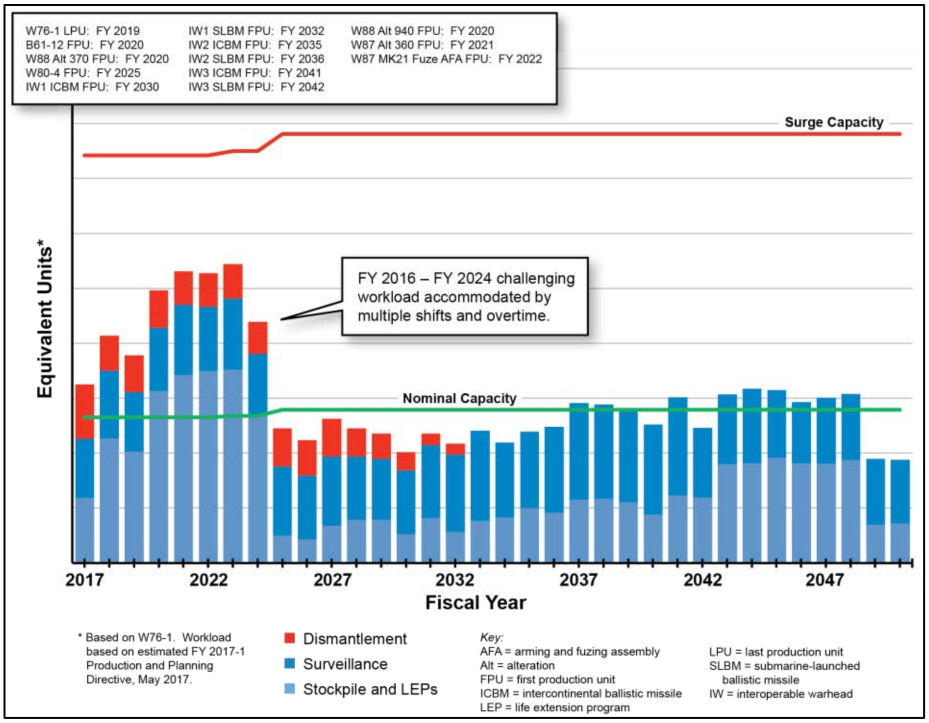


Figure 2–6. Projected out-year workloads for weapon assembly and disassembly at Pantex[15]

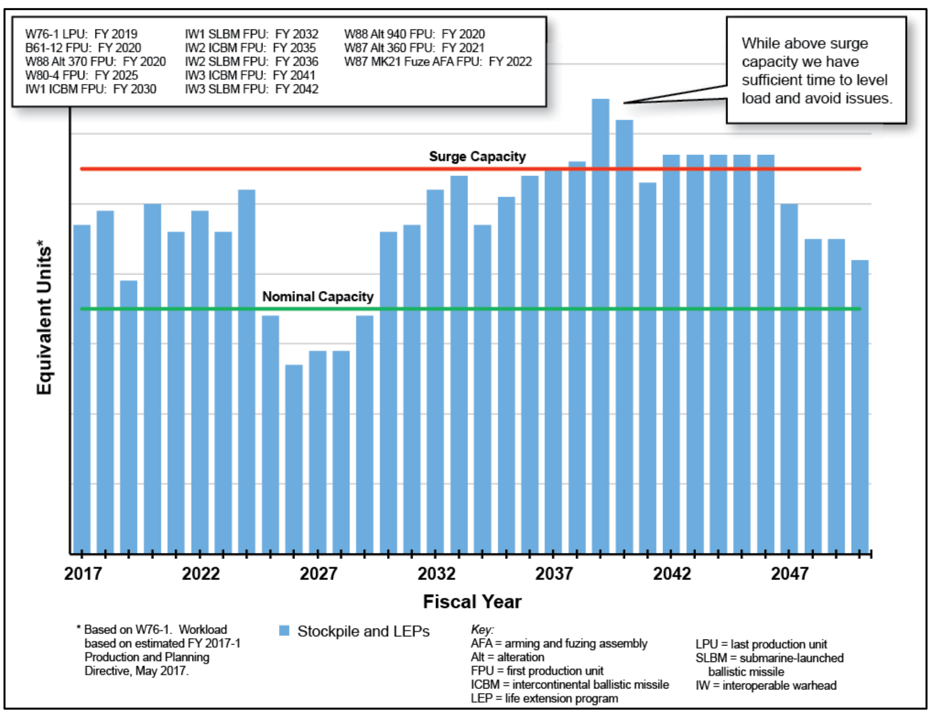


Figure 2–7. Projected out-year workloads for canned subassembly at Y-12

[15] Equivalent units are an indication of the amount of work required measured against the nominal capacity to meet mission goals for planning purposes.

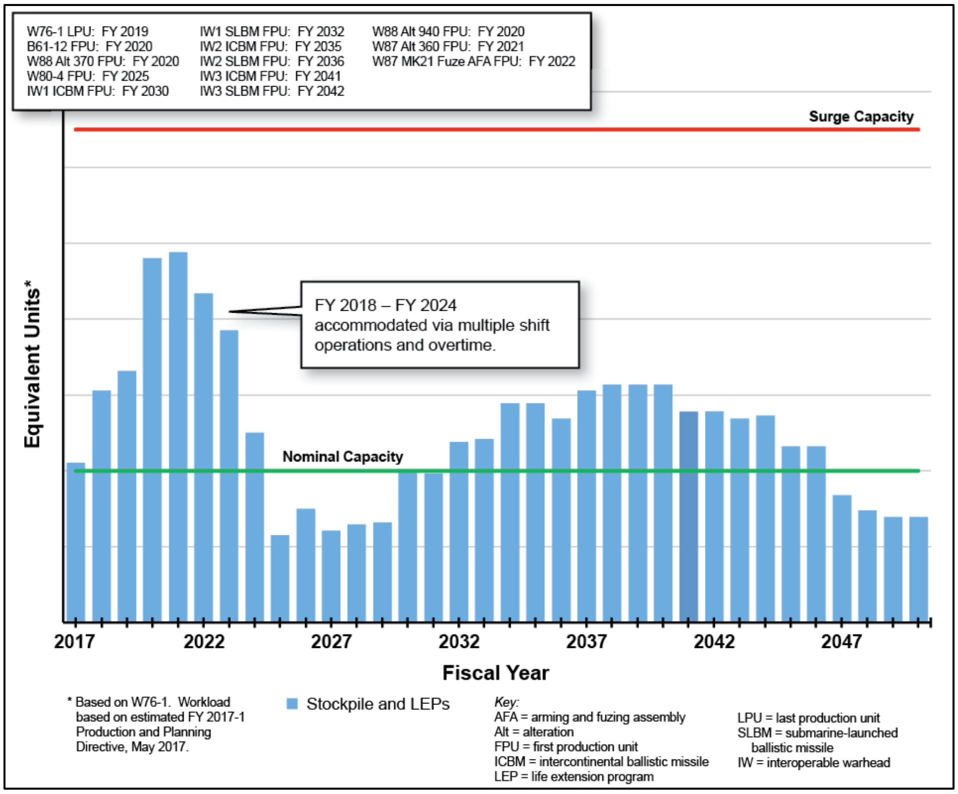


Figure 2–8. Projected out-year workloads for arming, fuzing, and firing and associated electronic production at KCNSC

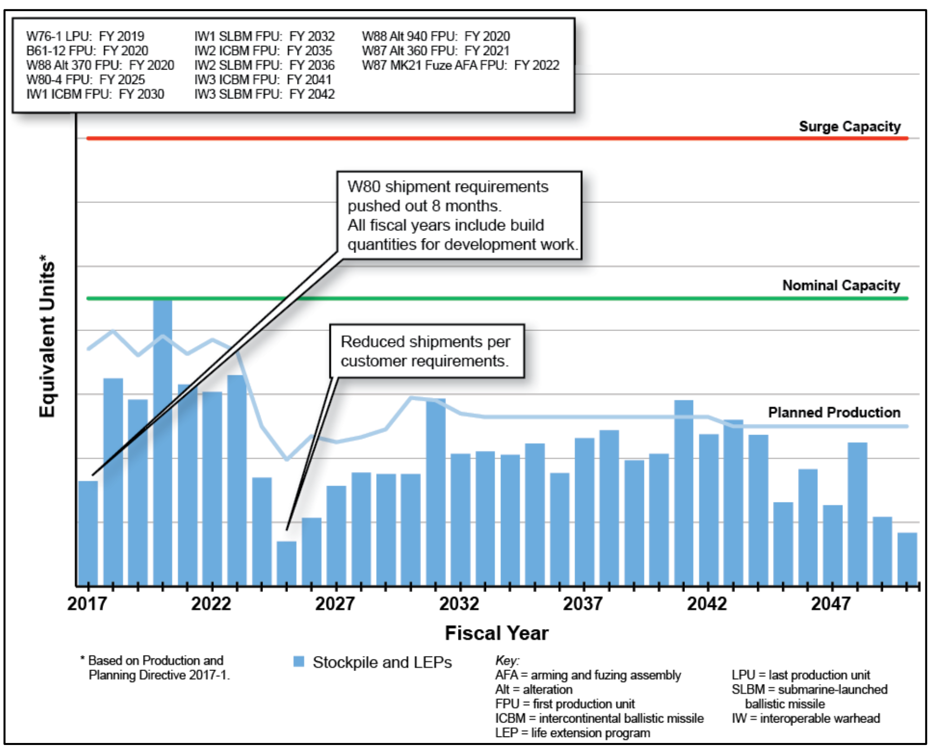


Figure 2–9. Projected out-year workloads for neutron generator production at SNL

2.3.1 The 3+2 Strategy

The 3+2 Strategy guides life extension efforts with emphasis on reduced warhead types and interoperability to enable smaller stockpiles and is the current program of record prior to the completion of the pending Nuclear Posture Review. As each of the remaining warheads or bomb variants within the seven deployed warhead families enters an LEP, the strategy will transition the stockpile into three interoperable NEPs to be used in SLBM and ICBM and will also include two air-delivered weapon types—one bomb and one cruise missile. When fully implemented, the 3+2 Strategy will allow the United States to reduce the number of weapon types, minimize the size of the stockpile, simplify maintenance requirements, and hedge against technological or geopolitical surprise.

When planning an LEP, NNSA evaluates options to reuse, refurbish, or replace components and systems to extend the service life of weapons by an additional 20 to 30 years. LEPs present prime opportunities to improve safety, security, and reliability. Critical and timely investments in areas such as technology maturation, RDT&E, Laboratory Directed Research and Development, and Plant Directed Research and Development will position NNSA to capitalize on innovative technological options. Development of technologies for insertion into the stockpile generally starts 5 to 10 years before an LEP is a formally authorized program of record in order to ensure that new technologies are mature enough for inclusion in an LEP's design strategy.

The 3+2 Strategy is a long-term investment in the U.S. nuclear deterrent, with LEPs scheduled in a steady stream over the next 40 years. Sections 2.3.2 to 2.3.6 describe the status, accomplishments, upcoming milestones and deliverables, and challenges for LEPs and major Alts. Funding estimates are detailed in Chapter 8 of this SSMP.

Challenges to Major Modernization Programs

All life extension programs (LEPs) and major alterations (Alts) face risks from a variety of sources, including:

- *single-point failures associated with aging equipment and facilities;*
- *technical issues in design and certification of components and subsystems; and*
- *budget cuts to other NNSA offices that support modernization efforts through Other Program Money (including Technology Maturation, Enhanced Surety, and other programs).*

Risk Identification Techniques

<u>Earned Value Management System</u>

An Earned Value Management System is a systematic approach to the integration and measurement of cost, schedule, and technical (scope) accomplishments on a project or task. It provides both the Government and contractors the ability to examine detailed schedule information, critical program and technical milestones, and cost data. By comparing actual costs to programmatic milestones accomplished, NNSA is able to determine if a program is within budget and on schedule. The system provides an important safeguard to the risks mentioned above by giving detailed transparency to the work.

<u>Reporting</u>

LEPs and major Alts continually interface with the nuclear weapons production facilities and national security laboratories to solve technical issues and single-point failures. Product team meetings, site reviews, and quarterly program updates to NNSA add accountability across all levels. Starting in Phase 6.3, the major modernization efforts also submit quarterly Selected Acquisition Reports to Congress detailing program expenditures.

<u>Risk-based Contingency</u>

Each LEP and major Alt maintains a management reserve for unexpected challenges. This reserve, or contingency, is an allotment of funds not obligated for specific scope; it helps guard against short-term budget gaps or scope that lags behind schedule.

2.3.2 W76-1 Life Extension Program

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, took place in FY 2009. The last production unit is scheduled for no later than the end of FY 2019. The program is making all warhead deliveries to the Navy on schedule and under budget.

2.3.2.1 W76-1 Life Extension Program Accomplishments

In 2016, the W76-1 LEP passed the 75 percent point in the total number of refurbished warheads scheduled for delivery to the Navy, according to the current program of record. In FY 2016, Pantex exceeded the fiscal year and cumulative warhead production and delivery requirements while delivering refurbished warheads to the Navy on schedule. In FY 2016 the highest quantity of refurbished warheads was produced in any given fiscal year since the first production unit was achieved at the end of FY 2008. In addition, Pantex built the highest number of JTAs for surveillance flight testing since the first flight test unit was built in FY 2009.

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

- 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.

2.3.2.2 W76-1 Life Extension Program Challenges

During FY 2016, several areas challenged NNSA's ability to meet its warhead production and delivery commitments to the Navy. These areas included:

- technical issues associated with production of various warhead components, and
- failure of aging production equipment and facility infrastructure.

These issues were resolved in a timely manner, allowing NNSA to exceed its FY 2016 and cumulative warhead production and delivery requirements while delivering refurbished warheads to the Navy on schedule.

2.3.2.3 Approaches and Strategies for the W76-1 Life Extension Program

Multiple strategies and approaches were used to mitigate program risk associated with production and delivery challenges. These approaches included:

- strategic acceleration for procurement of raw material,
- increased component production quantities to provide positive margin to component delivery schedules,
- allocation of carry-over funds to procure new production equipment to mitigate against aging and single-point failures, and
- use of production efficiencies to reduce program costs and gain positive schedule margin.

2.3.3 W88 Alteration 370

The W88 nuclear weapon, which entered the stockpile in late 1988, is deployed on the Navy's Trident II D5 SLBM system. The weapon is in its third decade of life. Provisioning and aging issues must be addressed to maintain its current state of readiness until the weapon undergoes a comprehensive life extension process.

The W88 Alt 370 includes a new AF&F system, lightning arrestor connector, trainers, flight test assemblies, and associated handling gear and spares. In November 2014, the Nuclear Weapons Council expanded the scope of the W88 Alt 370 to include replacement of CHE main charges and associated components. Changes in initial cost estimates for replacing the main charges are reflected in this SSMP. The W88 Alt 370 conversion is scheduled concurrently with limited life component exchanges of the GTSs and neutron generators.

2.3.3.1 Status of the W88 Alteration 370

Currently in Phase 6.4 (Production Engineering), the W88 Alt 370 is on schedule, with the first production unit planned in December 2019. NNSA recently completed the Baseline Cost Report, which provides a high-fidelity cost estimate. The Baseline Cost Report estimate is $2,618 million; this is approximately $255 million (or 11 percent) higher than the estimate reported in the 2015 SAR. The increased costs were primarily caused by increases in test and qualification, and planning margins for treating technical risks, accompanied by some offsetting reduction in scope associated with the nuclear components. This estimate represents the program baseline and will be reflected in future SARs.

2.3.3.2 W88 Alteration 370 Accomplishments

The following milestones for the W88 Alt 370 were completed:

- All remaining War Reserve component Baseline Design Reviews
- Final Design Reviews on long-lead components
- System Baseline Design Review
- Integrated Baseline Review
- Preliminary Design Review and Acceptance Group Review
- Inter-Laboratory Peer Reviews
- Fourth successful development flight test conducted for the Demonstration and Shakedown Operations test 26
- Baseline Cost Report

2.3.3.3 W88 Alteration 370 Upcoming Milestones and Deliverables

- System-level Final Design Review in FY 2018
- Final flight test qualification (Demonstration and Shakedown Operations tests) in FY 2019
- Phase 6.5 (First Production) with the first production unit in December 2019
- Final Design Review and Acceptance Group Review in FY 2020
- Phase 6.6 (Full-Rate Production) approval in FY 2020

2.3.3.4 W88 Alteration 370 Challenges

Risks

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

Risk Mitigation

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

2.3.4 B61-12 Life Extension Program

The B61 gravity bomb is the oldest nuclear weapon in the stockpile. This LEP will address the multiple components nearing end of life and the military requirements for reliability, service life, field maintenance, safety, and use control. The B61-12 LEP consolidates the B61-3, -4, -7, and -10 in order to reduce the number of gravity bomb variants in the stockpile.

2.3.4.1 B61-12 Life Extension Program Status

The program entered into Phase 6.4 (Production Engineering) in June 2016, which is the final development phase prior to production of War Reserve units. This major milestone included the completion of the B61-12 LEP System Baseline Design Review, 39 gated component baseline design reviews, 3 development flight tests, and over 40 system and subsystem ground tests. During Phase 6.4, the production agencies will adapt the development design for the LEP. This includes production of development hardware and performance of product- and system-level testing. The first production unit is planned for FY 2020. The program is executing on schedule and within budget.

The B61-12 LEP completed the Baseline Cost Report, updating the program cost and schedule. The Baseline Cost Report estimated program costs are $7.605 billion. The B61-12 LEP is continuing to leverage other NNSA programs for multi-system production process improvements. The costs of these other related programs are estimated to be $648 million. The overall program cost is $8.253 billion for a total increase of 1.1 percent from the baseline SAR that was submitted to Congress in FY 2013.

2.3.4.2 B61-12 Life Extension Program Accomplishments

- Third system-level test of Flight Test Development Unit 3, a guided flight at the Tonopah Test Range, completed in October 2015
- Integration tests with the F-15E, F-16, PA-200, F-35, and B-2A that included tests at aircraft simulation laboratories as well as on the aircraft
- System Baseline Design Review, completed in January 2016
- DOD Preliminary Design Review and Acceptance Group Review completed, resulting in a DOD determination that the baseline design meets all requirements
- Entry into Phase 6.4 (Production Engineering), authorized in June 2016
- Baseline Cost Report, completed in October 2016
- Eleven Interface Requirements Agreements maintained with other programs to document the B61-12 dependencies on programmatic deliverables
- First System Qualification Drop Test, completed in March 2017

2.3.4.3 B61-12 Life Extension Program Upcoming Milestones and Deliverables

- System Level Final Design Review in FY 2018
- Phase 6.5 with the first production unit in March 2020
- Final Design Review and Acceptance Group Review in FY 2020
- Phase 6.6 (Full Rate Production) approval in FY 2020

2.3.4.4 B61-12 Life Extension Program Challenges

Risks

Risks for the B61-12 LEP are similar to risks in 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. The schedule risks to the B61-12 will increase as NNSA gets closer to the first production unit as revealed by internal independent reviews.

Risk Mitigation

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

2.3.5 W80-4 Life Extension Program

The United States fielded the ALCM that delivers a W80 warhead in 1982. Both the missile and the warhead are well past their planned end of life and exhibiting aging issues. To maintain this vital deterrent capability, DOD intends to replace the ALCM with the long range standoff missile. In close coordination with DOD, NNSA is life extending the W80 warhead through the W80-4 LEP for use in the LRSO missile on a timeline consistent with the DOD platform modernization schedule.

The W80-4 LEP will consider W80-based reuse, refurbishment, and replacement options. Key design requirements include use of the existing IHE design, incorporation of modern components and safety features, maximum use of non-nuclear components developed for other LEPs, exploration of enhanced surety options, and parallel engineering with the Air Force on the warhead/missile interface.

2.3.5.1 W80-4 Life Extension Program Status

The program is currently in Phase 6.2 (Feasibility Study and Design Options). The first production unit is scheduled for FY 2025.

2.3.5.2 W80-4 Life Extension Program Accomplishments

- Continued advanced design of feasibility concepts
- Continued development of implementation documents (including the NNSA Program Plan, Risk Management Plan, Requirements Management Plan, Configuration Control Management Plan, Systems Engineering Management Plan, Program Controls Plans, and Integrated Phase Gate Implementation Plan)
- Performed the System Requirement Gate review and System Feasibility Gate review in FY 2017.
- Conducted an Inter-Laboratory Peer Review in FY 2017.
- Completed stand-up of Product Realization Teams.

- Provided input in FY 2017 to the Project Officers Group Phase 6.2 Report, identifying the preferred design options for the Nuclear Weapons Council Standing and Safety Committee.
- Completed the LEP infrastructure interface requirements agreement involving equipment and facility investments in FY 2017.

2.3.5.3 W80-4 Life Extension Program Upcoming Milestones and Deliverables

The following are some of the W80-4 LEP deliverables during FY 2017 and thereafter:

- Obtain Phase 6.2A (Design Definition and Cost Study) approval in FY 2018, and present a Weapon Design and Cost Report outlining the program baseline and development plans.
- Obtain Phase 6.3 (Development Engineering) approval at the start of FY 2019.
  - Develop a Baseline Cost Report and a SAR.
  - Complete a detailed design with regard to safety, performance, and production.
  - Produce the final draft of military characteristics.

2.3.5.4 W80-4 Life Extension Program Challenges

Risks

The program faces the unique risk of parallel design with the LRSO missile. This is the first effort in more than 30 years to design the warhead and delivery platform on similar timeframes. Changes or delays to either program may directly impact progress on the other.

Risk Mitigation

NNSA closely aligns its efforts on the W80-4 LEP with DOD to refine program goals and define interface scope. This ensures cost-informed decisions and schedule alignment.

2.3.6 Interoperable Warhead 1

The IW1, currently scheduled to restart in 2020, is planned as an IW for use in the Mark (Mk) 21 ICBM and the Mk5 SLBM aeroshells, with adaptable non-nuclear components and interoperable NEPs. When deferred by the interagency consortium in 2015, only concept development had been completed and military characteristics, particularly as a replacement for the W78 ICBM warhead, remained to be defined.

2.3.6.1 IW1 Accomplishments

- IW1 activities are scheduled to restart in FY 2020 to achieve a first production unit in FY 2030.
- PF-4 at LANL resumed operations and fabricated a W87 pit as part of the planned development series.
- NNSA and the Nuclear Weapons Council approved the selection of the W87 pit for the IW1.

2.3.6.2 IW1 Approaches and strategies

Current technology development efforts are focused on the 3+2 Strategy, which includes the IW1. The investments are being made against technologies that are less than TRL 5 to reduce the risk to future programs. These include investments in security and in security technologies for a more agile, assured, and affordable stockpile. The current pit production strategy supports both IW1 stockpile plans and requirements to address pit aging. The W88 Alt 370 effort, as well as exploratory design option development for future IWs, with Mk21 and Mk5 commonality, provides opportunities to leverage future design and capabilities applicable to IW1. For additional information on pit production strategy and infrastructure plans, see Section 2.4.1, Plutonium.

2.4 Strategic Materials

Strategic materials including but not limited to plutonium, HEU, tritium, and lithium are key for the safety, security, and effectiveness of the Nation's nuclear deterrent as well as addressing national security concerns such as nuclear proliferation and counterterrorism missions. Sustaining the capabilities to store and process these materials require a highly skilled workforce and significant programmatic infrastructure. Weapons components created with these strategic materials cannot be produced outside the United States. In addition to managing individual materials, 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. NNSA has long-term strategies to maintain the facilities, scientific equipment and production, and manpower to sustain the strategic materials. A common obstacle is the need to refurbish or replace the aging and obsolete facilities in which 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.

2.4.1 Plutonium

An agile, reliable, and flexible capability to process and handle plutonium is essential to assess and maintain a credible nuclear weapons stockpile. The manufacture and surveillance of pits and other plutonium components, as well as experiments and analysis of plutonium alloys, occur primarily at LANL's PF-4. SNL, LLNL, Pantex, and the Nevada National Security Site also provide the necessary expertise, capabilities, and facilities to support NNSA's defense-related plutonium missions. Plutonium requires proper storage facilities, safe and secure disposal pathways, and unique equipment and facilities.

U.S. Secretary of Energy Rick Perry visits Los Alamos National Laboratory.

2.4.1.1 Plutonium Accomplishments

- Resumed full operations at PF-4 in FY 2016, including pit surveillance and manufacturing operations.
- Fabricated a production development pit in FY 2016 at LANL; assembled two development pits in FY 2017. After the plutonium work stoppage at PF-4 in 2013, the next War Reserve pit is scheduled for 2023.
- Baselined and initiated construction activities for the first two CMRR subprojects, Radiological Laboratory Utility Office Building (RLUOB) Equipment Installation Phase 2 and PF-4 Equipment Installation Phase 1.

Artist's rendering of Uranium Processing Facility at Y-12 National Security Complex.

- Completed facility and equipment upgrades at LLNL and the Nevada National Security Site to support SNM target assembly fabrication for weapon-related experiments at the National Ignition Facility (NIF) and the Joint Actinide Shock Physics Experimental Research (JASPER) facility.

2.4.1.2 Plutonium Challenges

- NNSA must ramp up pit production over the next decade to meet the required capacity by FY 2030. Meeting these deliverables remains a challenge as LANL continues to invest in manufacturing equipment and associated facilities to reach capability, capacity, and reliability.
- NNSA continues to execute the CMRR project to maintain continuity in analytical chemistry and materials characterization capabilities. NNSA is transitioning these activities out of the Cold War-era Chemistry and Metallurgy Research facility.
- Two plutonium-based programs—radioisotope thermoelectric generator production and plutonium device fabrication for subcritical experiments—must be aligned with pit manufacturing.
- Aging infrastructure continues to impact other aspects of the plutonium mission, including waste processing and storage.
- Expanded storage capacity is needed for plutonium recovered from both retired and dismantled weapons. NNSA continues to execute a strategy to repurpose and reconfigure nuclear material bays to increase the pit storage capacity until a long-term staging facility is available.

2.4.1.3 Plutonium Long-term Sustainment Strategy

NNSA invests in these areas of infrastructure, equipment, and critical skills to meet its plutonium mission requirements. These investments are detailed below.

Plutonium Sustainment Program

The Plutonium Sustainment program provides the production equipment and necessary skills to manufacture pits in support of stockpile requirements. These requirements are outlined in both internal programmatic documents (*e.g.*, the *Requirements and Planning Document*) and external documents (*e.g.*, the current and prior versions of the NDAA). The program supports the production plan to meet these requirements, as shown in **Table 2–3**.

Table 2–3. Production plan

Type	2018	2019	2020	2021	2022	2023		2024	2025	2026	2030
Pit Production Series	Development Builds		Process Prove-in Builds		Qualification Builds	Qualification Builds	W87-like War Reserve Build	W87-like War Reserve Builds			
Pits per year	4	5	5	5	5	5	1	10	20	30	50–80

Chemistry and Metallurgy Research Replacement Project (Line-Item Construction Project)

The CMRR project optimizes the use of LANL's existing facilities by reconstituting analytical chemistry and materials characterization capabilities previously performed in the Chemistry and Metallurgy Research facility into laboratory space in PF-4 and the RLUOB. The first two phases of equipment installation subprojects (RLUOB Equipment Installation Phase 2 and PF-4 Equipment Installation Phase 1) achieved CD-2/3 (Approve Performance Baseline/Approve Start of Construction) in October 2016.

Pit Production

Additional infrastructure is needed to support increased pit production and plutonium mission requirements. CD-0 (Approve Mission Need) for the Plutonium Modular Approach was approved in November 2015, and an AoA is underway to consider a range of infrastructure options across DOE and NNSA that can support capabilities for increased pit production capacity and enduring plutonium mission needs. The AoA is targeted for completion in early FY 2018.

Aging Plutonium Facilities

NNSA is addressing the aging infrastructure at LANL that supports defense-related plutonium activities by modernizing waste processing and treatment facilities through recapitalization and line-item projects.

2.4.2 Uranium

Uranium is a strategic national defense asset with different assays and enrichments (depleted uranium, low-enriched uranium [LEU], and HEU) for a wide variety of applications, including weapon components, naval reactors, and in commercial power reactors for the production of tritium.[16] The primary production infrastructure to store and process uranium is located at Y-12.

2.4.2.1 Highly Enriched Uranium

HEU is a type of uranium in which the concentration of uranium-235 has been increased to 20 percent or greater, and up to 90 percent.

Highly Enriched Uranium Accomplishments

- Completed the relocation of radiography operations in Building 9212 by transitioning them to Building 9204-2E.
- Achieved CD-2/3 (Approve Performance Baseline/Approve Start of Construction) for several Uranium Processing Facility subprojects.
- Initiated electrical investments in Building 9215 and Building 9204-2E.
- Achieved TRL 6 (Representative of the Deliverable Demonstrated in Relevant Environments) on the calcination, electrorefining, and microwave technologies.
- Transferred multiple metric tons of enriched uranium material to the Highly Enriched Uranium Materials Facility for secure long-term storage.

Highly Enriched Uranium Challenges

- Construct a new Uranium Processing Facility at Y-12 by 2025 for a cost not to exceed $6.5 billion, and cease enriched uranium programmatic operations in Building 9212.
- Ensure the smooth transition of enriched uranium operations as certain Building 9212 capabilities are being relocated into existing facilities at Y-12 and other capabilities are transitioned into the Uranium Processing Facility.
- Plan and execute multi-year infrastructure investments to extend the operational lifetime of Building 9215 and Building 9204-2E into the 2040s.
- Sustain existing enriched uranium operations at a high rate of reliability.
- Mature key enriched uranium technologies for insertion into existing facilities at Y-12 and into the Uranium Processing Facility.
- Modify Uranium Processing Facility design to eliminate specified deficiencies to comply with industry codes and standards, and to reinstitute thermal barriers that minimize fire risk.

Highly Enriched Uranium Long-term Sustainment Strategy

NNSA approved the following long-term strategy to produce, process, recycle, and store uranium.

[16] Depleted uranium is primarily U^{238}; low-enriched uranium is less than 20 percent U^{235}; and HEU is primarily greater than or equal to 20 percent U^{235}.

- Phase out the mission dependency on Building 9212 by relocating several of the facility's enriched uranium capabilities into existing facilities at Y-12 and into the Uranium Processing Facility.
  - Deploy a calciner in Building 9212 to stop recovery of low equity materials and prepare the facility for eventual downgrading and decommissioning.
  - Deploy electrorefining technology in Building 9215 to supply purified uranium metal.
  - Relocate chip processing to Building 9215, where the machine turnings are produced.
  - Relocate the 2-million electron volt radiography operations to an existing x-ray vault in Building 9204-2E.
  - Construct the Uranium Processing Facility to house the enriched uranium capabilities in Building 9212 that are not suitable for relocation to Building 9215 or Building 9204-2E.
- Invest in the infrastructure of Building 9215 and Building 9204-2E to extend the operational lifetime of these facilities into the 2040s.
- Sustain and modernize the manufacturing capabilities for casting, machining technology, and purified metal production.
- Continue to transfer enriched uranium materials to the Highly Enriched Uranium Materials Facility for long-term safe and secure storage.

Figure 2–10 captures the movement of operations out of Building 9212 into other facilities.

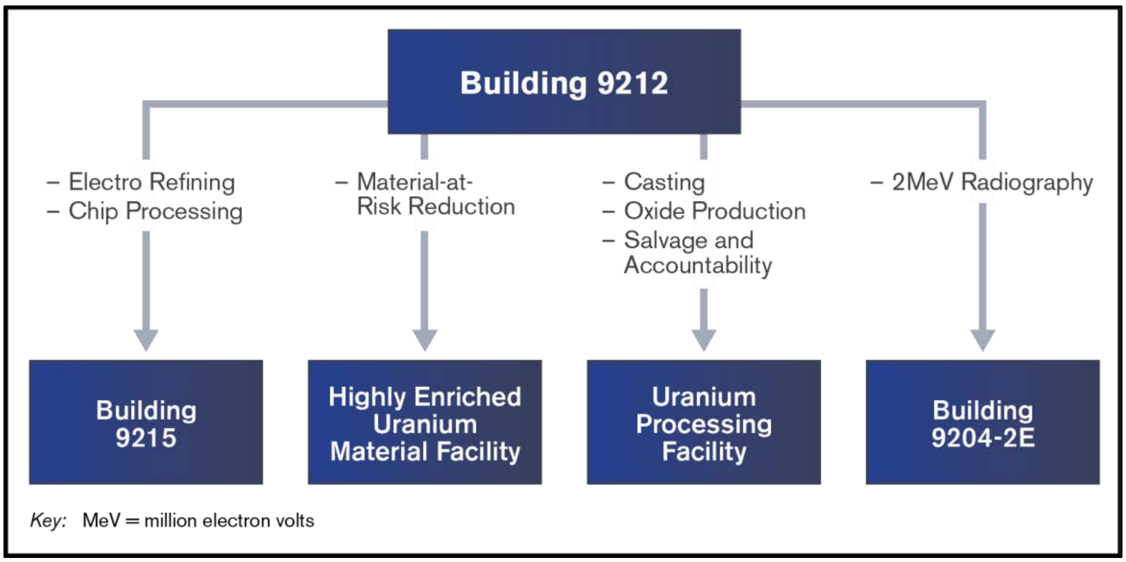


Figure 2–10. Diagram of the Uranium Strategy at Y-12

2.4.2.2 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.

Depleted Uranium Accomplishments

In December 2015, NNSA held a Depleted Uranium Summit at Y-12 and outlined a strategy to maintain this vital material, which has applications across multiple NNSA missions.

Depleted Uranium Challenges

Based on the current supply and demand model, NNSA estimates a shortfall of depleted uranium in the 2029 to 2031 timeframe.

Depleted Uranium Long-term Sustainment Strategy

- Complete ongoing procurement of additional depleted uranium feedstock.
- Survey potential depleted uranium source material internal and external to the nuclear security enterprise.
- Investigate procurement to convert depleted uranium hexafluoride (DUF_6) to depleted uranium tetrafluoride (DUF_4).
- Investigate alternate processes and technology improvements that increase the efficiency of traditional manufacturing processes.[17]

2.4.2.3 Domestic Uranium Enrichment (Low-enriched Uranium)

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 as well as for medical isotope production. A domestic uranium enrichment capability provides a reliable supply of enriched uranium to support the variety of U.S. missions.

Domestic Uranium Enrichment Accomplishments

- Centrifuge R&D efforts demonstrated reliability improvements to the AC100 Centrifuge.
- Component design began for a smaller, national security centrifuge that, based on Oak Ridge National Laboratory's Optimization Model, will maximize performance and minimize overall construction and operational costs.
- Completed updated analysis of uranium inventory availability to support tritium production.
- Completed CD-0 (Approve Mission Need) for a domestic uranium enrichment capability.

Enriched Uranium for Tennessee Valley Authority Power Reactors

Power reactors require many tons of low-enriched uranium (LEU). Normally, private industry supplies LEU fuel for these reactors. All fuel in the Tennessee Valley Authority reactors to produce tritium must be unobligated and unencumbered. This creates an additional strain on the current inventory of enriched uranium.

Domestic Uranium Enrichment Challenges

The United States no longer has a uranium enrichment capability for national security missions. The Nation's stockpile of HEU material is repurposed and/or down-blended to meet the enriched uranium requirements listed above; however, that supply is finite and, at present, irreplaceable. The near-term requirement is for LEU fuel to support tritium production in selected Tennessee Valley Authority (TVA) nuclear power reactors. U.S. policy requires enriched uranium for defense missions such as tritium production to be free from domestic peaceful use restrictions (*unencumbered*) and from foreign peaceful use obligations (*unobligated*).[18] These restrictions arise from U.S. nonproliferation policy chosen after a

[17] The majority of this work is funded by the Material Recycle and Recovery program and Storage program. For additional information on these programs see Section 2.4.6.

[18] Peaceful use obligations are stipulations placed on uranium by suppliers that the buyers not use the material for purposes related to SNM or nuclear explosive devices.

1998 interagency interpretive review of U.S. implementation of the 1970 "peaceful use" article of the Treaty on the Non-Proliferation of Nuclear Weapons.[19]

Domestic Uranium Enrichment Long-term Sustainment Strategy

To provide a reliable supply of unobligated and unencumbered enriched uranium, NNSA is implementing a three-pronged strategy.

- **Use the HEU inventory to delay the date for which LEU fuel is required for tritium production.** NNSA has identified existing unobligated and unencumbered material to power the TVA reactors through 2038 to 2041. Much of the material is less attractive HEU that will be down blended to LEU between FY 2019 and FY 2025. The timeframe for down blending is required to maintain continuous operations at the only commercial down blender, which would otherwise shut down in the absence of feed material. The annual cost of down blending is less than constructing a new enrichment facility. However, because the HEU inventory is finite and, at present, irreplaceable, down blending is a temporary solution.
- **Develop an enrichment technology.** Following an analysis of available enrichment technologies, NNSA determined that centrifuge technologies had the highest technical maturity and lowest risk. NNSA is conducting centrifuge R&D efforts at Oak Ridge National Laboratory.
- **Establish a national security enrichment capability.** Because of the finite nature of the HEU inventory, the United States will eventually need a new uranium enrichment capability. NNSA approved the mission need (CD-0) for this capability in December 2016.

2.4.3 Tritium

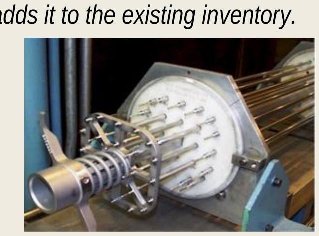
Because of its short radiological half-life, tritium must be periodically replenished. To sustain the tritium inventory, NNSA recovers tritium from two sources at SRS. Currently the primary source is end-of-life GTS reservoirs that are returned to SRS. The second source is irradiated TPBARs from TVA.

The DSW Production Support program is responsible for the return and unloading of GTS reservoirs at SRS. The Strategic Material Sustainment program is then responsible for processing and purifying returned gas for this material recovery.[20]

The Tritium Sustainment program is responsible for producing tritium through a commercial supply chain that includes fabrication of lithium targets, irradiation of these targets, transportation of the targets to SRS, and extraction of tritium in the Tritium Extraction Facility. Tritium is thus available to meet GTS production numbers and planning directives.[21] Maintaining the current infrastructure for the tritium supply chain and advancing new capabilities through R&D are vital to meeting national security needs. NNSA is committed to meeting these challenges.

Tritium-Producing Burnable Absorber Rods

Tritium is produced by irradiating lithium-aluminate pellets with neutrons in a commercial nuclear power reactor, Watts Bar 1, operated by the Tennessee Valley Authority. TPBARs are similar in dimension to reactor fuel rods; with irradiation, the tritium is produced and captured on getters. SRS extracts tritium from the irradiated rods, purifies it, and adds it to the existing inventory.



[19] Due to changing circumstances, the GAO, in GAO-15-123, is calling for a potentially re-interpretive review again of uranium policies related to tritium production.

[20] See Material Recycle and Recovery and Storage for additional information in Section 2.4.6.

[21] See the Section 2.2.4.1 (Gas Transfer Systems) for additional information on tritium production following tritium-producing burnable absorber rods (TPBAR) irradiation.

2.4.3.1 Tritium Production

The requirement for TPBAR irradiation is illustrated in **Figure 2–11** and nominally described as producing 2,800 grams of tritium every 18 months by 2025. Keeping to the ramp-up schedule and the number of TPBARs per cycle are both important for meeting the tritium production requirement.

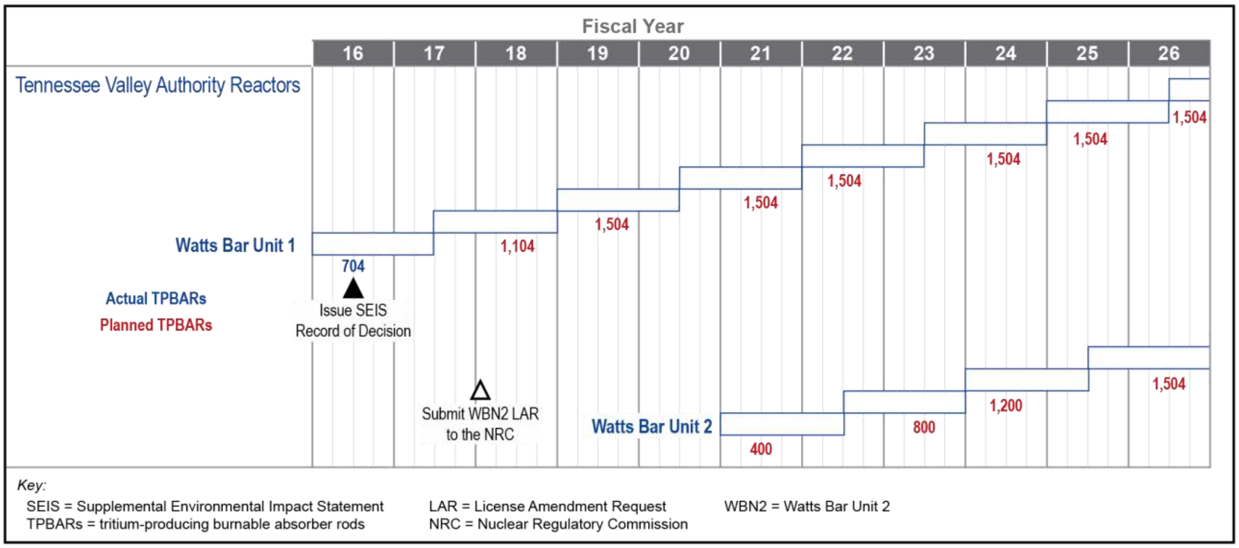


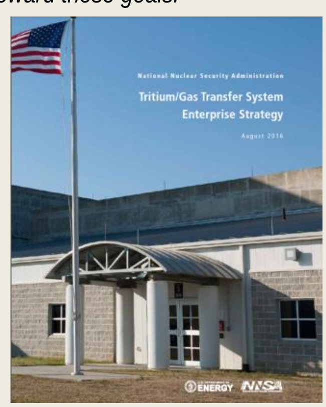
Figure 2–11. Schedule for irradiating tritium-producing burnable absorber rods in two reactors at the Tennessee Valley Authority

Figure 2–11 shows the numbers of TPBARs and the irradiation schedule to meet tritium production requirements. Each horizontal bar represents an 18-month irradiation cycle at TVA's nuclear reactor site.

The Watts Bar Unit 1 nuclear power reactor, operated by TVA, is currently being used to irradiate 704 TPBARs for tritium production. As illustrated above, TVA must ramp up the number of TPBARs in Unit 1 to 1,504 TPBARs. The Nuclear Regulatory Commission (NRC) approved TPBAR license amendment request allows Unit 1 to ramp up to 1,504 (and up to 1,792, if necessary). In addition, Watts Bar Unit 2 must begin irradiation of TPBARs by the end of FY 2020, which entails all necessary licensing, equipment installation, *etc.*, to begin irradiation and also ramp up to 1,504 TPBARs by 2025. As indicated, TVA will submit a License Amendment Request to NRC for Unit 2. NRC has already conducted an initial public meeting on irradiating TPBARs in Unit 2.

Tritium Enterprise Strategy

In 2016 the Office of Tritium and Materials Management published the long-term plan to maintain tritium reserves. This document outlines the goals of the program and the contribution of each major nuclear security enterprise site toward these goals.



In addition, the Tritium Extraction Facility must also ramp up extraction to accommodate the increased number of TPBARs. Currently, the Tritium Extraction Facility has conducted roughly one extraction per year in a responsive operations mode. In FY 2017, SRS conducted three back-to-back extractions to exercise full operations procedures and capabilities. By 2026, the Tritium Extraction Facility will be required to complete seven extractions every year. The Tritium Extraction Facility was designed to perform approximately 14 extractions per year. However, given the current facility status, several infrastructure enhancements or system upgrades, such as direct stacking, are needed to accommodate the increased processing of TPBARs and tritium at SRS.

2.4.3.2 Tritium Recycle

Most of the gas loaded into current GTSs comes from unloaded GTSs and containers at SRS. Unloaded gas is processed *via* flow through beds and diffusers to separate tritium from all other gases. As this tritium supply decreases, tritium production will eventually be increased to supply the tritium needed for the GTSs, R&D, and container loading. This recycle process is funded by the Material Recycle and Recovery (MRR) program.

2.4.3.3 Tritium Accomplishments

- Obtained approval from the NRC for the License Amendment Request that allows TVA to increase the maximum number of TPBARs irradiated per 18-month reactor cycle.
- Shipped 300 TPBARs from TVA to SRS and stored them in the Tritium Extraction Facility.
- Completed the Tritium Supplemental Environmental Impact Statement and Record of Decision.
- Designated the second TVA reactor, Watts Bar Unit 2, to produce tritium and held an initial public meeting on the license amendment request.

2.4.3.4 Tritium Challenges

- Operate with limited supplies of tritium, recapitalize the hydride storage beds and the Isotope Separation System column, replace unique equipment supplied by a limited number of vendors, and model the tritium inventories at SRS.
- Meet the TVA goal of producing 2,800 grams per 18-month cycle by 2025, as illustrated by the schedule in Figure 2–11. To achieve this production requirement, additional actions must be completed. These include obtaining appropriate licensing at Watts Bar Unit 2, demonstrating flag swapping and down blending of uranium for unobligated fuel, assessing transportation requirements to meet operational needs at TVA and SRS, demonstrating the continuous extraction capability at the Tritium Extraction Facility, and implementing infrastructure enhancements.[22] These actions are the responsibility of the Tritium Sustainment program.

2.4.3.5 Tritium Long-term Tritium Supply Strategy

NNSA's long-term strategy for sustaining a tritium supply is to recycle and recover tritium from limited life component returns and to provide a production capacity of 2,800 grams per TVA reactor cycle. This strategy is discussed further in the following sections. More details are provided in NNSA's 2016 *Tritium Enterprise Strategy*.

2.4.4 Lithium

NNSA uses lithium in manufacturing nuclear weapon components. NNSA also supplies lithium materials to the Department of Homeland Security and the DOE Office of Science.

2.4.4.1 Lithium Accomplishments

- Initiated a formal AoA for recapitalization of lithium production capability.

[22] See Section 2.4.2.3 (Domestic Uranium Enrichment) for additional information on the strategy to mitigate this risk.

2.4.4.2 Lithium Challenges

The United States no longer maintains full lithium production purification capabilities and relies on recycling as the only source of lithium for nuclear weapon systems. At over 70 years old, the existing lithium processing facility at Y-12 is one of the oldest operating facilities in the nuclear security enterprise. These factors increase the risk associated with direct material manufacturing generated supply and qualification issues.

2.4.4.3 Lithium Long-term Sustainment Strategy

NNSA is funded to continue to use the existing, aged lithium processing facility and its equipment to meet near-term stockpile needs while implementing a lithium bridging strategy and developing a plan for a new lithium production capability to address long-term capability requirements.

- NNSA has identified a number of retired weapons systems and CSA inventories that could be a source to recycle lithium to augment currently certified sources. LANL and LLNL will certify these additional sources for LEP components.
- A few processes will be restarted in the existing lithium processing facility in the near term to provide additional feedstock material and eventually accommodate newly identified material from retired weapons by deploying a new material recycle cleaning station and outsourcing purification and conversion capabilities.
- NNSA will upgrade the existing lithium processing facility's structure, heating, ventilating, air conditioning, electrical, and fire safety systems to ensure that the facility can continue to provide stockpile requirements until a new lithium production capability becomes operational.
- NNSA will mature and develop lithium production technologies to introduce efficiencies into the current process and to prepare for the insertion of these new technologies into the lithium production capability.
- NNSA has completed a comprehensive lithium production capability AoA that is part of the CD-1 process for capital construction project management. A conceptual design effort will commence for the new lithium production capability.

2.4.5 High Explosives

HE are used in the NEP and in non-nuclear support systems. The broad range of activities needed to formulate, process, and test HE materials and components requires numerous facilities across multiple nuclear security enterprise sites. The infrastructure to support these efforts includes unique experimental facilities, characterization laboratories, confined and outdoor firing and testing, fabrication operations that include pressing and machining, and materials development facilities. LANL has nuclear design, HE science, and detonator production missions. LLNL has nuclear design and HE science missions; SNL has non-nuclear component missions that require use of HE; and Pantex has production missions for boosters and main charges.

High Explosives Strategy

This strategy, approved in July 2016, sets three goals:

1) *Deliver high explosive (HE) materials for stockpile sustainment and modernization while working toward an all insensitive HE stockpile.*
2) *Sustain and modernize the HE infrastructure.*
3) *Achieve a responsive infrastructure for national security needs.*

2.4.5.1 High Explosives Challenges

Current challenges center on both maintaining the availability of HE materials and components and recapitalizing the infrastructure capabilities of HE, as summarized below.

HE Materials and Components Challenges

Commercial demand for these HE materials is very limited, so the United States must maintain production and processing capabilities for both CHE and IHE.

- **Conventional High Explosives.** Although NNSA would like to use-IHE wherever possible, the W88 Alt 370 includes a CHE refresh, which will keep CHE in the stockpile for the foreseeable future. CHE is also used in detonators and other non-nuclear components.
- **Insensitive High Explosives.** IHE is more resistant to shock and fire than CHE. However, both the active energetic ingredient and the binder ingredient were out of production between 1993 and 2014. NNSA has relied upon a stockpile of already-produced energetic ingredient and binder, but that stockpile is not sufficient to supply all upcoming LEPs.
- **Non-nuclear High Explosive Components.** These HE components include detonators, timers and drivers for neutron generators, actuators, initiators for spin-rocket motors, explosive firing sets, and isolators. These components span a wide range of functions, designs, and chemistries that make it difficult for commercial vendors to meet all nuclear weapon requirements. The stringent specifications and diversity of these energetic materials do not provide the economic incentives necessary for commercial vendors to improve their existing processes. In addition, the number of commercial vendors has decreased. NNSA must collaborate with DOD and industrial partners to produce HE as well as for in-house production authority such as War Reserve detonator powder production.
- **Infrastructure and Equipment.** Aging HE facilities for RDT&E require recapitalization, consolidation, and modernization to support current LEP activities and emerging weapons program needs. HE storage at LANL and LLNL is currently adequate; however, many facilities at Pantex were not constructed to meet modern safety design criteria for HE. Many Pantex facilities are World War II-era buildings that have been identified for replacement.
- **Baseline Analytical Tools.** Acceptance of HE materials and components for use in nuclear weapons requires high-precision testing and detailed understanding of material properties. Basic chemistry and testing laboratories are vital but suffer from infrastructural failings.

2.4.5.2 High Explosives Long-term Sustainment Strategy

HE facilities across the nuclear security enterprise require recapitalization to support LEP activities, improve efficiencies, reduce downtime, and maintain baseline capabilities. NNSA will continue to meet its near-term mission commitments and strengthen the existing HE capabilities, while planning and making capital investments. Capital investments include:

- construction of new facilities,
- modernization of other facilities,
- consolidation of like activities,
- return of several facilities to their intended purpose, and
- demolition of several facilities that are too costly to maintain or are no longer needed.

High Explosive Pressing Facility

The risk to high explosive (HE) operations will be reduced as a result of the completion of the High Explosive Pressing Facility in February 2017. That new Pantex facility, which consolidates operations from numerous buildings, will greatly reduce the movement of HE within Pantex. Programmatic operations at the new facility are scheduled to begin in the second quarter FY 2018.

As an example, critical baseline capabilities in characterization, diagnostic testing, and detonator production support work at LANL are under evaluation for modernization options. A new capability is also under development to reprocess available non-nuclear energetic materials by engineering their purity and morphology for existing and future applications. Weapon performance is sensitive to the manufacturing process for the high explosives. Development of new IHE formulations have the potential to improve the safety and other characteristics of explosives used in the future stockpile.

Work is currently ongoing across the nuclear security enterprise to reformulate triaminotrinitrobenzene (TATB) for use in LEPs. The US no longer has a store of TATB, and the binder that was historically used is no longer produced commercially. NNSA efforts will re-establish the capability to manufacture and qualify insensitive high explosives for life extension programs. With these ongoing R&D efforts to reformulate TATB and to develop new IHEs, NNSA will be able to meet its strategic goals to support the LEP schedule as well as stockpile surveillance and assessment. A TATB Working Group of scientists from LANL, LLNL, Pantex, and DOD partners has met to share research and collaborate on TATB reformulation. This group is making progress towards a reconstituted formulation capability goal that will not impact LEPs. In May 2016, DOE updated the IHE qualification standard for safety. This standard defines IHE performance better than the previous standard and will be helpful in formulating new IHEs.

2.4.6 Material Recycle and Recovery and Storage

The MRR program and the Storage program are integral to strategic materials sustainment. With materials recycled from assembly operations, limited life components, and weapons dismantlement, MRR provides vital quantities of strategic materials (*i.e.*, plutonium, uranium, lithium, and tritium) to sustain the Nation's nuclear deterrent, thereby allowing the nuclear security enterprise to forgo the expense of producing new quantities of these materials. The MRR program and the Storage program interface directly support the Federal managers for sustainment of tritium, uranium, plutonium, and the proposed lithium sustainment, as well as LEPs and weapons dismantlement and disposition. Important efforts overseen by the MRR program and the Storage program include the de-inventory of LANL's Chemistry and Metallurgy Research and PF-4 vault facilities, the re-establishment of the capability to deliver high purity depleted uranium feedstock, and the separation of tritium from other gases after limited life component unloading so the gas can be reloaded into GTSs. MRR processes provide capabilities supporting all tritium processing. The Storage program also provides for management of storage such as the cost of receipt, inventory logistics for nuclear and non-nuclear materials, surveillance, and storage of dismantled warhead components.

2.4.6.1 Material Recycle and Recovery and Storage Accomplishments

- Exceeded production goal to meet Defense Programs requirements, replenished metal, provided a risk mitigation inventory, and reduced the backlog of legacy materials in storage.
- Supported material-at-risk (MAR) reduction efforts at Y-12 by processing all remaining HEU in Building 9212 as a feed for purified metal and by removing many CSAs from Area 5.
- Exceeded expectations for activities associated with transuranic (TRU) waste management at LANL for the High Efficiency Neutron Counter-3 and mobile loading demonstration, which established an additional 25 kilograms of MAR TRU storage, helping to manage TRU waste issues until the Waste Isolation Pilot Plant becomes fully functional.
- Accomplished risk reduction activities and vault material disposition at LANL, including MAR reduction on the PF-4 main floor by 22 percent.

- Established a Nuclear Materials Management and Storage program at the Nevada National Security Site, which is compliant with DOE Directives (*i.e.*, DOE Order 410.2, *Management of Nuclear Materials*, and DOE Manual 441.1-1, *Nuclear Material Packaging*). That effort includes support of LANL initiatives for container surveillance and life extension activities.
- Processed unloaded and newly extracted tritium gas at SRS at the required quantities and purity to meet the GTS and R&D needs of the nuclear security enterprise.

2.4.6.2 Material Recycle and Recovery and Storage Challenges

- **Expanding the Storage Capacity for Plutonium from Retired Weapons.** The largest portion of the U.S. weapons-usable plutonium inventory is in the form of retired pits. 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. NNSA is validating the requirements for additional long-term pit storage space and taking near-term actions to increase the available storage space within existing facilities until the long-term requirements are validated.
- **TRU Waste Management and Storage Capacity at LANL and across DOE.** TRU waste management and storage capacities are critical for TRU drums. The radiological release at the Waste Isolation Pilot Plant in February 2014 stopped TRU waste shipments and imposed an operational constraint on plutonium programs throughout the nuclear security enterprise. The start-up of LANL's TRU Waste Facility is essential to provide waste staging capacity until the Waste Isolation Pilot Plant begins accepting full shipments from LANL.
- **Maintaining the Health of Storage Process Systems.** Safely, compliantly, and efficiently storing materials is necessary to meet Weapons Activities goals. Sustaining capabilities to process materials for storage and optimizing the existing storage space is challenged by funding levels and other funding priorities.
- **Re-establishing Capability to Produce Depleted Uranium and Depleted Uranium-Alloyed Component Feedstock.** Inventories of high purity depleted uranium metal feedstock are being exhausted. NNSA maintains an inventory of DUF_6 but does not have the capability to convert it to DUF_4. Commercial capabilities currently exist to convert DUF_4 to depleted metal but do not exist to convert DUF_6 to DUF_4. A supply of DUF_4 must be re-established to provide feedstock material for conversion to depleted uranium metal. NNSA projects a shortfall of depleted uranium in FY 2029 to FY 2031.[23]

2.4.6.3 Material Recycle and Recovery and Storage Long-term Sustainment Strategy

- **Expanded Storage Capacity for Plutonium from Retired Weapons.** In the near term, NNSA will execute a strategy to stage the pits in nuclear material bays until a long-term staging facility is available. A potential long-term solution to address storage capacity is a new material staging facility.
- **TRU Waste Management and Storage Capacity at LANL and across DOE.** Phase I of the Waste Isolation Pilot Plant Recovery Plan has been completed. Phase II involves *initial* resumption of waste disposal operations, followed by installation and operation of a new ventilation system. LANL has developed a strategic plan for the management of newly generated TRU waste until the Waste Isolation Pilot Plant is fully operational. At this time, LANL has received approval for only

[23] For more information on the sustainment strategy for depleted uranium, see Section 2.4.2.2.

prioritized/critical shipments. The TRU Waste Facility needs to receive drums by the end of 2017 in order to avoid impacting NNSA programmatic operations.

- **Replacement of Isotope Separation Systems and Hydride Storage for Tritium at SRS.** Tritium R&D has progressed to the point that the current Isotope Separation System columns can be replaced with newer technology that increases operating efficiency in a smaller column footprint. As tritium storage beds and separation systems age, NNSA will continue to replace these vital systems annually with more efficient beds and columns to retain the ability to recycle and enrich tritium to load GTSs.
- **Enriched Uranium Purified Metal.** Operations that support delivery of purified enriched uranium metal are currently housed in the aging Building 9212 facility. The Uranium Mission Strategy outlines the plan to cease enriched uranium programmatic operations in Building 9212 no later than 2025. This will involve transfer of the mission critical capabilities into new (*e.g.*, the Uranium Processing Facility) and enduring facilities (*e.g.*, the electrorefining in Building 9215).

2.5 Stockpile Services and Support Programs

2.5.1 Production Support

Production Support, the backbone for the manufacturing capability of the stockpile, includes multi-system manufacturing program activities that provide the workforce and individual site capability and capacity to sustain the nuclear security enterprise's production mission. Production Support funding sustains DSW capabilities and enables modernization of production capabilities to improve efficiency and prepare manufacturing operations to meet future requirements.

To improve cost efficiency, Production Support implemented a neutron generator funding model in FY 2016 that provides the base capability to develop and produce neutron tubes and neutron generators for all weapon systems, while Stockpile Systems maintenance funding pays for production of the neutron generators to be installed in the individual systems. Production Support requires close coordination with the Component Manufacturing Development (CMD) activity under the Advanced Manufacturing Development Program, which is charged with development and initial deployment of new manufacturing and production capabilities.

The Production Support mission includes the following elements.

Engineering Operations. This element includes internal plant-wide activities that establish product process flows and improvements; develop and maintain operating procedures; determine critical design parameter and manufacturing process capabilities; establish process controls, metrics, and quality indices; establish and maintain methods for resiliency to subversion; and develop process safety controls and assessments.

Manufacturing Operations. This element includes activities that manage and provide oversight to manufacturing departments and include all internal non-weapon-type specific manufacturing operations and processes, material controls, supervision, planning and scheduling, inventory control, packaging, shipping and procurement, and internal production-related transportation and safety activities. This element also includes classified manufacturing operations that cannot be associated with a particular warhead.

Quality, Supervision, and Control. This element includes activities dealing with quality control of operating expenses, supervision of general in-line inspection and radiography, development and execution of procedures, process control certification for War Reserve products, measurement standards and calibration techniques as well as calibration of equipment, tooling, gauges, and testers and quality assurance-related equipment and processes for certification.

Tool, Gauge, and Equipment Services. This element includes preparation of specifications and designs for non-weapon-type specific tooling (tools, gauges, jigs, and fixtures), test equipment and design, and development of tester software (including tester control and product assurance).

Purchasing, Shipping, and Materials Management. This element includes activities relevant to planning, engineering, supplier management, and logistics associated with the materials supply chain.

Electronic Product Flow. This element includes activities relevant to internal plant-wide purchase, design, development, installation, configuration, testing, training, and maintenance of computer systems (hardware and software). These activities are directly linked to the performance of site-specific production functions, but are separate and distinct from general-use administrative and office-automated systems. Supported systems in both unclassified and classified environments enable manufacturing and quality assurance functions. In these environments, information technology (IT) elements are directly linked to plant-wide productions.

2.5.1.1 Production Support Accomplishments

- Improved detonator cable assembly manufacturing and inspection processes for production efficiency at LANL.
- Launched a multi-year project to modernize the LANL production plant by making it paperless through the use of digital data.
- Completed 112 percent of required neutron generator builds and shipped 100 percent of required neutron generator shipments at SNL.
- Completed procurement of an additional ion mill for electronics fabrication and a focused ion beam microscope for supplier product verification at KCNSC.
- Created and deployed a common Stockpile Program Production Baseline that merges Pantex and Y-12 production commitments.
- Completed conceptual designs and planning estimates for two projects at SRS: Replacement of Production Unloading Lasers, and Function Test Station Data Acquisition System Upgrades. Both projects are critical to sustain the limited life component exchange loading and GTS surveillance missions.
- Acquired an additional mass spectrometer from Idaho National Laboratory to serve as a critical spare at SRS.
- Upgraded and/or replaced multiple machine tools and other equipment throughout the nuclear security enterprise.

2.5.1.2 Production Support Challenges

- Production Support maintains the base capability of the production sites. As the production sites prepare for the increased workload and throughput as LEPs enter production, these sites are growing capabilities both in personnel and equipment to meet deliverables. Part of the manufacturing base consists of unique, aging equipment. As the production sites procure new equipment and hire additional personnel, the existing workforce is needed to manage the increasing workload, install new equipment, and train new personnel. This creates risk to the program in the near- to mid-term.

- Aging infrastructure (*e.g.*, power distribution systems, heating, ventilation, and air conditioning) at multiple sites across the nuclear security enterprise continues to impact aspects of the Production Support mission.

2.5.1.3 Production Support Near-term Strategy

- Provide the manufacturing capabilities (*e.g.*, engineering, manufacturing, quality assurance) and capacity for LEP production, enduring stockpile weapon assembly, weapon disassembly, component production, depleted uranium production, and weapon safety and reliability testing.
- Provide the foundation for capabilities and capacity within the nuclear security enterprise to sustain DSW activities.
- Assess and prioritize needed technologies to maintain base capabilities of the enduring stockpile weapons.
- Prepare (engineering and quality) for B61-12 LEP non-nuclear components at KCNSC.
- Operate five neutron generator production lines at SNL.
- Continue funding of NEA at SNL and KCNSC.
- Support the needs of the B61-12 LEP through equipment and process costs for neutron generator and production workload to meet schedules.
- Develop robust IHE production capability to meet B61-12 LEP and W80-4 LEP schedules.
- Conduct a multi-year effort, through FY 2021, to upgrade and integrate weapon logistics, nuclear materials accountability, production planning, and scheduling systems.

2.5.1.4 Production Support Long-term Strategy

- Increase efforts through FY 2021 at Y-12 to support lithium direct material manufacturing.
- Increase the detonator cable assembly production at LANL from one to five lines, invest in new equipment to enable higher yield rates, improve the shop floor design, and develop a manufacturing modernization project to support digital product acceptance and increased production.

2.5.2 Management, Technology, and Production

Management, Technology, and Production activities sustain the stockpile by providing the workforce, products, components, and services for multi-weapon system surveillance in the form of laboratory and flight test data collection and analysis, weapons reliability reporting to the DOD, weapon logistics and accountability, and stockpile planning.

Management, Technology, and Production funding is pooled across NNSA sites for a coordinated product realization approach to information systems used to record the quantities, values, and status of weapon and component transactional activities.

The Management, Technology, and Production mission includes the following elements.

Product Realization Integrated Digital Enterprise. This element manages the operation, maintenance, and enhancement of electronic information management systems that provide optimized and secure information management capabilities concerning weapon design, manufacturing, and surveillance activities, weapons accountability, vendor material purchases, limited life component exchanges, dismantlement, and weapons refurbishment. Future activities include using model-based engineering approaches to manage the IT operations.

Weapons Training and Military Liaison. This element includes staffing the multi-weapon subject matter experts for unsatisfactory reports associated with DOD's field issues for testing and handling gear, technical publications, and coding issues; it also allows maintenance operations to return weapons back to active status. This activity also sustains critical manufacturing skills at the nuclear security enterprise sites.

Studies and Initiatives (Non-Use Control). The objective of these activities is to re-establish critical uranium-related capabilities (skilled labor, casting, rolling, forming, and machining) at Y-12 to manufacture cases and CSAs for the stockpile and LEPs and to upgrade the nuclear security enterprise's Logistics, Accountability, Planning, and Scheduling system.

General Management Support. This element includes non-programmatic costs for Federal program management and oversight, assignees and support services contracts

Assessments and Studies (Use Control). This element includes in-depth vulnerability assessments of nuclear weapons in the stockpile; identification or development and deployment of common technologies to address such vulnerabilities, if found; and special studies to support the decision processes for optimizing LEP designs and for option down-select decisions by senior officials.

Surveillance. This element includes efforts that focus on multi-system, common use, or non-weapon specific activities (*e.g.*, data capture, reliability assessments, flight test planning) that directly contribute to stockpile evaluation, including activities and new capabilities for surveillance transformation. Lengthened surveillance cycles to collect data for weapon systems, (caused by scope reprioritization) could violate weapon reliability, annual assessment stockpile rationale standards, and laboratory and flight test requirements. In particular, such prioritizations causing the lengthening of surveillance cycles increases the time that a potential defect could go undetected in the stockpile and subsequently increases the amount of time DOD could have a deficient nuclear deterrent.

External Production Missions. This element is executed by weapon response subject matter experts across all systems and all laboratories. These experts are critical for Pantex to return to operations in bays and cells (should an unexpected weapon condition or anomaly be observed during limited life component exchange replacements). Weapon delivery schedules rely on throughput at the Pantex bays.

Base Spares (Production). This element includes activities associated with production of new non-weapon-specific base spares, containers, limited life component forging procurements, detonators, mock HE, and other weapon components.

Base Spares (Maintenance). This element includes activities associated with maintaining existing non-weapon-specific base spares, test handling gear and containers, GTSs, use control equipment, code management system equipment, and other weapon components.

Nuclear Safety R&D. This element ensures weapon safety and security for nuclear-related and HE activities. Studies focus on extreme temperature and environmental effects, modeling of CHE and IHE based on safety qualification tests, damage effects and limitations caused by detonations, and nuclear material safety analysis.

2.5.2.1 Management, Technology, and Production Accomplishments

- Completed all required and backlogged FY 2016 power supply surveillance work and shelf-life units at LANL.
- Provided diagnostics on JTA performance for both ICBM and cruise missile flight tests. This included support for the first JTA3-CR W80 mission at Utah Test and Training Range.
- Provided weapons response services for continued operations at Pantex and several high visibility events, including completion of the first W84 safety surveillance unit.
- Deployed the capability to share real-time telemetry data between the Tonopah Test Range and Albuquerque.
- Exploited opportunities to procure Life of Program Buy parts for the Code Management System to reduce program and schedule risk.
- Deployed Quality Evaluation Requirements Tracking System versions 4.1 and 4.2 to better manage surveillance data.
- Exceeded goals for Function Test Equivalents (135 completed versus goal of 98) and Destructive Examinations (25 completed versus goal of 24) of GTSs at SRS.
- Under the Studies and Initiative element, corrective maintenance on the rolling mill was completed, restoring it to operation, and the machine press has been reconfigured for hot forming with practice operations conducted at Y-12.

2.5.2.2 Management, Technology, and Production Challenges

- Keep pace with the increasing demands of upcoming LEPs, potentially delivering key items ahead of the actual LEP production schedule.
- Balance the immediate and growing need for weapon response subject matter experts to address unexpected weapon conditions and anomalies at Pantex, while (at the same time) using these same experts to train and mentor additional weapon responders to meet even greater future needs.

2.5.2.3 Management, Technology, and Production Near-term Strategy

Management, Technology, and Production must continue the following:

- Annual activities that provide products, components, and/or services for multi-weapon system surveillance, weapons reliability reporting to the DOD, weapon logistics and accountability, and stockpile planning
- Design use control technology and Code Management System
- Surety multi-application product development commensurate with the FY 2017 budget priorities
- Multiple-system technology development and exploratory studies to address current and emerging stockpile issues, as well as develop replacement limited life components caused by sunset technologies
- Archival of weapons data and upgrading of R&D and engineering tools to remain current with evolving technologies
- Weapon assembly, weapon disassembly, component production, and weapon safety and reliability testing

2.5.2.4 Management, Technology, and Production Long-Term Strategy

- Increase non-destructive evaluation activities for pits and CSA surveillance.
- Increase flight testing support for the Tonopah Test Range.
- Maintain uranium processing capability.
- Develop required processes to enable the nuclear security enterprise to convert to a model-based product definition system from the current drawing-based product definition system.
- Replace the multi-port test valve for the GTS function testing at SRS for all systems.

2.5.3 Advanced Manufacturing Development

The Advanced Manufacturing Development Program develops, demonstrates, and deploys next-generation production processes and manufacturing tools so that future weapons are affordable, agile, and assured. The program contributes to the capability to provide rapid response to evolving scientific and technical developments. Advanced Manufacturing Development has three subprograms: CMD, which focuses on modernizing manufacturing technology and process development; additive manufacturing, which focuses on the technology also known as three-dimensional (3D) printing; and Process Technology Development, which supports uranium processing technologies. As the production sites procure new equipment and hire additional personnel, the existing workforce is needed to manage the increasing workload, as well as to install new equipment and train new personnel. This creates risk to the program in the near- to mid-term.

The strategic developments of Advanced Manufacturing Development include:

- deploying advanced production technology to allow demonstration of novel design concepts and shorten the time to prototype manufacturing builds, thereby reducing costs;
- designing trustworthiness into the basic weapon architecture and enhanced techniques to validate product and supply chain integrity and assurance;
- developing new, faster methods to qualify and certify non-nuclear processes and components; and
- deploying new advanced design architectures and layered surety into systems.

2.5.3.1 Component Manufacturing Development

CMD develops innovative manufacturing processes to replace sunset technologies, upgrade existing technologies, and introduce future technologies in support of maintaining the safety, security, and effectiveness of the nuclear weapons stockpile. This effort entails improving the required manufacturing scientific and engineering capabilities and providing NNSA with cost-effective production processes that reduce risks for future weapon systems. This subprogram is responsible for developing the proofs of concept for manufacturing processes and validating that those processes meet component design requirements with initial prototype builds. CMD coordinates with other programs to ensure proper transition of the technology. The four CMD focus areas are advanced production development, manufacturing process integration, manufacturing diagnostic development, and material obsolescence and sunset processes.

Advanced Production Development. Draws on exploratory manufacturing research at the national security laboratories and the nuclear weapons production facilities to inform decisions on process improvements. This focus area is intended to improve current capabilities through the development of new techniques for manufacturing specific materials and for production processes.

Manufacturing Process Integration. Facilitates introduction of new manufacturing techniques into production lines. It ensures that materials and components produced by novel manufacturing processes meet design requirements and are on a well-defined path for insertion into a weapon system or production line.

Manufacturing Diagnostic Development. Enables new manufacturing processes by developing process monitoring and control diagnostics to observe and study novel production methods and materials. These diagnostics provide a path to qualification and certification for manufacturing processes and ensure the integrity of the nuclear weapon supply chain.

Material Obsolescence and Sunset Processes. Pursues alternatives for obsolete or hazardous materials and aging production processes, and includes new approaches designed to better conserve materials that are scarcely available or challenging to produce. These alternative approaches are critical to develop new techniques or materials before aging issues or material shortages affect the status of LEPs, Alts, or Mods.

Component Manufacturing Development Accomplishments

- Transferred the Joint Radar Module to the B61-12 LEP and the W88 Alt 370 at the end of FY 2016.
- Finalized the W80-4 LEP and CMD Interface Requirements Agreement for technology development projects that details the transition of technologies from CMD to the W80-4 LEP.
- Used topology optimization and additive manufacturing to allow NNSA to meet B61-12 LEP requirements while avoiding costs and downtimes associated with sourcing the fixtures to outside vendors.
- Demonstrated LLNL advanced additively-manufactured component concept capability, which significantly improved the physics performance through execution of two hydrodynamic tests, in collaboration with the Advanced Certification subprogram of the Science program.

2.5.3.2 Additive Manufacturing

The Additive Manufacturing Program vets manufacturing concepts that can shorten design cycles and production schedules in some cases. Compared to the projects in CMD, the Additive Manufacturing focuses on innovative and revolutionary processes not yet demonstrated in a relevant production environment, using multi-site collaborations to share results quickly and speed development.

Additive Manufacturing reduces risks to program schedule and avoids costs traditionally associated with subcontracting work to outside vendors in direct support of the nuclear security enterprise. Additive manufacturing plays an integral role in supporting the nuclear security mission through rapid prototyping, JTA components, tooling, and polymer pad and cushion production.

Additive Manufacturing is focusing on longer-term investments that will result in the reduced cost of design-to-manufacture iterations. These specific processes require fully characterizing additively manufactured materials and capabilities and then producing methodologies that enable qualification and certification for weapon applications. Additive manufacturing also offers tremendous performance advantages in comparison to legacy manufacturing processes by allowing better, faster, and cheaper production.

Additive Manufacturing Accomplishments

- Printed 25,000 developmental tools, fixtures, and molds at KCNSC to support LEPs, resulting in multi-million dollar cost avoidance since the subprogram's inception in early 2015.
- Printed polymer pads and cushions for the stockpile with a 90 percent reduction of required production space and time.
- Reduced production times for a W88 Alt 370 component from 16 weeks to 5 weeks.

2.5.3.3 Process Technology Development

The Process Technology Development subprogram supports development, demonstration, and use of new production technologies to enhance manufacturing capabilities for nuclear weapon materials. Funding will be used to ensure new technologies with the potential to shorten production schedules, reduce risks, enhance personnel safety, or reach optimal maturity levels in time to support mission needs.

At present, this subprogram focuses on uranium processing technology and, specifically, on acquiring major items of equipment for Y-12 by 2025. The purpose of the subprogram is to ensure priority technology investments have a dedicated funding source and can reach optimal levels of maturity without competing against other program priorities.

Chapter 3
Stockpile Stewardship Science, Technology, and Engineering

DOE/NNSA's science, technology, and engineering (ST&E) activities underpin stockpile stewardship. These activities focus on efforts to develop and maintain the critical capabilities, tools, and processes needed to support science-based stockpile stewardship, refurbishment, and certification. They are integral in assessing the stockpile over the long term without the need for underground nuclear testing.

Stockpile Stewardship Science, Technology, and Engineering Accomplishments

- *Provided data on new and aged plutonium, in Technical Area 55 and Z experiments, that are improving models for B61 pit aging.*
- *Provided precise plutonium phase transition data under dynamic conditions at Joint Actinide Shock Physics Experimental Research (JASPER).*
- *Examined impacts of early defects, aging, and life extension programs (LEPs) on primary performance at Dual-Axis Radiographic Hydrodynamic Test (DARHT) and Los Alamos Neutron Science Center (LANSCE).*
- *Supported LEP designs for hydrodynamic experiments as a result of updates to the Flash X-Ray accelerator that enabled double-pulse radiographic images.*
- *Executed vessel qualification experiments to meet over-pressure and fragment mitigation requirements for the Sierra Nevada subcritical experiment series at U1a.*
- *Published an updated tri-laboratory 10-year boost science plan in support of LEPs and stockpile modernization.*
- *Advanced a breadth of LEP options through milestone completions, capability readiness exercises, Joint Technology Demonstrator activities, experiments in additive manufacturing, and restoration of aged components.*
- *Designed an additively manufactured component that has the potential to improve primary performance.*
- *Upgraded safety modeling simulation capabilities that contributed to resumption of plutonium activities at LANL's Plutonium Facility.*
- *Developed the tri-laboratory Warhead Hostile Environment Survivability Plan to address emerging threats for LEPs.*
- *Deployed the 41-petaFLOPS Trinity supercomputer.*
- *Conducted National Ignition Facility (NIF), LANSCE, and Z experiments relevant to pit reuse options.*
- *Developed new NIF platforms to study plutonium equation of state, complex hydrodynamics, boost, and radiation effects, and identified two critical issues hindering development of a robust thermonuclear burn platform.*
- *Exceeded operational goals on NIF with 417 experiments.*
- *Provided capabilities for aiding in predicting weapon lifetimes.*

3.1 Stockpile Stewardship Overview

The Stockpile Stewardship Program ST&E portfolio is central to maintaining a credible deterrent and for the safety, security, and effectiveness of the Nation's stockpile. With a significant number of the warheads in some stage of the life extension process, the Stockpile Stewardship Program enhances the understanding of internal nuclear weapon functions by maintaining the scientific, technological, and engineering proficiency of the workforce and infrastructure.

The NDAA for Fiscal Year 1994 (Pub. L. 103-160) established the Stockpile Stewardship Program to sustain the deterrent in the absence of nuclear testing. The development of nuclear weapons over many decades led to common practices for determining when nuclear testing was required.[24] In the final years of nuclear

[24] A notable exception was that of a stockpile confidence test. Usually, the test was conducted after the weapon system had entered the stockpile.

testing, the United States executed nuclear tests to support several objectives, including development of new weapon systems and IHE-based primary options as well as the exploration of weapons physics, nuclear safety, and survivability. With the cessation of underground nuclear tests, scientists and engineers had to find an alternative approach to acquire data in support of the research, development, certification, and assessment of nuclear weapons. The approach taken by DOE in the mid 1990s formed the basis of science-based stockpile stewardship and led to the birth of the Stockpile Stewardship Program. After more than 20 years, stockpile stewards have established a solid record of success in hydrodynamic testing, subcritical experiments, HED physics, materials and weapon effects science, and modeling and simulation. These achievements have provided detailed knowledge to support stockpile assessments and have resolved a number of stockpile issues since the end of nuclear testing. The Stockpile Stewardship Program provides the capabilities required by the safeguards discussed during the Comprehensive Nuclear-Test-Ban Treaty debate.

The Stockpile Stewardship Program requires a scientific understanding of the performance of nuclear weapons throughout the entire life cycle. The life cycle of a nuclear weapon includes design, development engineering, production, surveillance, storage, flight testing, survivability through benign and/or hostile environments, and the nuclear explosion process. Each of these phases has distinct scientific and engineering challenges. A science-based understanding of aging and improved surveillance diagnostics guards against unexpected changes that may result in the weapon not functioning as designed. Simulation, experiments, and environmental testing facilities are used to ensure the weapons will survive under extreme environmental conditions. Ensuring the performance of the weapon once it begins to detonate relies on a scientific understanding of materials at the extreme densities, pressures, velocities, temperatures, and timescales reached during a nuclear detonation. This scientific understanding is obtained through experimentation, theory, and simulation. NNSA develops large-scale weapon simulation codes using this scientific understanding in order to predict the performance of the weapon. Subsequent validation and enhancement of weapon simulation codes use additional experimental data.

NNSA has made advances in computational and experimental capabilities since the Stockpile Stewardship Program began in 1994. New generations of high performance computers developed in the last 25 years have increased NNSA's simulation capabilities and multi-dimensional weapon simulation codes now allow unprecedented resolution for simulating weapon performance with high fidelity. Many of NNSA's major experimental facilities that existed prior to 1992 have continued to make essential contributions; others began operating more recently and are providing high quality data in systems closer to that of an actual weapon.

Examples of facilities that provide unique experimental or R&D capabilities built since 1992 include the Dual Axis Radiographic Hydrodynamic Test (DARHT) facility at LANL, NIF at LLNL, the U1a Complex (U1a) at the Nevada National Security Site, JASPER gas gun at LLNL, and the MESA facility at SNL. The quality and resolution of the data from such facilities and capabilities are used to benchmark new physics models in weapon simulation codes and to supplement the physical data used in conjunction with the codes. Aging NNSA facilities that have been maintained continue to make essential contributions. Examples of these facilities include the Z pulsed power facility (Z), the Los Alamos Neutron Science Center (LANSCE), Saturn, the High Explosives Applications Facility, the Contained Firing Facility, and the High Energy Radiation Megavolt Electron Source (HERMES) III.

Z is crucial to NNSA's mission since it allows scientists to study materials under conditions similar to those produced by the detonation of a nuclear weapon.

NNSA is developing a Stockpile Responsiveness Program, as directed by Section 3112 of the FY 2016 NDAA, that will work with the Stockpile Stewardship Program and the Stockpile Management Program to ensure that NNSA is exercising the capabilities required to support all phases of a nuclear weapon's life cycle.

3.2 Stockpile Stewardship Science, Technology, and Engineering Elements

The Stockpile Stewardship Program comprises four major elements, which underpin stockpile stewardship: Science; Advanced Simulation and Computing (ASC); Engineering, Stockpile Assessments, and Responsiveness (ESAR); and Inertial Confinement Fusion Ignition and High Yield (ICF).

3.2.1 Science Program

The Science Program provides capabilities for the development, maturation, and qualification of advanced safety and security concepts, new materials and manufacturing processes, primary and secondary reuse and other options for LEPs, and contributions to weapon lifetime assessments. These capabilities are achieved through a balanced, priority-driven, science-based program supporting the assessment of weapon performance as aging materials and production obsolescence associated with the life extension modifications evolve the stockpile beyond tested configurations. The Science Program includes experimental projects to develop predictive and validated weapons physics models for assessing the performance of a variety of stockpile needs, such as evaluating aging effects, certifying new production methods and technologies, extending weapon lifetimes, developing enhanced surety systems, and meeting future challenges.

Scientific efforts are used to address these areas. Studies of shock and compression phenomena that occur in a nuclear weapon are crucial to evaluating performance and surety. Implosion hydrodynamics encompasses the design, execution, data analysis, and interpretation of both focused and integral hydrodynamic and subcritical experiments to deliver essential data in support of annual assessments, SFI resolution, and options for the future stockpile.[25] The study of HED physics examines matter and radiation at the extreme energies and densities that occur at the onset of nuclear yield in a weapon and focuses on understanding phenomena that are critical for predicting primary and secondary performance. These data can be used to validate physics-based models and codes. The Science Program has made, and continues to make, significant advances in understanding phenomena from the initial conditions required for boost, to the subsequent dynamics and the predicted thermonuclear yield of stockpile weapons.

Materials science provides equation-of-state and constitutive property data to support the improvement of theories and models relevant to weapon performance. These data are used to validate models and simulation codes and to identify and develop new material options in support of component reuse and LEPs. Similarly, nuclear physics experiments provide data in the form of nuclear cross sections (*i.e.*, the probabilities of nuclear reactions) and neutron output spectra that underpin databases used to simulate transport, criticality, boost, and weapon outputs. The Science Program also supports advanced experimental technology development and analysis techniques to diagnose weapons experiments. This work includes both the extension of current technologies and the exploration of emerging technologies

[25] **Focused** experiments typically are designed to elucidate a specific fundamental weapon physics or materials property question within a limited framework, component, or parameter regime. **Integral** experiments are designed to characterize performance of a broader system of components and can approach weapon scale. Well-designed integral experiments attempt to constrain the results such that the outcome can be predicted only for exactly the right and unique reasons.

such as Enhanced Capabilities for Subcritical Experiments (ECSE) to conduct and diagnose experiments over a broad range of experimental conditions. The development of neutron sources for both Neutron Diagnosed Subcritical Experiment (NDSE) and future capabilities for dynamic radiography are active efforts. Because diagnostics play a central role in the experimental effort, the Science Program supports the development of advanced breakthrough, transformational diagnostics and analysis techniques for weapon physics and materials experiments. In the future, Stockpile Stewardship will employ science to increase the efficiency and quality of production for the stockpile and improve the agility of the manufacturing capabilities for small-scale and integral experiments. The Science Program also develops predictive capabilities for application outside of the U.S. stockpile design domain in support of broad national security priorities, also called Capabilities for Nuclear Intelligence. Through the Stewardship Science Academic Alliances, the Science Program contributes to development of the future national security laboratory workforce. These alliances foster university research in unique fields relevant to stockpile stewardship through direct funding.

The Science Program partners across all the ST&E programs. The Science Program partners with ESAR to assess weapons effects. Science and ASC Program activities are integrated in the Predictive Capability Framework (PCF), and HED experiments leverage diagnostic platforms generated by ICF.

3.2.1.1 Accomplishments of the Science Program

- Supported the beginning of the B61-12 LEP certification process by evaluating the impacts of plutonium aging on performance at Technical Area (TA)-55 and Z. The data will be used to characterize material property differences between new and aged plutonium. A second Z experiment used a shock ramp platform to provide plutonium data at higher pressures in regimes that were previously inaccessible.
- Advanced development of test platforms on Z for warm x-rays and high-energy neutron sources.[26, 27] In addition to achieving several record x-ray and neutron yields, improvements to test capabilities resulted in record fluences on test objects.
- Conducted the 417th NIF experiment of the year, effectively doubling the pace of experiments over a 3-year period, providing key data for stockpile stewardship.
- Advanced a breadth of LEP options by completing the secondary LEP capability PCF pegpost (see Section 3.6.2), initial Certification Readiness Exercises, and JTD activities, as well as experiments on additively manufactured new parts and restoration of aged components.
- Completed the planning phase deliverables for the JTD initiative to support risk mitigation for the 3+2 Strategy through technology maturation and advancing the skills of next-generation stockpile stewards.
- Examined the primary performance impact of features that could arise as a result of defects, aging, and LEPs using DARHT and LANSCE.
- Completed 11 JASPER experiments: 2 to validate projectile velocity and gun performance, 4 to test the integration of the new seven-channel pyrometer, and 5 to provide precise phase transition data for plutonium to understand its properties under dynamic conditions.
- Obtained double-pulse radiographic images on Flash X-Ray accelerator experiments in which a new three-frame camera was used to acquire two radiographs in separate frames.

[26] Warm x-rays = 10 to 100 kiloelectronvolts *(i.e.,* 10–100 keV).
[27] High-energy neutrons = greater than 1 million electronvolts (*i.e.*, >1MeV).

- Conducted photofission experiments at DARHT and pulsed static experiments on the Dense Plasma Focus at the Nevada National Security Site that show promise as a possible neutron source for NDSE.
- Designed and experimentally validated an innovative concept for the use of an additively manufactured component that could improve primary performance for LEP applications.
- Obtained plutonium phase and strength data on NIF at previously inaccessible high-pressure regimes.
- Published an updated 10-year tri-laboratory boost science plan that integrates theoretical, computational, and experimental efforts in support of LEPs and stockpile modernization.
- Executed, as part of the Sierra Nevada subcritical experiment series, vessel qualification experiments to meet over-pressure and fragment mitigation requirements.

3.2.1.2 Challenges of the Science Program

In addition to the overarching challenge of maintaining a safe, secure, and effective nuclear stockpile that meets military requirements without performing underground nuclear tests, the Stockpile Stewardship Program faces other key challenges:

- **Certification of the Evolving Stockpile.** Stockpile Stewardship Science must provide the tools to assess aging, LEPs, stockpile modernization, and evolving threat environments so that changes to the stockpile can be certified without underground nuclear tests.
- **Boost.** The development of an empirical understanding of initial conditions, as well as models and simulations of boost and thermonuclear burn, is important to advancing predictive capability. Boost characteristics have long been handled as parameters (multipliers) in the models that are fit to experimental data rather than determined from the beginning based on the physics alone.
- **Materials.** Deterioration (aging) of materials used in the stockpile must be evaluated to determine the effects on weapons performance.
- **Predicting Performance.** HED physics is important in predicting primary and secondary performance. The HED environment consists of hot dense plasma, replete with energetic charged particles, neutral particles, and radiation over a wide range of energies. Evaluating this environment requires innovative, sophisticated diagnostics.

3.2.1.3 Strategies of the Science Program

The FY 2018–2025 strategic objectives are as follows:

- Develop enhanced capabilities to recreate more weapon-like conditions in experimental facilities focused on delivering data for materials and nuclear physics.
- Support annual assessments and resolution of SFIs by executing focused experiments (*e.g.*, materials characterization at HED) and integral hydrodynamic tests that support validation of weapon models.
- Understand the impacts on weapon performance of aging (in particular, for plutonium) and of new materials and processes.
- Continue to provide the United States with the capability to conduct subcritical experiments.
- Deliver the experimental capabilities required for stockpile stewardship, including hydrodynamic testing and HED experiments that are necessary to support the program of record and the PCF.

- Deliver high-pressure materials property data at weapon-relevant regimes for plutonium and its surrogates.
- Achieve (in collaboration with the ASC Program) a more-physically detailed understanding of boost, supported by burning plasma experiments at HED facilities (NIF and Z).
- Continue R&D for scaled-up production of IHE for the W80-4 to ensure a robust material supply.
- Develop and exercise capabilities to evaluate foreign and proliferant-based nuclear threats.
- Anticipate long-term stockpile changes and requirements, and address gaps in capabilities to devise and certify technical solutions.
- Develop capabilities to address potential changes in stockpile-to-target sequence environments.
- Deliver viable options for LEP applications and the assessment and certification of these options.
- Develop ECSE next-generation radiographic capabilities to examine late-time plutonium behavior in hydrodynamic experiments and to study the effects of plutonium aging.
- Develop techniques to carry out NDSE measurements to bolster the capabilities to certify LEPs and to study the effects of plutonium aging.
- Execute radiographic and NDSE reactivity capabilities in subcritical experiments at U1a to assess aging effects and stockpile evolution options.
- Promote academic alliances to recruit and train new generations of scientists and engineers.

3.2.2 Advanced Simulation and Computing Program

The ASC Program develops, deploys, and supports predictive simulation capabilities for nuclear weapons systems, including simulation of nuclear performance at nominal or near nominal conditions; engineering in normal, abnormal, and hostile environments; weapons surety; and weapon outputs. IDCs, coupled with experimental programs, are the medium through which ASC serves the needs of LEPs, SFIs, and other aspects of DSW.

ASC is linked to the understanding, experience, and data gained through the DSW, Science, and Engineering Programs. The activities of ASC and other programs are integrated through the PCF, as explained in Section 3.6.2. In addition, ASC collaborates with DOE's Office of Science for Advanced Scientific Computing Research (ASCR) program (see Appendix C).

3.2.2.1 Accomplishments of the Advanced Simulation and Computing Program

- Improved models for dynamic compaction of additive manufacturing materials by reducing computational cost in simulating struts in a lattice-structured material. Additive manufacturing materials are of interest for potential production of lattice-structured materials in LEP designs because of their high stiffness-to-weight ratios compared to some materials in the stockpile.
- Upgraded safety modeling capabilities that contributed to resumption of plutonium R&D activities at LANL's PF-4.
- Resolved a long-standing discrepancy between theory and plutonium experiments performed at JASPER, thereby improving confidence in the plutonium equation of state data.
- Developed an equation of state for products of an HE used to study effects of material aging.
- Discovered a new mechanism by which foam-filled parts age that provides a better understanding of the polyurethane foam that protects electronics in the W76, W88, and B61. This new understanding improves the ability to predict material decomposition in stockpile-to-target sequence and abnormal environments.

- Worked closely with the DOE's Office of Science to support the DOE/NNSA exascale computing goals and the National Strategic Computing Initiative, as directed.[28]
- Deployed CTS-1 (Commodity Technology System) powerful HPC platforms at LLNL, LANL, and SNL during the third and fourth quarters of FY 2016.
- Completed a new building at LLNL to house unclassified CTS machines.
- Installed first partition of ATS-1 (Advanced Technology System), Trinity, at LANL for classified use. Deployed the second partition of ATS-1, to complete the 41-petaFLOPS system; that partition is now available for unclassified applications.

Installation of the first row of cabinets of the new Trinity supercomputer. Trinity is NNSA's first advanced technology system.

3.2.2.2 Challenges of the Advanced Simulation and Computing Program

ASC's major challenges in the near future are: (1) the changing stockpile is evolving away from as-tested designs through aging and LEPs, (2) the threat space is evolving for which weapons must be certified, and (3) the HPC ecosystem is changing. Other areas include:

- Current simulation capabilities are at risk because of the evolving computer architecture, potentially leading to productivity decreases related to stockpile stewards waiting longer for or relying on lower-fidelity solutions, as well as the lack of models that run efficiently on emerging computer architectures.
- Both recruiting and retaining personnel with the necessary skill sets is difficult because of the unique training and experience prerequisites and the limited availability of qualified graduates with advanced degrees in the requisite specialties. Recruitment is further complicated by competition for those resources with defense, domestic, and international industry.
- The modeling capability is currently inadequate to incorporate advanced manufacturing methodologies fully with maximum efficiency.
- Water and power supply requirements will drive changes in the facilities, network, and archival infrastructures. Facility upgrades are required for the ATS-3 and ATS-4 systems that will be delivered in 2020 and 2023, respectively.
- User demand for computer time for nuclear security applications is outstripping availability.

3.2.2.3 Strategies of the Advanced Simulation and Computing Program

As required by Congress, ASC's updated plan for achieving exascale computing is outlined in Appendix C, "Advanced Simulation and Computing." The key elements are:

- an increased understanding of the fundamental physics that underscores the models and physical data used in the IDCs and upon which the stockpile stewardship user community depends (in collaboration with the Science Program),
- an agile simulation code base that can respond quickly to disruptive changes in computer architectures,

[28] See Presidential Executive Order 13702, "Creating a National Strategic Computing Initiative," July 29, 2015.

- processes which support the user community by streamlining the flow of work through ASC simulation capabilities, and
- extension of scientific understanding to serve the broadening mission space (in collaboration with the Science Program).

The ASC Program is following a path that addresses these key elements for delivery of a validated predictive capability to fulfill the stockpile stewardship and national security missions. At the same time, the ASC Program will seek to innovate, inspire, and create a more agile environment for capability development and user responsiveness. To accomplish these missions, the Program has four strategic goals:

- Meet the needs of today's Defense Programs mission.
- Anticipate and prepare for the future needs of Defense Programs.
- Establish ASC as a community of excellence for national security simulations.
- Provide national leadership in HPC and support the National Strategic Computing Initiative as detailed in Presidential Executive Order 13702.

This strategy recognizes the need for exascale computing capabilities to support out-year objectives for stockpile assessments. Until exascale systems become available, ASC will accomplish the Stockpile Stewardship Program mission with the available computational resources.

Exascale Computing

NNSA simulation capabilities that support the Directed Stockpile Work mission are being challenged as high performance computing technologies evolve to radically different and more complex architectures. Until addressed, these changes will be increasingly disruptive to the NNSA's broad national security missions.

A partnership between NNSA and the Office of Science has been executing a joint program focused on providing exascale–class computing to the Nation by the early 2020s. The planned exascale systems represent a fifty-fold improvement in performance over today's computing capabilities and will enable NNSA to address increasingly complex national security questions and the Office of Science to address next-generation science, engineering, and data problems.

3.2.3 Engineering, Stockpile Assessments, and Responsiveness

The ESAR program provides capabilities for an agile and responsive nuclear stockpile that will survive the complex environments encountered during the lifetime of a weapon. ESAR's mission is focused on design, qualification, and assessment of the integrated weapon system prior to detonation. Nuclear weapons are complex systems with thousands of specialized components. Before having to be used, a weapon can experience many years of aging, the bumps and vibrations of travel on roads or submarines, the shocks and vibrations associated with flight, and possibly nearby nuclear explosions caused by an adversary's attempt to disable the weapon. Confidence that all of the components will work together for proper functioning of the weapon requires experiments, validated modeling and simulation, and flight testing.

The Stockpile Responsiveness Program in ESAR maintains and exercises the required capabilities to respond to emerging threats, technical challenges, and technical opportunities that could threaten the deterrent and to identify opportunities to accelerate the nuclear weapons life cycle and reduce costs of development and production.

The ESAR mission includes collaboration within the NNSA and DOD organizations responsible for the nuclear weapon stockpile. ESAR partners with ASC by providing the experimental tools and diagnostics that complement the development of simulation capabilities. The Science Program complements the efforts of ESAR by providing the capabilities to assess the performance of the weapon after detonation begins. Finally, NNSA collaborations with the DOD are a key element for threat assessment and developing a responsive stockpile.

3.2.3.1 Accomplishments of Engineering, Stockpile Assessments, and Responsiveness

- Developed the Warhead Hostile Environment Survivability Plan to address emerging threats for LEPs in the next 10 years.
- Developed the *Understanding Capabilities and Gaps in Reentry Vehicle Flight Dynamics Modeling and Testing* report to ensure evolving weapon flight environments are addressed in the next 10 years.
- Initiated an effort to ensure legacy data are available for future weapon designers by archiving critical weapon data across the nuclear security enterprise.
- Defined a Stockpile Responsiveness Program at the request of Congress and established a joint working group with the DOD.
- Helped ensure weapon safety in accidents by developing an embedded sensor for verifying operation of a safety mechanism.
- Improved the ability to qualify weapons in flight environments by demonstrating a capability for ground testing with combined acceleration, vibration, and spin that have historically been tested separately.
- Worked with the USSTRATCOM, the Defense Threat Reduction Agency, the UK Ministry of Defence, and the Atomic Weapons Establishment to deliver operational capabilities to model nuclear effects. One aspect of this work involved experimental trials at the HERMES III facility.
- Deployed the first 12-by-12-inch square praseodymium-doped gadolinium lutetium oxide advanced x-ray scintillator in the Confined Large Optical Scintillator Screen and Imaging System for x-ray computed tomography at Pantex. The increased brightness and resolution afforded by this material will increase the throughput on Confined Large Optical Scintillator Screen and Imaging System-I, which scientists are using to identify potential problems and anomalies in pits.
- Improved the prediction of material failure as part of LLNL's IHE damage model development by incorporating the effect of strain rate and hydrostatic strengthening as determined from mechanical properties experiments on IHE specimens.
- Improved design and implementation of electrical systems in weapons by delivering age-aware specifications for two critical factors—gold electrical contact coatings and mechanically induced degradation of electrical contacts.
- Updated critical experiments to demonstrate the increased safety associated with use of IHE rather than CHE in nuclear weapons: no deflagration-to-detonation transition response and insensitivity to defined, high-level shocks.
- Matured a weapons model used to predict yield by improving the starting state of the weapon to include spatially aware uranium corrosion predictability with real-time feedback and a new uranium materials model.
- Improved the bandwidth for qualifying ongoing concurrent LEP systems to electromagnetic environments by completing the delivery of six unique high voltage pulsers and commissioning the new Gigahertz Transverse Electromagnetic test facility.
- Progressed in determining the future source of trusted radiation-hardened microelectronics for deployment in nuclear weapons. Produced an independently validated mission need statement and program requirements document related to this effort.

3.2.3.2 Challenges of Engineering, Stockpile Assessments, and Responsiveness

Key challenges for ESAR are:

- Technologies with the potential to impact survivability and other military requirements are continuously changing and require timely response.
- Opportunities are limited for facilitating knowledge transfer in designing and qualifying new nuclear weapon systems from experienced weapons scientists and engineers to the next generation of stockpile stewards.
- Limited ability to conduct destructive surveillance testing on aging weapons that are being kept in the stockpile past original lifetimes exacerbates uncertainty in predicting aging effects on the stockpile.
- Assuring that nuclear weapons will survive environments associated with nuclear explosions created by adversary defenses requires experiments that cannot be recreated in the laboratory. The number of nuclear tests to understand these environments before enactment of the test ban is limited.
- Predictive capabilities to describe the response of nuclear weapons to the conditions encountered during flight do not yet exist. Assuring that weapons will survive flight increasingly relies on modeling and simulation validated by laboratory experiments.

3.2.3.3 Strategies of Engineering, Stockpile Assessments, and Responsiveness

The ESAR strategy for responding to these challenges includes the following:

- Develop the ability to anticipate and respond to changes in technology that impact survivability and other military requirements.
- Collaborate with DOD and the Intelligence Community to anticipate the evolution of threats to the stockpile.
- Demonstrate an agile capability for responding to emerging threats or requirements through the conduct of comprehensive exercises that include the entire nuclear weapon life cycle.
- Provide the infrastructure and engineering needed to accelerate the development cycle for nuclear weapons components. There will be a particular focus on capabilities for accelerating flight testing, hydrodynamic testing, and subcritical testing.
- Identify aging phenomena with the greatest potential to degrade stockpile performance and build the science and diagnostic tools to detect these aging problems early.
- Improve the computational models and experimental validation to move beyond the present ability to assess failure modes in individual components or subsystems to the capability needed for assessing failure modes in integrated weapons systems in real-world environments.
- Improve the ability to determine the aerodynamic environments experienced by weapons without the need for flight testing through sounding rocket flights, ground testing, and simulations.
- Improve predictive capabilities enabling the determination of margin-to-uncertainty for the performance of weapons in hostile environments.

Execution of this strategy relies on harnessing the technical strengths and manufacturing capabilities of the national security laboratories and the nuclear weapons production facilities. In addition, this strategy relies on an active partnership with DOD to anticipate and respond to DOD's military requirements.

Each activity within ESAR has specific goals and milestones targeted at a few large deliverables cited in the ESAR planning document. Seven subprograms within ESAR support these goals:

- **Stockpile Responsiveness** strengthens the ability of the United States to accelerate the development cycle of nuclear weapons.
- **Enhanced Surveillance** provides diagnostics and science needed to ensure that aging will not harm the stockpile.
- **Delivery Environments** (also known as Weapon Systems Engineering Assessment Technology) provides experimental capabilities, diagnostics, and data needed for assessing that weapons will not be damaged by delivery environments and will behave appropriately in possible accident conditions.
- **Nuclear Survivability** provides the tools and technologies necessary for ensuring that U.S. weapons meet DOD requirements for surviving encounters with adversary defenses.
- **Base Hydrodynamics and Subcriticals** provides the capabilities for hydrodynamic and subcritical experiments needed for a responsive stockpile.
- **Archiving Data and Management** is responsible for conserving the knowledge and expertise derived from the nuclear testing era.
- **Assessments** develop capabilities for benefits across multiple weapon systems that support the annual reporting process to the President on the health of the stockpile.

3.2.4 Inertial Confinement Fusion Ignition and High Yield Program

The ICF Program provides scientific understanding and experimental capabilities to evaluate weapon, material, and component performance at HED in order to validate the weapons simulation codes and models that enable assessment of the U.S. nuclear weapons stockpile and certification of components and subsystems for LEPs. The overwhelming majority of a nuclear weapon's energy is generated in the HED state (pressures greater than 1 megabar) increasing the importance of understanding this regime. ICF facilities such as NIF, Z, and the Omega Laser Facility (Omega) at the University of Rochester's Laboratory for Laser Energetics provide the only platforms on which the simulation codes that couple transport processes with hydrodynamic models of HED environments can be experimentally validated. This experimental basis, combined with archived legacy data from underground nuclear tests, gives confidence in the codes and models used to support annual assessments and certifications, to plan LEPs, and to resolve SFIs.

ICF supports stockpile stewardship in two principal ways. First, ICF conducts non-ignition HED research, develops new diagnostic platforms, and provides experimental expertise. The experiments explore issues in materials science, radiation transport, and hydrodynamics to provide fundamental scientific knowledge relevant to nuclear weapons and to test and then improve the codes and models. Second, ICF conducts ignition and high-yield HED research to determine whether a credible path to ignition in the laboratory is possible. If successful, the resulting ignition-driven platform will be able to validate models at extreme conditions of pressure, temperature, and density that approach those achievable only with nuclear explosive testing. The demonstration of ignition remains a major goal for NNSA and DOE.

Early ignition experiments on NIF that evaluated laser indirect drive capsules indicated differences between the code predictions and the data. These indirect drive experiments revealed unknown physics and technical complexities that will require time to study and resolve. Advances in diagnostic platforms and experimental techniques have provided insight into where the models used in the codes are diverging from the experimental data; this insight is of great interest to stockpile stewardship. Today, the implosion experiments are more hydrodynamically stable and yield performance closer to that predicted by the code simulations. Future progress will require better understanding and control of hydrodynamic instabilities and implosion symmetry.

The ICF Program is pursuing two additional approaches to ignition. One path is laser direct drive, principally studied on Omega. If this path is shown to be more promising, it may be possible to convert NIF to symmetric direct laser drive to achieve multi-megajoule yields with the present laser energy. The second path is magnetic direct drive, which is principally studied on Z. If this path is shown to be promising, it may be possible to build a larger pulsed power facility capable of 10-megajoule-class yields, and eventually greater than 500-megajoule yields. Scientists and engineers working on all three approaches are collaborating with one another in what has become a national effort. The national effort is outlined in two documents produced by DOE/NNSA in May 2016, the *2016 Inertial Confinement Fusion Program Framework*, and the *2015 Review of the Inertial Confinement Fusion and High Energy Density Science Portfolio: Volume I*, as well as summarized by a workshop, “Addressing Common Challenges in ICF,” that was held in 2016.

The national ICF Program must continue to pursue the challenge of ignition in order to maintain scientific leadership and credibility, while recruiting and training scientists and engineers to participate in stockpile stewardship. Much ICF research provides an avenue to establish the quality of relevant science through engagement with the broader scientific community.

3.2.4.1 Accomplishments of the Inertial Confinement Fusion Ignition and High Yield Program

- Conducted high-impact stockpile stewardship experiments relevant to pit reuse options, which provided critical data on plutonium properties including phase, mix, and radiation transport on NIF, including the first plutonium strength experiment.
- Developed new NIF platforms to study plutonium equation of state, complex hydrodynamics, boost, and radiation effects.
- Executed plutonium experiments on Z to support B61-12 LEP certification. The data will be used to characterize material property differences between new and aged plutonium.
- Identified two obstacles to obtaining ignition on the NIF: the time-dependent symmetry of the implosion and the perturbations arising from capsule support mechanisms. Approaches were developed to mitigate these issues.
- Demonstrated a new high case-to-capsule ratio target using a beryllium capsule that will mitigate the effects of asymmetric drive and the capsule-holding “tent” features.
- Developed new or improved capabilities to continue the pursuit of ignition.
- Reached a stable, efficient operating point for the NIF. Over the last 2 years, NIF has met the goals of the congressionally mandated 120-day study by performing a record 417 experiments in FY 2016 (more than twice the 191 experiments in FY 2014).

- Produced record x-ray yields and fluences on Z using new z-pinch sources. These "warm x-ray" sources extended the range for obtaining useful radiation effects data on Z to higher energies.
- Established the National Direct-Drive program at the Laboratory for Laser Energetics and developed two Integrated Experimental Campaigns: the 100 gigabar campaign on Omega and the Megajoule Direct-Drive campaign on the NIF.
- Commissioned and qualified the Advanced Radiographic Capability, the world's most energetic short-pulse laser. That laser will provide unique radiographic data from complex hydrodynamic experiments and the study of the cold fuel in ICF experiments. The data are important for stockpile stewardship.
- Developed the Virgil high-resolution x-ray spectrometer at the Naval Research Laboratory, augmenting the NIF's Dante diagnostic to monitor the radiation environment important in the interpretation of laser-driven indirect drive implosions.

3.2.4.2 Challenges of the Inertial Confinement Fusion Ignition and High Yield Program

The major ICF challenges are:

- pursuing R&D of thermonuclear burning plasmas for the three major ignition approaches (laser indirect drive, laser direct drive, and magnetic direct drive);
- improving the efficiency of facility operations and providing targets and transformative diagnostics for HED experiments and to progress toward ignition;
- maintaining robust experimental and theoretical support for weapons-relevant HED physics validation and verification;
- recruiting, retaining, and maintaining a cadre of talented scientists and engineers; and
- conducting ignition research to provide a better understanding of differences among codes, models, and experimental data.

3.2.4.3 Strategies of the Inertial Confinement Fusion Ignition and High Yield Program

- Use the ICF program planning documents (*i.e.*, the *2016 Inertial Confinement Fusion Program Framework* and the *Pulsed Power Science & Technology Plan*), working group recommendations (*i.e.*, the *National Implosion Stagnation Physics Working Group Report*), and the recommendation in the *2015 Review of the Inertial Confinement Fusion and High Energy Density Science Portfolio* to balance ignition efforts, technology investments, and development of scientific stewards for the stockpile.
- Establish an annual program meeting to cover the progress to date on the 2020 Goal: determine the efficacy of reaching ignition on the NIF and of achieving credible physics scaling to multi-megajoule fusion yields for each of the three major ICF approaches.

3.3 Recent Stockpile Stewardship Science, Technology, and Engineering Accomplishments

ST&E plays a major role in the full range of stockpile activities. The high-level accomplishments in the sidebar on the first page of Chapter 3 are the result of using ST&E's experimental, modeling, and simulation capabilities to design weapon subsystems and quantify expected performance for the B61-12 LEP, the W88 Alt 370, and the W80-4 LEP, and to enable the nuclear survivability qualification of several components. Using these capabilities, NNSA's national security laboratories have determined that certain limited life components can be replaced less frequently.

Stockpile Stewardship Science, Technology, and Engineering Contributions to Life Extension Program Down-select

- *Enhanced Surveillance assisted in evaluating B61-12 component reuse by providing the technical basis for reuse of three components and of the design for an additional four.*
- *Scientific exploration of advanced technologies and physics assessment of design alternatives for the Long Range Stand Off down-select decision used computational modeling and experimental capabilities, including integral hydrodynamic experiments and small-scale focused experiments.*
- *Advanced manufacturing capabilities have allowed early evaluation of material properties for future life extension applications.*
- *Science and Inertial Confinement Fusion Ignition and High Yield programs executed a plutonium experiment on Z to support the B61-12 Life Extension Program certification. Data will be used to characterize material property differences between new and aged plutonium.*

3.4 Enduring Challenges

Despite significant advances in capabilities, a variety of ST&E technical challenges remain. These fall broadly into four areas: responding to current and future stockpile challenges, sustaining the stockpile through LEPs, providing ST&E for broader national security missions, and attracting and retaining expert stockpile stewards for the indefinite future.

3.4.1 Responding to Current and Future Stockpile Challenges: Aging of Components

Nuclear weapons in the enduring stockpile were initially designed to have certifiable service lifetimes between 20 and 30 years. Considerably longer weapon system lifetimes are now planned. Assessing potential age-related failures sufficiently in advance of occurrence to allow for correction is a central challenge. Stockpile Stewardship ST&E provides the diagnostics, materials models, and experimental capabilities to provide timely forecasting of aging phenomena that could harm weapons and components. Improved test capabilities, coupled with modeling and advances in materials science have been and are continuing to be developed to provide both functional system-level testing and component-level performance data to support reliability calculations and aging assessments.

HE-driven subcritical experiments at U1a on the Nevada National Security Site are the only way to reproduce the pressures and temperatures that plutonium reaches during a primary implosion in a weapons-relevant geometry. The capability to diagnose these integral experiments with sufficient accuracy is still under development. Once developed, such techniques will contribute to assessments of the effects of aging on performance as well as the effects of changes to the warhead configurations introduced by reuse designs. NNSA has proposed the ECSE portfolio to develop an underground test facility and deploy an advanced radiography diagnostic at U1a, as well as a NDSE capability.

Declining stockpile numbers are driving the reliance on nondestructive testing for surveillance of the stockpile. New evaluation techniques and specific component-level studies are needed to develop and deploy improved surveillance diagnostics to make timely assessment of the state of the stockpile and decisions to replace or reuse components. As a result of research in this area, new techniques are being developed and placed into service:

- Pantex uses laser gas sampling and x-ray computed tomography to surveil pits.
- Y-12 uses similar laser gas sampling techniques for CSA surveillance.
- Residual gas analysis and x-ray computed tomographic scanning of non-nuclear components are used to detect evidence of aging or contamination that could adversely impact the functioning of specific components.

3.4.2 Stockpile Stewardship Science, Technology, and Engineering's Role in Life Extension Programs

The Stockpile Stewardship Program ST&E efforts for the B61-12 LEP, the W88 Alt 370, and the W80-4 LEP include:

- development of reliable, radiation-hardened compound semiconductor transistors to provide an adequate margin for future hostile environment requirements;
- incorporation of high-fidelity modeling into the design process to reduce the number, duration, and cost of design cycles;
- provision for validated modeling and experimentation to optimize qualification testing of new components and aging components; and
- qualification where test capabilities no longer exist (*e.g.*, for hostile environments).

The first and last two advances listed above also risk the certification of weapon systems by moving the systems away from as-tested configurations.

Future LEP challenges and opportunities that Stockpile Stewardship ST&E will address include pit and secondary reuse, establishment of advanced manufacturing capabilities, and improving efficiency at the nuclear weapons production facilities. Pit reuse will involve designing and certifying an IHE implosion system for a pit that was originally designed and tested within a CHE implosion system. Experimental and computational capabilities are critical to these efforts, particularly since congressionally sanctioned independent review has indicated that such untested new configurations may represent a significant hurdle for certification.

Improved surety (*e.g.*, safety, security, and use control), more cost-effective design and production processes, and decreased waste streams are also major challenges. Using Stockpile Stewardship ST&E's capabilities, NNSA has an opportunity to reduce the life cycle cost of a weapon, including the associated production processes, through an improved understanding of material properties, aging phenomena, and weapon performance.

Current and future LEPs will require new supplies of HE. The most pressing need is IHE for main charges. Production of a crucial component of IHE ceased in the United States in 1993 and stockpiles of that legacy material have largely been exhausted. A new U.S. manufacturer of this component was established in 2014, through partnership with private industry. This was a result of the application of Stockpile Stewardship ST&E expertise in the areas of crystal synthesis, formulation of IHE with binders, and charge pressing and machining, as well as the evaluation of chemical characterization and engineering and physics performance. Work continues to evaluate and improve the production process and materials for the stockpile. Small-scale focused capabilities and integral hydrodynamic experiments are being used to characterize the material properties and the mechanical and detonation performance behavior for newly produced IHE explosives and to make direct comparisons to stockpile qualification and performance criteria.

The data acquired during the era of underground nuclear tests contribute to validating current and future predictive capability and to underwrite assessment of the current stockpile and certification of future LEPs. NNSA's capabilities in HPC and new developments in data sciences, in particular data analytics, have led to the development of machine learning and intelligent retrieval systems that will soon be applied to the rapid comprehensive interrogation of archived nuclear test data.

3.4.3 Supporting Broader National Security Missions

Since inception, the national security laboratories have applied nuclear weapons expertise to challenges beyond maintaining the Nation's stockpile. These challenges include nuclear nonproliferation, assessing and countering nuclear threats, and understanding the nuclear capabilities of adversaries.[29] Historically, these activities were built on the periphery of the core Stockpile Stewardship Program. Today the complex global security environment demands dedicated new experiments, enhanced theoretical and computational models, and reinterpretation of archival nuclear test data. The Capabilities for Nuclear Intelligence program addresses many of these demands. In addition, funding from global security programs leverages Stockpile Stewardship Program investments. The Stockpile Stewardship Program benefits from these efforts because they provide further validation opportunities.

Stockpile Stewardship ST&E is increasingly being applied to develop advanced conventional (*i.e.*, non-nuclear) systems. In performing such activities, national security laboratory experts exercise critical nuclear design and engineering skills and provide broader experience and validation opportunities, turning synergistic technology advances in those areas into direct benefits for stockpile maintenance and sustainment (*e.g.*, enabling efficient modern radar design for LEPs).

3.4.4 Attracting and Retaining Expert Stockpile Stewards

Without a cadre of highly skilled scientists, engineers, and technicians to exploit NNSA's world-class experimental and computational facilities, the Stockpile Stewardship Program would fail. In a sense, the expertise of the stockpile stewards acts as a deterrent in itself. Some essential capabilities have slipped below state-of-the-art, hampering the ability to attract and retain scientists and engineers and adversely impacting research quality. This is increasingly becoming a nationwide problem. The national security laboratories must continue to develop and maintain leading edge research facilities and forward-looking scientific and technical programs to attract and retain top talent. NNSA's core mission is compelling and provides a wide range of research opportunities. These opportunities are supplemented by broader national security applications that provide other unique research challenges. In addition, NNSA's seven M&O partners offer new staff the opportunity to team with more experienced staff to pursue challenging, innovative research funded by Laboratory and Plant Directed Research and Development. Once fully developed and funded, the Stockpile Responsiveness Program will provide additional opportunities for the workforce to develop and exercise skills crucial to maintaining and modernizing tomorrow's stockpile.

[29] Additional information can be found in NNSA *Prevent, Counter, and Respond--A Strategic Plan to Reduce Global Nuclear Threats FY 2018 – FY 2022.*

3.5 Key Technical Challenges

As part of Stockpile Stewardship Program work, NNSA's national security laboratories have identified several specific challenging areas that require additional focus. These key technical challenges are described in detail in Chapter 3 of the classified Annex of this FY 2018 SSMP.

3.5.1 Certification of the Evolving Stockpile

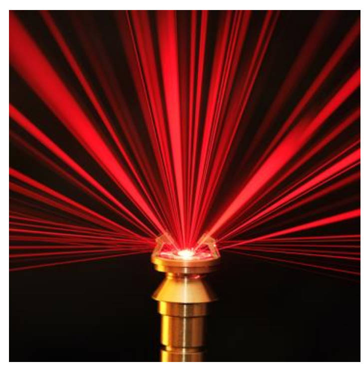
The aging of weapon components, LEPs, and stockpile modernization will inevitably introduce changes in the stockpile. Evolving threat environments may also introduce more taxing operational conditions; weapons performance under these conditions must be certified while abiding by the policies of no nuclear testing and no new nuclear weapons. These certification challenges require an evolving set of stewardship capabilities, such as the ability to assess weapon performance, outputs, and effects.

3.5.2 Hydrodynamics of Implosions

Understanding the hydrodynamic processes that occur in a nuclear weapon implosion is critical to making accurate assessments of the performance of weapons as well as of the failure modes associated with configuration changes in the evolving stockpile. The challenge of understanding hydrodynamic processes in nuclear weapons is directly relevant to predicting the performance or failure of pit reuse design concepts, understanding the implications of changes associated with advanced safety and security features, and including new components and other features provided by advanced manufacturing processes. A significant subset of this challenge is understanding the dynamic behavior of plutonium, which is investigated using subcritical experiments.

3.5.3 Development of New Experimental Diagnostics

Creating, developing, and engineering instrumentation that allows for the collection of experimental data requires dedicated investments. Without new diagnostics, NNSA cannot collect the data to assess aging effects, to study and map hydrodynamic processes that occur in a weapon implosion, or to improve understanding of the thermonuclear burn and boost processes. Continued investment in developing advanced diagnostics, such as ECSE, is crucial to sustain these integral efforts to assess and support the certification of future LEPs.



Photonic Doppler velocimetry diagnostic instruments measure the velocity of the inner surface of an imploding subcritical experiment at U1a.

3.5.4 Boost

Boost increases the nuclear yield of the pit, which contains fissile material, through fusion reactions. A key challenge for the Stockpile Stewardship Program is developing an empirical and physics-based understanding of the initial conditions for boost, improving the capability to model and simulate boost, and developing metrics that assess the effectiveness of boost.

3.5.5 Physics of Thermonuclear Burn

The physics of thermonuclear burn is fundamental to understanding the functioning of nuclear weapons. The overwhelming majority of the energy produced by a nuclear weapon is generated when the conditions within the NEP are in the HED state. The three major HED facilities (*i.e.*, NIF, Z, and Omega) provide capabilities and develop the expertise of stockpile stewards who contribute to the models and codes that simulate thermonuclear burn. These facilities allow experiments to determine the state of materials in an HED environment that has some similarities to the HED environment in a nuclear weapon. Additionally, the pursuit of ignition continues to add to understanding some aspects of thermonuclear burn. HED science, and, more specifically, the pursuit of fusion yield in the laboratory, is critical for the long-term health of the Stockpile Stewardship Program.

3.5.6 Material, Plasma, and Nuclear Properties

The performance of a nuclear weapon is strongly dependent on its material, plasma, and nuclear properties. Accurate material and plasma properties, including composition, phase, strength, equation-of-state, ionization state, and temperatures, are critical for accurate modeling of implosions and explosions. Nuclear properties, including fission and radiochemical cross sections, are important in assessing and analyzing weapon performance. HED experiments provide precision data, at regimes previously only accessible by theory or models, that are needed to assess and certify some aspects of weapon performance.

3.5.7 Vulnerability and Hardening

DOD requires that U.S. weapons will function after encountering extreme environments created by nearby nuclear explosions caused by adversaries or by fratricide. The Stockpile Stewardship Program must provide the capabilities to assure that the Nation's weapons will meet the DOD survivability requirements. It will be possible, with appropriate NNSA capabilities, to obtain data on combined environments (*i.e.*, x-rays, gamma-rays, and high-energy neutrons) in an aboveground laboratory facility or group of facilities. With that data, NNSA can qualify components and subsystems using complex, multi-scale, multi-physics calculations and thereby continue to assure that the weapons will meet military requirements. The principal challenge is to duplicate the environments created by adversary defenses, which requires several specialized capabilities.

3.5.8 Flight Environments

During delivery to a target, a weapon will experience extreme shocks, temperatures, and vibrations. These conditions are complicated by a flight environment that can include a broad range of other atmospheric conditions. Assuring that the weapon will function after flight depends on an understanding of coupled aerodynamic response, material thermal response, and structural dynamic response. This assurance requires an integrated program of flight testing, ground testing, and simulations.

Mechanical engineer adjusts a microphone for an acoustic test on a B61-12 system. The unit is surrounded by banks of speakers that expose it to an acoustic field. The sound pressure reaches 131 decibels, similar to that of a jet engine.

3.5.9 Predictive Capability

A challenge for the Stockpile Stewardship Program is improving the ability to model key physical phenomena through the development and deployment of new simulation technologies. This predictive capability is achieved through higher geometric and scientific fidelity *via* improved IDCs and HPC systems.

3.5.10 Computing Technology Disruption

The computing technology required for stockpile stewardship without nuclear testing has been stable for the past two decades. That technology is reaching physical limits that will preclude performance advances much beyond that of today.[30] The computing industry and the Federal national defense apparatus are entering a period of rapid change over the next 5 to 10 years to overcome these limitations. Ensuring continuity of the stockpile stewardship mission mandates radical modifications or perhaps the introduction of entirely new IDCs to keep pace with advances in computing technology.

3.6 Management and Planning

NNSA's tools and approaches to management and planning are unchanged from the FY 2017 SSMP. NNSA continues to improve its planning processes by aligning activities with programmatic elements and recent stockpile decisions. The Stockpile Stewardship ST&E planning processes described in Chapter 3 of the FY 2016 SSMP (*i.e.*, the Defense Programs Advisory Committee and the PCF) facilitate assessment of the condition of the Nation's stockpile, evaluation of effects of anomalies associated with warhead performance, and implementation of solutions to these concerns. Stockpile Stewardship ST&E also supports broader national security by providing capabilities to avoid technological surprise and assure confidence in weapons system performance.

To further the efforts, a subcritical experiment Integrated Project Team was formed to craft an integrated, multi-site, experimental framework that can be optimized to best fit anticipated funding profiles. This Integrated Project Team, together with an updated governance model for U1a operations, will allow experiments to be performed at an increased tempo.

3.6.1 Defense Programs Advisory Committee

In 2013, the Office of Defense Programs chartered the Defense Programs Advisory Committee. The committee is composed of experts from outside DOE and NNSA. The committee provides advice to the Deputy Administrator for Defense Programs regarding stewardship and maintenance of the Nation's nuclear deterrent.

The committee's activities may include, but are not limited to, periodic reviews of the diverse, major activities of the Office of Defense Programs (*i.e.*, assessments of the Nation's stockpile; the RDT&E infrastructure to maintain the stockpile and the overall nuclear deterrent; and the nuclear weapons production facilities and related manufacturing technologies). The Defense Programs Advisory Committee is currently evaluating the status of our understanding of plutonium aging.

3.6.2 Predictive Capability Framework

In the last decade, NNSA and the national security laboratories formulated the PCF to guide and communicate advances in "predictive science." Such advances are necessary to continue to assess the current status of each weapon system annually and to certify, without testing, that a weapon will meet the required military specifications before entering the stockpile. These advances address the key challenges discussed in the classified Annex. The PCF reflects the assessment of where weapon science will be heading in the early-to-mid 2020s.

[30] This has been termed the pending end of Moore's law. Moore's law is defined as the number of transistors per square inch on integrated circuits doubling approximately every 18 months. This doubling was enabled by the consistent reduction in the characteristic feature size of the constituent electrical elements. The impact of Moore's law is that computers have increased in speed and computational capability over the last several decades. However, the reduction of feature size is nearing a fundamental physical limit: the size at which quantum effects begin to dominate. As a consequence, advances in computational capability require much larger HPC systems that need significantly more electrical power to operate them.

Predictive Science encompasses all aspects necessary to obtain a capability to predict the behavior and performance of nuclear weapons. Whereas high performance computers and sophisticated multi-physics integrated nuclear performance codes are central to that predictive capability, a host of experimental studies are necessary both to provide fundamental material properties and to validate the predictive capability. NNSA's national security laboratories developed a series of "pegposts" to progress systematically toward the ultimate goal of replacing empirically calibrated simulations with high-fidelity simulations based on advances in weapon science research.

NNSA is projecting major advances over the next decade, as depicted in **Figure 3–1**. The schedule of achieving these goals will depend on unexpected technological hurdles, resources, and NNSA prioritization. The figure illustrates 13 pegposts aligned under four strands of activity: primary physics, secondary physics, weapon engineering, and surety. Each pegpost represents a major effort to integrate the scientific contributions to stockpile assessment or certification and relies on advances in modeling, experimentation, and simulation capabilities. For example, the pegposts rely on simulations of increasing complexity that require improvements in both the capability and capacity of high performance computers. Validation of the simulation models and advances in understanding nuclear weapon performance rely on the data from experimental facilities, such as DARHT and other hydrodynamic facilities, NIF, Z, as well as on the experimental platforms at U1a.

Near-term PCF pegposts will build upon completion of the primary reuse and secondary LEP capability pegposts in FY 2015 and FY 2016, respectively, by developing common models to quantify uncertainties in predictions, as well as models to assess the impact of variability caused by engineering, aging, or manufacturing. The culmination of all these advances shown in Figure 3–1 will support the delivery of high-fidelity, full-system weapon outputs.

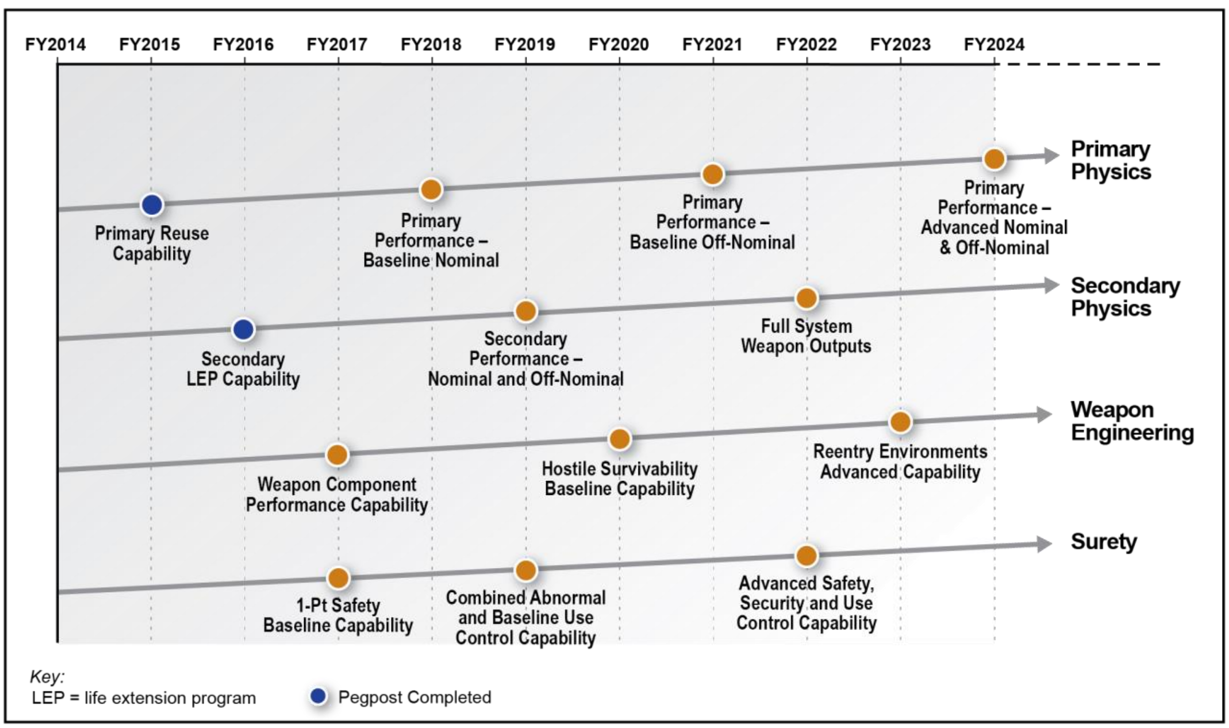


Figure 3–1. Version 3.1 of the Predictive Capability Framework, identifying major efforts required to advance stockpile assessment, sustainment, and certification capabilities

3.7 Experimental and Computational Capabilities

There are capabilities needed for stockpile stewardship in modeling, simulation, and experiments conducted at large-scale facilities, specifically HED experiments and hydrodynamic and subcritical experiments. Smaller, laboratory-scale activities are also crucial to long-term sustainment of the nuclear deterrent.

3.7.1 Modeling and Simulation

The modeling and simulation capability relies on IDCs, science codes, and HPC systems, together with the software and hardware infrastructure. Weapon designers and analysts use IDCs to simulate component and system performance in normal, abnormal, and hostile environments for both nuclear and non-nuclear components. IDCs are also used for experimental design and analysis. Researchers use science codes to investigate specific phenomena in detail, which results in implementing and validating the material and physical models in IDCs. Calculations with IDCs and science codes are performed on the Stockpile Stewardship Program's computing platforms. Simulation is also used to predict the outcomes of manufacturing processes to optimize the process and to improve responsiveness by accelerating development schedules in lieu of the traditional build-test-redesign cycle.

The capability embodied in IDCs is a key element for assessing the Nation's stockpile. IDCs are the principal tools used for design studies, maintenance analyses, experimental design, qualification, Annual Assessment Reports, LEPs, Alts, SFIs, warhead safety assessments, and weapons dismantlement. Their predictive capability supports most of today's stockpile stewardship missions. However, as the life of the stockpile is extended and weapons move further from the configurations tested in underground nuclear tests, maintaining the stockpile will require IDCs to be more predictive. Changes to threat environments also are driving improvements in IDCs. The predictive capability is limited by approximations in the physical models and the inability to resolve critical geometric and physical features at very small length scales. Experiments on NNSA's HED, hydrodynamic, and subcritical facilities are instrumental in improving and validating the predictive capability of the physical models in the IDCs, as well in quantifying the uncertainties in the models and codes.

The science codes calculate physical models and data to interpolate and extrapolate from measured data and to make predictions when performing the experiments is impractical, impossible, unsafe, or prohibited by treaty. Examples of such data include material strength and damage models, HE behavior, equations of state, x-ray opacities (*i.e.*, the probability of an x-ray interacting with matter), and nuclear cross sections. These codes typically model a single physical phenomenon using methods such as molecular dynamics and density functional theory.

Exascale computing systems[31] represent the next generation in computing systems. These systems will reduce the need for approximations, allow simulations to run at substantially smaller length scales, and provide more accurate quantification of margins and uncertainties. Improved understanding of the behavior of weapon materials, such as those created by additive manufacturing, will require predictions spanning a range of scales from the mesoscale (that is, the scale of the material's internal structure) to the scale of the weapon. An exascale computing capability, coupled with a diagnostic capability to measure the dynamic response of materials at the mesoscale, will allow more accurate safety and reliability performance predictions in extreme environments. Details of the plan for achieving exascale computing are presented in Appendix C, "Advanced Simulation and Computing."

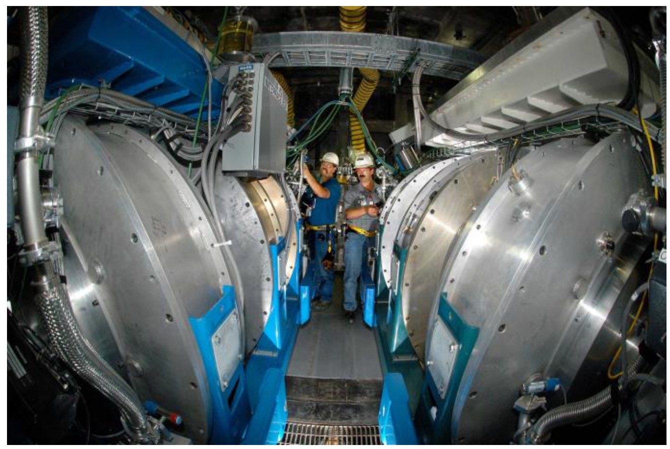
[31] Computer systems capable of at least a thousand petaFLOPS or a quintillion (10^{18}) floating point operations per second.

3.7.2 Key Capabilities for Understanding Nuclear Weapon Functioning

A modern thermonuclear weapon functions through a sequence of events, beginning with the primary-stage implosion, which compresses a fissile material—most often plutonium—into a super-critical configuration. The energy generated by the fissioning of the fissile material is drastically increased through fusion reactions in a process known as boost, resulting in the release of a massive amount of x-ray radiation. That radiation is trapped inside a radiation case and provides the energy to trigger the secondary stage. Understanding how the primary pit is compressed, the boost process, and the subsequent flow of x-ray radiation is fundamental to nuclear weapon design. The following sections describe some of the key capabilities necessary to ensure a safe, secure, and effective nuclear weapons stockpile.

3.7.2.1 Hydrodynamic and Subcritical Experiments

The Stockpile Stewardship Program assesses the effects of aging and various manufacturing processes on LEPs and SFIs as well as other concerns that can affect the viability of the stockpile. Fulfilling these responsibilities without underground nuclear tests requires hydrodynamic primary implosion tests with surrogate materials and subcritical experiments with plutonium. These integral experiments, along with theory, modeling, and simulation tools and small-scale focused experiments, underwrite the confidence in the Nation's nuclear deterrent. These experiments both improve NNSA's understanding of the current stockpile and help investigate issues of primary performance that will enable future primary reuse capabilities.


Cygnus takes radiographs of subcritical experiments at U1a.

Hydrodynamic tests are conducted and diagnosed with both radiography and other advanced diagnostic techniques at a number of NNSA facilities: DARHT at LANL, Contained Firing Facility at LLNL, and the Cygnus Dual-Axis Radiographic Facility at the Nevada National Security Site. In addition to these large-scale facilities, smaller experimental installations provide data to inform NNSA's modeling and simulation capabilities and to study single physics issues of interest.

DARHT is a critical resource to characterize the hydrodynamic conditions required for primary boost. One DARHT axis generates a single x-ray pulse; the other axis provides a multi-pulse capability, at a different angle from the first axis, to characterize the final moments of a primary implosion by producing time-dependent data. Other diagnostics include pin and photon Doppler velocimetry and high-speed cameras. Experiments at DARHT use surrogates in place of plutonium. NNSA conducts hydrodynamic experiments with plutonium only at U1a.

The **Contained Firing Facility** has long provided single-frame, single-axis radiographic hydrodynamic test capabilities within a building rated for tests of the largest primaries in the stockpile. Multiple diagnostics are available for a single hydrodynamics test, including pin and photon Doppler velocimetry diagnostics, wide-angle radiography, double-pulsed radiography, and optical framing cameras (as above).

U1a at the Nevada National Security Site is presently the only facility where focused and integral subcritical experiments that combine HE with plutonium can be conducted. Cygnus, located at U1a, provides a dual-axis radiographic source as part of the suite of diagnostics that produce data on the performance of surrogates and plutonium. Other diagnostics, similar to those at DARHT, are available at Cygnus. However, an integrated NNSA facility that can adequately diagnose the final, high-density stages of a primary implosion using plutonium does not exist. The ECSE program will address this inadequacy (see Section 3.7.2.4, Emerging Capabilities) and will enable an increased pace of subcritical plutonium experiments.

3.7.2.2 High Energy Density Physics Capabilities

A modern nuclear weapon multiplies the initial chemical energy stored in the HE by many orders of magnitude to achieve full system output. Energy densities become sufficiently high that plasma effects are important. Characterizing this HED regime is critical to predict the performance of nuclear weapons and to understand boost. The phenomena of interest include dynamic material behavior under extreme conditions, radiation transport, hydrodynamics, and thermonuclear burn, along with weapon outputs and effects. Achieving the requisite experimental conditions is only possible at facilities specifically designed to reach these conditions: NIF at LLNL, Z at SNL, and Omega at the University of Rochester's Laboratory for Laser Energetics.

The 192-laser-beam NIF was designed to produce thermonuclear ignition. Since completion of the National Ignition Campaign in 2012, NIF's role has expanded to tackle a broad array of weapons physics issues, including material properties, radiation flow, thermonuclear burn, and outputs and effects, while continuing the pursuit of thermonuclear ignition. NIF can reach higher densities, pressures, and temperatures than any other facility in the world. NIF is conducting experiments to determine the properties of high atomic weight materials, including very small quantities of plutonium, at conditions relevant to nuclear weapons performance. NIF works in tandem with Omega and Z to provide an array of national capabilities to probe and understand fundamental weapon physics issues.

Z is a pulsed-power facility capable of delivering 26 million amps of current to small radii targets (10 centimeters or less), where the electromagnetic forces drive dynamic experiments to investigate weapon physics topics such as the properties of materials, opacity, radiation flow, and thermonuclear burn. Z can create environments relevant to weapon operations and effects. Continued upgrades and improvements will realize Z's full potential of 32 million amps. The higher current will increase x-ray outputs for radiation effects experiments and magnetic pressures for studying material equations of state and thermonuclear burn.

The 60-beam Omega laser facility provides a platform for HED experiments to investigate issues for both weapons performance and inertial confinement fusion. The main Omega laser is supported by Omega Extended Performance, an additional laser that can operate independently or in tandem with Omega. Both lasers include an extensive suite of optical, nuclear, and x-ray diagnostics to probe high-energy phenomena. Omega also contributes to diagnostic development and serves as a staging platform for experiments at NIF.

NIF, Z, and Omega are supported by many smaller-scale facilities. These intermediate-energy facilities enable experiments that do not require the highest energy densities and serve an important role in diagnostic development and calibration.

3.7.2.3 Laboratory-Scale Experiments

The large projects and facilities described above depend on a great deal of laboratory-scale science to improve predictive capability, understand weapons performance, support large-scale experimental efforts, and evaluate the effects of manufacturing processes on component behavior. This laboratory-scale science is conducted by individuals or small teams using smaller facilities at the national security laboratories, the nuclear weapons production facilities, and academic institutions. The following describes some of these small-scale science areas:

- **Nuclear physics.** To improve predictive capability, experiments are conducted at LANSCE/Weapons Neutron Research to reduce the uncertainties in nuclear cross sections and to study the physics of fission and fusion processes. Research on the synthesis of heavy elements supports the reassessment of nuclear yields in underground tests, which aids in understanding weapons performance.
- **Plasma and atomic physics.** Atomic data such as x-ray opacities and plasma physics parameters are central to NNSA's predictive capability. This research also includes development of new neutron and x-ray sources for radiation effects studies and radiography as well as development of new diagnostics for HED platforms to enhance understanding of fusion physics.
- **Chemistry.** Research at laboratory scale on the chemistry of organic and inorganic materials in weapon components, especially aged components, is useful to predict the impact on weapons performance.
- **High explosives.** Understanding all aspects of the development, manufacturing, processing, and disposition of HE is essential for the safe and effective use of HE. The details of the dynamic behavior as HE detonate is required for accurate predictions of primary performance. Dynamic behavior is particularly important when considering the replacement of CHE with IHE in the context of operational safety in the nuclear security enterprise.
- **Nuclear explosive package materials.** Understanding the behavior of NEP materials at the extreme conditions in a nuclear weapon is essential to predict weapons performance in normal, abnormal, and hostile environments. These extreme conditions can only be reached in large facilities such as Z, NIF, DARHT, and LANSCE. However, much useful information at relevant, albeit much less extreme, conditions can be extracted from experiments on gas guns and other small laboratory devices.
- **Additive manufacturing.** Additive manufacturing, also known as 3D printing, could have broad impact on NNSA's mission by enabling new and novel design alternatives, simplifying weapon component production, accelerating design iteration and production development schedules, and reducing costs. Analyzing the behavior of materials and components made with this advanced technology is challenging because the behavior must be characterized over a range of scales from microscale to mesoscale and validated by testing. NNSA is characterizing these additive manufacturing materials in a variety of laboratory-scale experiments.
- **Engineering science.** The ability to deliver a weapon safely and reliably and to arm, fuze, and fire it requires a broad suite of theoretical, computational, and experimental research. Some of that research, particularly materials science and radiation science, can be conducted in laboratory-scale facilities.
- **Materials science.** A deep scientific understanding of materials performance, reliability, and aging is essential to provide rapid, confident resolution of stockpile and production issues as they emerge, to inform decisions about material selections and replacements, evaluate component lifetimes and potential reuse, and anticipate and mitigate future stockpile issues.
- **Radiation science.** Research on the interaction of radiation with a weapon and the weapon's subsequent response is essential to meet military requirements. This multi-disciplinary research is coupled with engineering and materials science. Whereas many experiments require HED

facilities such as Z, NIF, and Omega, the unique capabilities of Saturn, HERMES III, the Ion Beam Laboratory, and the Annular Core Research Reactor are key to advancing radiation science.

- **Microsystems science.** The extreme radiation requirements for weapons can far exceed the capability of commercial microelectronics to survive and function. Microsystems research provides designs and manufacturing processes that enable devices and circuits to meet stringent radiation requirements.

3.7.2.4 Capability Goals

The Matter-Radiation Interactions in Extremes (MaRIE) project has been discussed for years and is currently undergoing the CD-0 (Approve Mission Need) portion of the approval process. MaRIE would provide a capability to address the production of materials and the control of performance at the mesoscale (that is, at the scale of a material's internal structure). When combined with diagnostics from across the three national security laboratories and with NNSA's modeling and simulation capabilities, MaRIE would allow rapid, thorough characterization of microstructure, physical properties, and materials. These capabilities are essential to achieving the goals of rapidly developing new materials from conception to fabrication, characterization, and application, including those materials produced with advanced manufacturing techniques. The capabilities of MaRIE would facilitate the rapid characterization of such materials by allowing a direct, *in situ*, real-time comparison of the structure, properties, and performance of both existing and new materials and components. The recently completed formal review of the scientific functional requirements for MaRIE will form the foundation for the AoA's process on the path to CD-1 (Approve Alternative Selection and Cost Range).

Enhanced Capabilities for Subcritical Experiments will provide an enhanced radiographic imaging capability of dynamic plutonium configurations—a capability that currently does not exist within the nuclear security enterprise. NNSA approved the mission need for ECSE in September 2014 (CD-0), and this need was further supported by an external JASON study in 2016. The first phase of this program, the U1a Complex Enhancements project, will perform mining and provide the supporting structures, systems, and components within the U1a Complex for this initiative, to include improvements to the down-hole ventilation and excavation of space for radiographic equipment. The second phase of the program will provide the equipment supporting the capability. NNSA continues R&D of the sources and detectors that will support advanced capabilities (such as NDSE) into the future. An AoA to determine the exact type and required capabilities of the equipment to support ECSE is underway, and will be completed in early FY 2018.

Strategic Radiation-Hardened Advanced Microsystems are currently the subject of interagency discussions with other Federal groups and departments like the intelligence community and Departments of Defense, Justice, Energy, and others. All have similar trusted foundary requirements after 2025 that will provide integrated circuits supporting secure weapon systems, communications, and operations. Until 2025, NNSA requirements will continue to be met by the MESA fabrication facilities at SNL, which are currently the only sources of strategic radiation-hardened custom microelectronics for nuclear weapon components. The MESA SiFab reached its design end of life in 2013 and relies on fabrication tools no longer supported by commercial manufacturers. In addition, SiFab capabilities are inadequate for future War Reserve microsystems. Continued advanced microsystems R&D is critical to increase safety and security and to maintain the effectiveness of the nuclear weapons stockpile in an

Microsystems and Engineering Sciences Applications Complex for producing radiation-hardened silicon microelectronics evolving global security environment. Efforts are in place to sustain the MESA SiFab until 2025. NNSA has established mission need for a Trusted Microsystems Capability and is currently performing an AoA to meet that mission need.

3.8 Nuclear Test Readiness

The United States continues to observe the 1992 nuclear test moratorium called for under an article of the Nuclear-Test-Ban Treaty. NNSA maintains the readiness to conduct an underground nuclear test, if required, for the safety and effectiveness of the Nation's stockpile, or if otherwise directed by the President. NNSA's evaluation of the response time has changed over the years, and the fundamental approach taken to achieve test readiness has also changed.

Nuclear test readiness covers a broad range of potential activities. Assessments of nuclear test readiness require a clearly defined technical basis and other assumptions. Key considerations include the following:

- As required by the 1993 Presidential Decision Directive (PDD-15, "Stockpile Stewardship") NNSA has to maintain the capability to conduct a nuclear test within 24 to 36 months.
- Nuclear test response time is dependent on the specific details of the projected test, if needed.
- Full compliance with domestic regulations, agreements, and laws relating to worker and public safety and the environment, as well as international treaties, could significantly extend the time required for execution of a nuclear test beyond 36 months.
- The assumption is that a test would be conducted only when the President has declared a national emergency or other similar contingency and only after any necessary waiver of applicable statutory and regulatory restrictions.

General testing estimates based on these considerations, NNSA interpretation of PDD-15, and needs and conditions are as follows:

- **6 to 10 months** for a simple test, with waivers and simplified processes
- **24 to 36 months** for a fully instrumented test to address stockpile needs with the existing stockpile
- **60 months** for a test to develop a new capability

Since FY 2010, there has been no funding specific to nuclear test readiness as a separate program. At present, in addition to leveraging artifacts of prior underground nuclear tests (test site, holes, cranes, *etc.*), NNSA maintains test readiness by exercising capabilities at the national security laboratories and the Nevada National Security Site through the Stockpile Stewardship Program. Test readiness is a product of a robust, technically challenging Stockpile Stewardship Program that invests in development of both the personnel and infrastructure of the nuclear security enterprise. This strategy relies on reconstituting the remaining underground testing elements when needed, rather than maintaining obsolete facilities.

Operations such as subcritical experiments at U1a exercise the people, physical assets, and infrastructure support services required for an underground nuclear test. These operations involve critical skills and formality of operations, including weapon design; the design, preparation, and fielding of advanced diagnostics; modern safety analysis; experimental execution; and recovery and analysis of the data. These subcritical experiments are challenging, multi-disciplinary efforts that enhance the technical competency of the national security enterprise workforce. Experiments on HED platforms such as NIF, Z, and Omega also preserve the capability for prompt measurement of optical, x-ray, gamma-ray, and neutrons from experiments with next-generation technologies similar to underground nuclear test measurements.

Chapter 4
Physical Infrastructure

One of the most pressing challenges for the nuclear security enterprise is sustaining, recapitalizing, and upgrading aging physical infrastructure.[32] The sheer size, value, and varied nature of the asset portfolio necessitates budgeting, planning, and managing the programmatic infrastructure across several segments of Defense Programs, plus the general purpose infrastructure of the Office of Safety, Infrastructure, and Operations. Sustaining and recapitalizing the infrastructure is a complex, expensive task because a majority of the assets are well beyond designed service lives. As illustrated in **Figure 4–1**, more than half of NNSA's buildings are over 40 years old, nearly 30 percent date to the Manhattan Project era, 13 percent are excess to mission needs, and 61 percent (nearly two-thirds) are in less than adequate condition.

This chapter describes the current state, challenges, recent accomplishments, and strategies of both the general purpose and the programmatic infrastructure. Chapter 4 also contains information on the challenges and strategies of disposing of the aged infrastructure.

Physical Infrastructure Accomplishments

- *Completed Transuranic Waste Facility construction at LANL.*
- *Completed the KCNSC White Space Expansion to Support the B61 Life Extension Program.*
- *Completed the SNL Tonopah Test Range 03-57 Control Tower electrical/mechanical upgrade.*
- *Completed 90 percent of construction for the High Explosives Pressing Facility at Pantex.*
- *Broke ground on three Leadership in Energy and Environmental Design (LEED®) Gold buildings: Administrative Support Complex, which consolidates administrative functions in 35 legacy facilities at Pantex into a single building, a multi-disciplinary advanced manufacturing laboratory at LLNL, and a first permanent structure for Y-12's Uranium Processing Facility project, the Construction Support Building.*
- *Transitioned radiography operations from Building 9212 to 9204-2E to phase out mission dependence on Building 9212.*
- *Began equipping the Radiological Laboratory Utility Office Building space and the Plutonium Facility space at LANL as part of the Chemistry and Metallurgy Research Replacement project.*
- *Conducted risk reduction activities at 5 of NNSA's top-10 high-risk facilities.*
- *Completed Capabilities Based Infrastructure Bays & Cells Upgrade Project at Pantex & U1a Drift Connection project at the Nevada National Security Site.*

4.1 Introduction

The NNSA mission to support the nuclear deterrent depends on specialized experimental facilities, diagnostic equipment, and high performance computers. The overall enterprise is long overdue to create a modern, smaller nuclear security enterprise that will reduce risk to the mission and improve worker, public, and environmental safety. The increased load on the existing infrastructure due to multiple LEPs, along with R&D activities in the LEPs, has highlighted this concern.

[32] The aging infrastructure has been reported in Government Accountability Office documents, in independent reviews chartered by the Secretary of Energy in 2005 and 2008, and by Congress in 2014 (see pp. 4-2 to 4-3 of the FY 2016 SSMP).

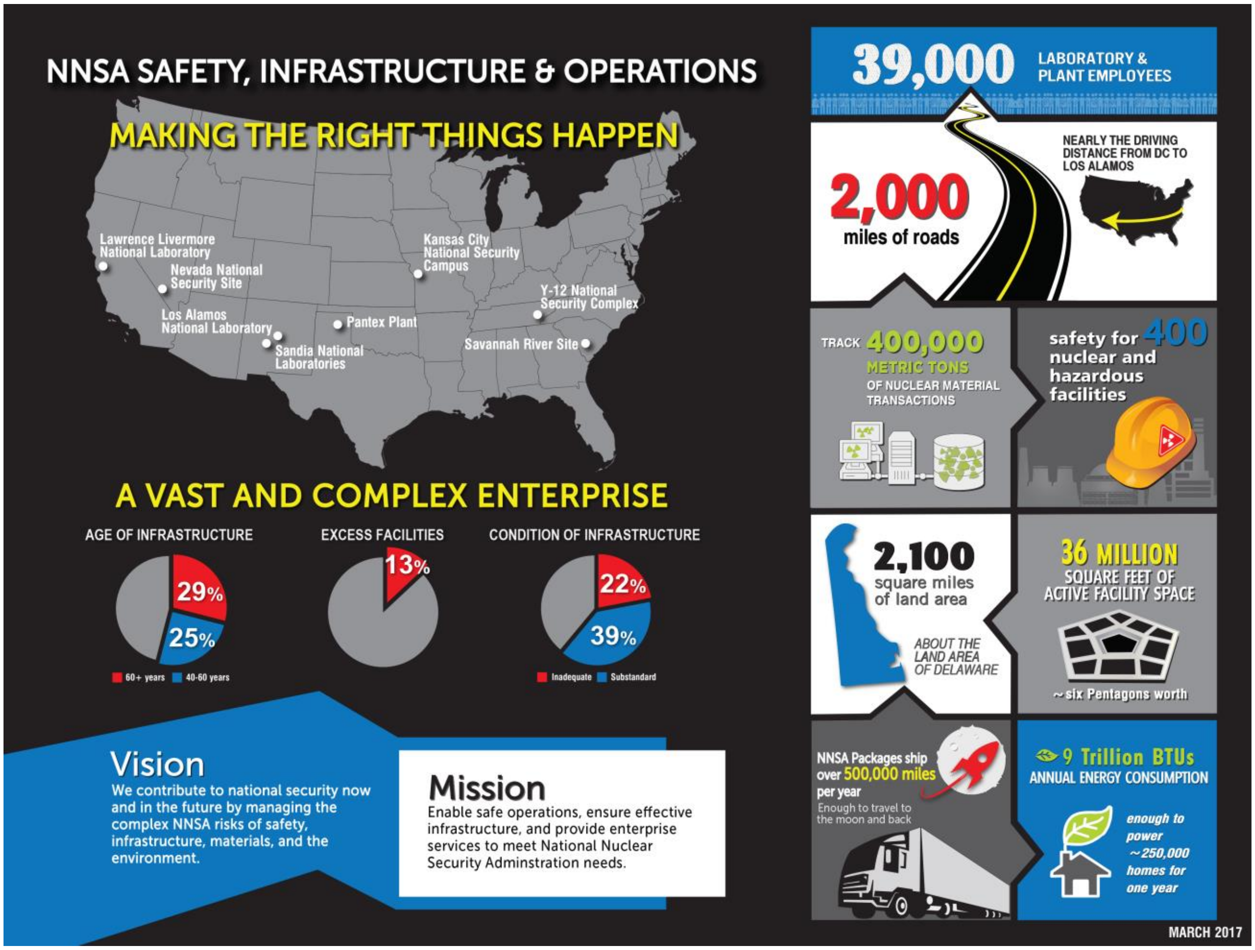


Figure 4–1. NNSA general purpose infrastructure scope

Safely operating and modernizing the infrastructure to meet mission demands, now and in the future, is a complex challenge that is made problematic due to infrastructure that is failing at an increasing frequency due to age and condition. To address these challenges, NNSA has made significant efforts to modernize the infrastructure, eliminate excess facilities, and improve management practices. There has also been an increase in resources allocated to improving the condition and functionality of existing infrastructure. NNSA's vision for its infrastructure includes the following:

- **Modernize**: Arrest the declining state of 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 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 across the enterprise.

NNSA's physical infrastructure is funded and managed in two categories, programmatic infrastructure and general purpose infrastructure:

- **Programmatic Infrastructure** includes specialized experimental and production facilities, high performance computers, diagnostic equipment, processes, and other capabilities housed within the buildings. Programmatic infrastructure allows NNSA to conduct research, tests, production, sustainment, and material disposition for NNSA' national security missions.
- **General Purpose Infrastructure** is the infrastructure not specifically dedicated to programmatic efforts (such as roads, office buildings, and site utilities), but which supports mission execution. This category also includes offices, operational support, and general laboratories, general building systems (*e.g.*, fire suppression systems, and heating, ventilation, and cooling systems) 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 purpose infrastructure.

The two categories differ in a number of respects and lead to distinct approaches and processes for the short- and long-term management of physical assets. Both general purpose and programmatic infrastructure must be maintained safely until revitalization or disposition. Sections 4.2 and 4.3 describe the specific strategies that NNSA has implemented to provide and sustain the buildings and specialized facilities and equipment necessary to accomplish NNSA's missions.

Despite budgetary challenges and the age of physical assets, NNSA has made progress by:

- using management tools to prioritize and address infrastructure deficiencies and to make better-informed decisions in meeting mission requirements;
- laying the groundwork for integrated, nuclear security enterprise-wide planning;
- developing plans to manage the risk of the aging physical infrastructure in the short term;
- halting the growth of deferred maintenance in NNSA's buildings and facilities, for which the remaining backlog is about $2.5 billion;[33] and
- completing several new mission-critical facilities.

4.2 Programmatic Infrastructure

Programmatic infrastructure allows NNSA to carry out research, tests, production, sustainment, and disposition tasks related to the entire range of those commitments. Programmatic infrastructure includes all the special tooling, equipment, and specialized facilities for R&D, manufacture, qualification, and surveillance activities for the nuclear weapons stockpile.

4.2.1 Current Status

Many specialized programmatic facilities and much of the diagnostic and testing equipment have been in service well beyond their designed technical life spans (that is, over 35 years). Previous decisions to repair, rather than recapitalize, have pushed much of the equipment to the point that maintenance staff must rely on third-party sources and used parts to keep the systems operational. Dedicated efforts by the M&O

[33] During 2015, NNSA worked with the sites to standardize a method for determining deferred maintenance and repair needs. In 2016, NNSA used this standardized approach to revalidate information on the condition of infrastructure. This resulted in some amount of deferred maintenance being reclassified as repair needs, so there is an administrative reduction to the current deferred maintenance total. Fundamentally, the state of NNSA infrastructure did not change.

partners and field office personnel have kept the availability rate high and minimized the loss of production, but that pace is not sustainable in the long term. Recapitalization and process technology improvements through Capability Based Investments (CBI), line-item construction, capital equipment installation, and site-specific investments have allowed NNSA to fulfill its vital missions.

While investment levels have historically been adequate to address most past mission workloads, the increased workload of the current LEP schedule, along with increased testing requirements, is taxing the aging programmatic facilities and equipment and increasing the risk of unplanned failures and capability gaps. The capability-based infrastructure approach, management strategies, and sustainment budgets are being used in concert to address these growing risks and are discussed in Section 4.2.3.

4.2.2 Challenges

Investments in programmatic infrastructure have not kept pace with the needs of an aged enterprise with a growing workload. Additional investment is necessary to decrease risk in ongoing LEPs, re-establish the capability to produce strategic material needed for the stockpile, and position the enterprise for long-term stockpile stewardship without having to resort to underground nuclear explosive testing. These additional investments will also reduce maintenance, operating, and associated security costs and reduce the NNSA footprint. Additional challenges of the programmatic infrastructure recapitalization program are summarized in Sections 4.2.2.1 and 4.2.2.2.

4.2.2.1 Equipment Repair Versus Replacement Tensions in a Budget-restricted Environment

Nuclear security enterprise-wide recapitalization of programmatic equipment has been revitalized only in the last 3 years. Prior to that time, NNSA repaired or replaced programmatic equipment to meet the needs of specific weapon development or sustainment programs. NNSA made minimal investments to meet immediate needs with less regard for long-term strategies to support future programs. The result was an inventory of outdated and often obsolete equipment with few or no commercial options for maintenance and spare parts. NNSA has established the Recapitalization program to attempt to better balance short-term mission needs with more efficient long-term investments to build a sustainable nuclear security enterprise.

4.2.2.2 Role of Safety and Security in Infrastructure Challenges

Current approaches to safety and security regarding nuclear facilities and equipment result in high levels of rigor as a means of avoiding risk, often resulting in delays and additional costs. This issue was cited in the report, *A New Foundation for the Nuclear Security Enterprise: Report of the Congressional Advisory Panel on the Governance of the Nuclear Security Enterprise*, as an obstacle to effective management of infrastructure.[34] Since NNSA and DOE safety directives provide the flexibility to grade requirements to achieve the level of protection appropriate to the actual hazard in a facility, NNSA is reviewing them for opportunities to make better use of this flexibility.

[34] Action item 5 from the final report of *A New Foundation for the Nuclear Enterprise: Report of the Congressional Advisory Panel on the Governance of the Nuclear Security Enterprise*, November 2014: "It is imperative that existing rulemaking practices and execution oversight be overhauled so that risk is better assessed and balanced with the needs of mission execution."

4.2.3 Accomplishments

4.2.3.1 Recapitalization of Capability Based Investments

The CBI subprogram has grown and evolved substantially since the FY 2014 SSMP.[35] The CBI has been updated and the portfolio now includes programmatic equipment and facility investments at all three national security laboratories, the four nuclear weapons production facilities, and the Nevada National Security Site. These projects are prioritized based on requirements and risks documented by LEPs, major Alts, material bridging strategies, strategic material sustainment activities, and RDT&E investments. All CBI projects must meet the following criteria: they must provide an enduring capability, and they must not be specific to a single weapon system. Some recent CBI accomplishments and ongoing activities include the following:

- Completion of upgrades to the environmental testing capability upgrades at LANL. These upgrades increased the reliability and accuracy of combined shock, vibration, and thermal test and qualification activities.
- Construction of a drift connection at U1a on the Nevada National Security Site. This connection will allow larger subcritical experiment vessels and enhance worker safety.
- Completion of updates to the development laboratory at KCNSC. These updates included tools required to verify coating and substrate capabilities for component manufacture on all warheads.
- Completion of overhauls of the assembly bays and cells, the digital radiography capabilities, SNM work stations, and some of the pit surveillance equipment at Pantex. These upgrades have increased the efficiency and effectiveness of assembly and surveillance operations at Pantex.
- Recapitalizing warhead assessment capabilities at LLNL to prepare for the upcoming W80-4 LEP. So far, LLNL has replaced hundreds of pieces of obsolete equipment ranging from component prototyping and environmental testing to explosives synthesis and high-speed digital cameras for explosives testing.
- Replacing and upgrading fabrication capabilities at SNL for radiation-hardened microelectronics. This project will extend and maintain SNL's ability to develop and manufacture critical microsystems until a successor to the current MESA facility can be identified. This is currently in interagency discussions with other groups and agencies like the intelligence community and Departments of Defense, Justice, Energy, and others.
- Updating component manufacturing capabilities at Y-12 for future warhead component production.

4.2.3.2 Capital Construction Projects

- CD-2/3 (Performance Baseline and Start of Construction) was approved for PF-4 Equipment Installation (PEI1) and RLUOB Equipment Installation update (REI2) for CMRR.
- Construction of the Uranium Processing Facility and related subprojects supports NNSA's goal to cease enriched uranium programmatic operations in Building 9212 at Y-12 by 2025. For additional information on this project see Chapter 2, Section 2.4.2.
- The CD-2/3 submittal package, including the completion of 100-percent design and 100-percent Preliminary Documented Safety Analysis for the Transuranic Liquid Waste Treatment Facility, was submitted in June 2017. Construction is expected to begin, following approval of CD-2/3 in

[35] See Chapter 5, Section 5.1 of the FY 2014 SSMP.

FY 2018. This project will construct and start up a new facility to treat TRU liquid waste generated at PF-4 at LANL.

- The TA-55 Reinvestment project invests in upgrades for PF-4; Phase III will install a new fire alarm system, extending the life of the facility at LANL. The AoA for the TA-55 Reinvestment project's Phase III was completed, and the project team reconvened to pursue CD-1, which is expected in FY 2018.
- The Transuranic Waste Facility constructed at LANL consolidates radioactive waste storage and characterization operations into a compact area, thereby enhancing safety, security, and efficiency. Programmatic operations are expected to begin in early FY 2018.
- The High Explosives Pressing Facility (HEPF) at Pantex consolidates HE operations from multiple buildings, improving the safety and efficiency of material movement.[36] HEPF also provides better support for the projected LEP workload. Programmatic operations are expected to begin by the end of FY 2018.

4.2.4 Strategies for the Future

Investments to support programmatic infrastructure for a safe, secure, and effective nuclear stockpile include the following:

- **Initiating line-item construction projects to replace facilities identified as beyond repair and maintaining the capabilities provided by those facilities.** Two examples are the Uranium Processing Facility at Y-12 and the CMRR at LANL, which will provide new facilities for the uranium and plutonium production missions, respectively.
- **Recapitalizing small-scale equipment through multiple NNSA programs, including the CBI subprogram, the Component Manufacturing Development subprogram, and the Science Program.** These investments can modernize and sustain individual capabilities as well as provide a "bridge" for capabilities in need of large-scale recapitalization. For example, CBI is investing in MESA to sustain SNL's microelectronics fabrication capability while an AoA is being conducted to determine the long-term strategy to meet radiation-hardened fabrication needs. Another example is investment in engineering and HE equipment to support LEP activities at LLNL.
- **Collaborating in a DOD-DOE threat assessment to continue efforts such as assessing risk**. In many cases, application of a graded approach to assessing threats allows selection of appropriate safety standards to meet DOE requirements. To improve mission effectiveness and reduce cost, NNSA and oversight personnel must be empowered to balance risk against costs when approving an approach that ensures compliance with fundamental safety requirements.

Given the myriad programmatic infrastructure goals and the competing priorities across the nuclear security enterprise, NNSA is striving to implement the three high-priority investment strategies to "modernize, streamline, and sustain" to achieve the greatest programmatic impact. To this end, NNSA engages in strategic planning efforts, such as the Construction Working Group, and authors infrastructure strategies to determine how best to sustain the weapons activities capabilities of the nuclear security enterprise.

[36] Completion (CD-4) of the HEPF at Pantex occurred on February 28, 2017.

4.3 General Purpose Infrastructure

Planning and managing the extensive, diverse general purpose infrastructure across NNSA's eight sites necessitates an understanding of function, age, and condition and a variety of new tools, techniques, and approaches to manage the complex suite of infrastructure assets. NNSA has focused on ways to operate efficiently and prioritize investments across the nuclear security enterprise. These new approaches have already yielded some success, but many challenges remain. NNSA must sustain these efforts over the next 25 years to support mission needs. This complex task requires balanced investment decision-making across four key elements:

- Acquire assets as required to meet mission needs.
- Maintain assets appropriately throughout their service lives.
- Recapitalize assets to respond to changing needs and extend their service lives.
- Dispose of assets that are excess to the mission and have surpassed their useful service lives.

Figure 4–2 illustrates the cyclical nature of asset management from acquisition to disposition and captures the evolving interplay among these elements to support NNSA's national security missions.

Figure 4–2. Asset life cycle portfolio management

4.3.1 Current Status

Some aspects of that 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. NNSA is taking steps to arrest the declining state of the general purpose infrastructure by enhancing and optimizing resources. To this end, NNSA is deploying innovative management tools to facilitate a data-driven, risk-informed planning process that will guide investment decisions. A number of ongoing programs address these challenges specifically.

4.3.1.1 Operations of Facilities

The Operations of Facilities Program provides the funding to operate NNSA facilities in a safe and secure manner and includes essential support such as water and electrical utilities, safety systems, lease agreements, and activities associated with Federal, state, and local regulations associated with the environment and with worker safety and health.

4.3.1.2 Maintenance and Repair of Facilities

The Maintenance and Repair of Facilities Program provides direct-funded maintenance activities across NNSA for the day-to-day work required to sustain and preserve NNSA facilities and equipment in a condition suitable for their designated purposes. These efforts include predictive, preventive, and corrective maintenance activities to maintain facilities, property, assets, systems, roads, equipment, and vital safety systems.

4.3.1.3 Recapitalization

The Recapitalization Program addresses the numerous obsolete support and safety systems by revitalizing facilities that are beyond the end of their design life and prioritizes investments to improve the reliability, efficiency, and capability of infrastructure to meet mission requirements. The Recapitalization Program includes modernization to extend and renew the life of existing structures, capabilities for weapons activities, and systems. The program includes minor construction projects to renovate existing facilities or construct new facilities and additions that, by definition, cost less than $10 million. Examples of such projects are the ongoing Dynamic Equations of State Facility at LANL and the planned Battery Test Facility under design at SNL. Similarly sized modernization projects are constructed as institutional minor construction projects with indirect site funding to address multi-user infrastructure needs. Both of these minor construction investments are used in conjunction with capital construction to provide timely, appropriately sized and integrated infrastructure needs.

The Recapitalization Program budget includes disposition, a separate subprogram that is discussed in Section 4.5.

4.3.1.4 Capital Construction Projects

NNSA's general purpose infrastructure capital investments modernize the aging nuclear security enterprise by replacing existing facilities and weapons activities capabilities that are beyond their intended lifetimes. The projects in this section, as well as other planned capital improvements, are necessary to provide capabilities to meet future mission demands:

- Emergency Operations Centers at LLNL, SNL, and Y-12 to improve the emergency management response and survive high-consequence natural phenomena
- Electrical distribution system projects at LANL, LLNL, and the Nevada National Security Site to improve capability, capacity, and reliability
- New fire station at Y-12 to improve emergency response
- New High Pressure Fire Loop for Zone 11 at Pantex to provide a reliable fire protection system to support HE production and development operations

4.3.1.5 Public-Private Partnerships

NNSA is using public-private partnerships (*e.g.*, the leased KCNSC and the planned lease of the Administrative Support Complex at Pantex). 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.[37] It is not likely that operating lease solutions will be viable for many of the enduring infrastructure needs described elsewhere in this SSMP although there are some cases in which a capital lease may be possible.

[37] OMB Circular No. A-11, Preparation, Submission, and Execution of the Budget.

4.3.2 Challenges

The main challenges to sustaining, revitalizing, and operating NNSA's general purpose infrastructure are:

- the growing need for refurbishment or modernization of key assets;
- the allocation of limited capital construction resources to replace these assets;
- sustaining facilities and halting growth of deferred maintenance, especially for mission-essential assets; and
- the backlog of excess assets awaiting deactivation and decommissioning for especially-high-risk buildings that must be transferred to DOE's Office of Environmental Management.

4.3.3 Accomplishments

4.3.3.1 Implementation of New Program Management Tools and Processes

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 in this section.

DOE Laboratory Operations Board Assessment Tools

In 2013, the Secretary of Energy formed the Laboratory Operations Board to provide a nuclear security enterprise-wide forum to engage DOE's national laboratories and programs in a joint effort to identify opportunities for improving the effectiveness and efficiency of operations. The Laboratory Operations Board established an integrated plan to conduct DOE's first assessment of its general purpose infrastructure across all 17 DOE national laboratories, as well as its NNSA sites and the Environmental Management clean-up sites, using common standards and a DOE-wide approach. Data from that assessment informs NNSA's Budget Request and goal of preventing growth in the deferred maintenance backlog above FY 2015 end-of-year levels. To build upon that initiative, NNSA formed an Infrastructure Executive Committee, which has been charged with providing an annual update on the state of the general purpose infrastructure to the Secretary of Energy and other senior DOE leaders.

BUILDER

BUILDER is a web-based software tool that enables decisions concerning when, where, and how to best maintain, repair, and recapitalize infrastructure. Developed by the Army Corps of Engineers, the BUILDER Sustainment Management System has been recognized by the National Academies of Sciences, Engineering, and Medicine as a best-in-class practice for infrastructure management.[38] BUILDER uses pre-existing engineering data to predict facility and component conditions, prioritize maintenance tasks, and support analysis of different spending scenarios. In FY 2014, NNSA selected BUILDER as its new facility assessment system. NNSA's ultimate goal is to collect all condition assessment and functionality data in BUILDER and use it as the auditable, consistent single source of information on the condition of all NNSA physical infrastructure. BUILDER implementation is more than halfway complete and will be operational throughout the nuclear security enterprise by late 2018.

[38] See the *Predicting Outcomes of Investments in Maintenance and Repair of Federal Facilities*, The National Academies Press, 2012.

Enterprise Risk Management

NNSA developed its Enterprise Risk Management (ERM) approach as a risk-based methodology that measures the consequence to the mission associated with an investment and the likelihood of the consequence occurring. ERM provides a framework to evaluate the potential impact of investment efforts as well as opportunities for future investment. “Consequence” is measured by the Mission Dependency Index; “Likelihood” is measured by BUILDER and the Laboratory Operations Board.[39] The ERM strategy represents a fundamental shift in the methods and tools that NNSA has used for the past 15 years and requires repurposing or disposition of lower-priority (hedge) assets.

Program Management Information System Generation 2

The Program Management Information System Generation 2 (G2) empowers NNSA’s M&O partners to manage infrastructure at the project level and provides NNSA senior management with a common, transparent picture of the allocation and execution of spending on that infrastructure. G2’s flexibility[40] provides this transparency without burdening M&O partners with additional data tracking and reporting requirements by:

- tracking scope, schedule, cost, for project status;
- automating change control, business rules, and notifications;
- maintaining geospatial data for maps, diagrams, photographs, inventories, and conditions; and
- using ERM questions and formulas to assess risk and prioritize projects.

4.3.3.2 Progress in Addressing NNSA’s Key Challenges

Recapitalization investments are now evaluated and prioritized according to enterprise-wide, risk-based assessments of programmatic and safety impacts, sustainability, return on investment, and deferred maintenance reduction. The risk assessments include prioritizing systematic replacement of obsolete and failing building systems as multi-year investments, which has stabilized complex planning for resources, as well as increased productivity, operational efficiencies, and programmatic flexibility. The ongoing 50-year sprinkler head replacements portfolio is an example of a multi-year investment that enables a crew to be trained to perform replacements continually without impacting the production schedules in the operating nuclear facilities at Y-12. Maintenance and disposition programs are similarly evaluated according to enterprise-wide risk assessments.[41]

Recapitalize and Maintain

In FY 2016, NNSA planned 30 but completed 33 recapitalization projects. This improved performance reflects the impact of advanced planning based on detailed data and the use of the reporting tools and processes described above. Examples of several completed recapitalization projects that address specific criteria in the risk-based assessments are:

- KCNSC White Space Expansion to support the B61-12 LEP (programmatic risk);
- Pantex High Pressure Fire Loop Lead-in and Flame Detection Replacements in five bays and two support facilities under the Pantex Bay and Cell Safety System Improvements Portfolio (safety risk);

[39] The Mission Dependency Index measures the consequence to the mission by combining the impact if the asset were lost, the difficulty of replacing that asset, and the interdependency of assets. The index also shows the interconnectivity of facilities.
[40] See the FY 2015 SSMP, Chapter 8, Section 8.10.12, p. 8-23.
[41] Accomplishments in disposition of facilities are discussed in Section 4.5 of this SSMP.

- LANL Radioactive Liquid Waste Collection System Upgrade with renewable power and wireless communications (sustainability risk);
- Savannah River Nuclear Solutions Fire Suppression Systems Expansion that consolidated warehouse storage (return on investment and deferred maintenance reduction); and
- 9204-2 Oven Room Ceiling Replacement at Y-12 and the PF-4 Potable Water Line Replacement at LANL (return on investment and deferred maintenance reduction).

With additional maintenance funding granted in the *Consolidated Appropriations Act, 2016* (Pub. L. 114-113), NNSA also increased investments in the Roof Asset Management program by replacing and repairing additional roofs throughout the nuclear security enterprise. Additional funds also addressed rain event damage that occurred at the Nevada National Security Site as well as a snow storm event at Pantex that led to electrical power outages that temporarily shut down several operations in 2016.

To track deferred maintenance accuracy and consistency, NNSA standardized the implementation of the definitions of deferred maintenance and repair needs to align with the current Federal Accounting Standards Advisory Board *Statement of Federal Financial Accounting Standards 42: Deferred Maintenance and Repairs*. In FY 2016, NNSA made progress in updating infrastructure conditions, to include a new category for repair needs that captures the investment necessary to restore an asset to its most recently configured design or capability.[42] Consistent definitions and implementation of repair needs were a primary reason for the 40 percent decrease in total deferred maintenance as compared to the FY 2015 value. Deferred maintenance growth was halted in FY 2016 for the first time in nearly a decade.

Acquire

Groundbreaking to construct the new Administrative Support Complex, a leased building at Pantex, occurred on August 18, 2016, after a rigorous acquisition and project management process that included (1) an AoA, (2) a CD-1 decision to pursue a lease rather than a purchase, and (3) a life-cycle cost analysis approved by OMB. The new building will house approximately 1,100 employees currently located in functionally inadequate and technologically obsolete buildings. The new building will enable elimination of approximately $20 million in deferred maintenance. Moreover, because Texas Tech University will also lease space in the building, collaborative opportunities on new technologies and wind research will be possible. The completion of the building is expected in spring 2018.

4.3.4 Strategies for the Future

This section summarizes the strategies under development to address general purpose infrastructure challenges, including those for long-term strategic planning.

4.3.4.1 NNSA Master Asset Plan

The NNSA Master Asset Plan, currently in development, will serve as a roadmap to meet general purpose infrastructure needs by identifying the capabilities that drive these needs. The plan will provide a look at the current condition of the general purpose infrastructure and the major infrastructure gaps and risks that impact NNSA's ability to meet mission needs. The Master Asset Plan process draws upon the DOE's Office of Science's proven infrastructure strategic planning process.

[42] Repair needs are the sum of deferred maintenance and the additional maintenance needs above deferred maintenance.

A key tool in the Master Asset Plan strategy is the future application of BUILDER, which will house and analyze infrastructure data that will be used to:

- identify condition and functionality gaps and risks;
- estimate the cost of maintenance, repair, and modernization;
- calculate deferred maintenance, repair needs, and replacement plant value; and
- integrate BUILDER with site-specific computerized maintenance management systems (software that determines, schedules, and records day-to-day maintenance needs).

As the Master Asset Plan will demonstrate, NNSA is implementing processes to identify and understand the infrastructure condition, functionality, gaps, and risks and impact. These processes are assisting NNSA in making integrated investment decisions concerning all infrastructure resources according to a comprehensive enterprise-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. The programs described in Sections 4.3.4.2 through 4.3.4.6 are dedicated to planning and management of general purpose infrastructure in coordination with programmatic, indirect, and other infrastructure organizations in order to make appropriate investment decisions.

4.4 Non-Weapons Account Activities

Several other DOE/NNSA programs rely on infrastructure funded by Weapons Activities (*e.g.*, Defense Nuclear Nonproliferation and Emergency Management). These programs are described in DOE/NNSA's *Prevent, Counter, and Respond—A Strategic Plan to Reduce Global Nuclear Threats (FY 2018 – FY 2022)*.

4.4.1 Support of Nonproliferation Efforts

The DOE/NNSA Office of Defense Nuclear Nonproliferation's Office of Material Management and Minimization relies heavily on the infrastructure maintained by other DOE and NNSA offices. Impacts of the aging infrastructure on the implementation of key nonproliferation programs are summarized below.

- **Conversion Program.** Y-12's uranium facilities perform casting activities that produce low-enriched uranium-molybdenum (LEU-Mo) material that will allow the conversion of the U.S. high performance research reactors that currently use HEU. Aging casting furnaces at Y-12 are a programmatic risk and a potential single point of failure in the production of future LEU-Mo material. The casting technology for the Uranium Processing Facility will be different than what is currently available at Y-12, but the capabilities at the Uranium Processing Facility are expected to accommodate the Office of Material Management and Minimization's casting needs for the U.S. high performance research reactors conversion project in the future.
- **Conversion Program.** The Sigma facility at LANL develops and optimizes LEU-Mo fuel fabrication processes.
- **Material Disposition Program.** The PF-4 facility at LANL disassembles nuclear weapon pits and converts the resulting plutonium metal into an oxide form using the Advanced Recovery and Integrated Extraction System.
- **Material Disposition Program.** The enriched uranium operations infrastructure at Y-12 allows for analysis, processing, and packaging of materials to be down blended or properly disposed.

- **Nuclear Material Removal Program.** NNSA's Office of Secure Transportation provides resources for multiple removal campaigns. Secure Transportation facilitates these projects by providing safe and secure transport of the nuclear material when within the United States.

The Office of Defense Nuclear Nonproliferation's Office of Nonproliferation and Arms Control (NPAC) also relies on the infrastructure maintained by other DOE and NNSA offices, as summarized below.

- NPAC relies on the availability of Category I, II, and III SNM standards and sealed sources for detector and system development, as well as for training foreign partner personnel in the fundamentals of safeguards and material measurement. While the health of the facility and SNM infrastructure remains sufficient at this time, downsizing over the last decade has required programs to use less Category I and II materials and more Category III and IV materials for detector development and training. As NNSA recapitalizes facilities that are critical to the NPAC mission, Defense Nuclear Nonproliferation offices will work with the appropriate program managers and through the Construction Working Group to ensure NPAC goals are incorporated as resources allow.
- NPAC uses the Nevada National Security Site as a training ground for employees who will perform on-site inspections for the Comprehensive Nuclear-Test-Ban Treaty. In May 2016, NNSA hosted the Nevada Familiarization Activity for 50 international on-site inspection experts from 32 countries; NNSA plans to host another Comprehensive Nuclear-Test-Ban Treaty on-site inspection training event in early FY 2018. A dozen international diplomats also visited the Nevada National Security Site in October 2016 to obtain information about the application of world-class science, technology, and engineering to various national security missions. Using the U.S. former nuclear explosive test site for on-site inspection training and hosting international diplomats indicates the U.S. commitment to maintaining a safe, secure, and effective nuclear stockpile without nuclear explosive testing.
- NPAC and the U.S. interagency rely on NNSA's Office of Defense Programs to support transparency initiatives in fulfilling the Nation's Article VI commitments under the Nuclear Nonproliferation Treaty. NPAC also co-hosted, with Defense Programs support, two Nuclear Nonproliferation Treaty Transparency Visits for Non-Nuclear Weapon State Representatives to stockpile stewardship facilities at LANL and SNL. These visits demonstrated how stockpile stewardship supports the U.S. commitment to forego nuclear explosive testing.

4.5 Addressing Excess Facilities

Facilities that are no longer needed and are at the end of life are identified as excess. These excess facilities require resources to maintain them safely until NNSA can dispose of them.

4.5.1 Current Status

Approximately 13 percent of NNSA's facilities are identified as excess. Over the next 10 years, NNSA's total disposition requirement will exceed 10 million gross square feet. The old Bannister Federal Complex in Kansas City accounts for 2.9 million gross square feet of that excess and is currently slated for transfer to a private developer in early FY 2018.

The highest-risk facilities are those that are nuclear-process-contaminated facilities. DOE's Office of Environmental Management must decontaminate and demolish these facilities. As stated in the annual Report to Congress, "Fiscal Year 2016 Facilities Disposition," NNSA will make significant progress in reducing risk of the highest-risk contaminated facilities that are not under the jurisdiction of the Office of

Environmental Management by conducting de-inventory, stabilization, characterization, and disposal activities. The backlog of non-contaminated excess facilities is also projected to increase and NNSA is making an effort to manage the risks posed by these facilities as well. NNSA dedicated $58 million toward disposition in FY 2016 and $252 million[43] in FY 2017.

4.5.2 Challenges

The main challenges facing NNSA with respect to the disposition of excess facilities are:

- the allocation of limited facility disposition resources to demolish excess assets and
- the backlog of excess assets awaiting decontamination and decommissioning, which results in ongoing costs to manage risks in unoccupied spaces.

These interrelated challenges must be considered as a whole to develop an integrated approach to investment planning to ensure resources are prioritized to address the greatest risks. NNSA must also become more efficient and resourceful in prioritizing the funding it receives.

4.5.3 Accomplishments

In FY 2016, NNSA funded the disposition of two high-risk facilities located at LANL, installation of temporary power at Y-12's Building 9204-04 (Beta 4), demolition of facilities at SNL's Tonopah Test Range, and demolition of excess trailers at LLNL. With the additional maintenance funding granted in the *Consolidated Appropriations Act, 2016*, NNSA reduced the risk posed by several top-10 high-risk facilities.

In 2016 NNSA and the DOE Office of Environmental Management teamed together to accomplish the first evaluations of NNSA's higher-risk contaminated facilities since 2008. These evaluations, called "walk-downs," were conducted at Y-12 and LLNL, with the objective of documenting condition for eventual transfer of those facilities to the Office of Environmental Management for final disposition.

4.5.4 Strategies for the Future

NNSA's ERM strategy for addressing the decontamination and decommissioning backlog applies funding to tasks that will eliminate the most risk for the least investment. NNSA's Excess Facility Risk Index, currently under development, considers asset condition; presence of contaminants; proximity of the asset to workers, the public, and mission work; and the probability of external initiators (*e.g.*, seismic activity, forest fires, and tornadoes). NNSA's highest priorities for disposition are to stabilize degraded process-contaminated buildings, characterize hazards and conditions, remove hazardous materials, and place buildings in the lowest risk condition possible. While process-contaminated buildings pose the greatest hazards, non-process-contaminated buildings also pose risks as a result of structural degradation, industrial contamination, and increased vulnerability to fire or other accidental events. NNSA annually screens excess facilities to identify highest risks to support risk-informed decisions by senior management. NNSA is currently investing, and will continue to invest over the FYNSP, substantial resources to minimize the risks posed by the top-10 high-risk and all other excess facilities.

The Excess Contaminated Facilities Working Group, established by the Secretary of Energy in January 2015, is a DOE-wide group tasked with developing analyses and options for DOE prioritization to address the numerous contaminated excess facilities owned by various program offices. This group developed the Report to Congress, *Plan for Deactivation and Decommissioning Nonoperational Defense*

[43] This includes disposition of the Bannister Federal Complex.

Nuclear Facilities, which was issued in December 2016. This report addresses concerns raised by DOE Inspector General and the GAO reports regarding DOE's management of high-risk excess facilities, particularly those awaiting transition to DOE's Office of Environmental Management.[44, 45] Those reports described what the Inspector General characterized as increasing levels of risk caused by delays in the cleanup and disposition of contaminated excess facilities. The *Plan for Deactivation and Decommissioning Nonoperational Defense Nuclear Facilities* describes the plan for completing the aforementioned walk downs of the higher-risk facilities that will establish conditions that process-contaminated facilities must meet prior to transfer to the Office of Environmental Management for eventual demolition.

[44] Department of Energy, Office of Inspector General, DOE/IG-0931, *The Department of Energy's Management of High-Risk Excess Facilities* (2015).

[45] Government Accountability Office, GAO-15-305, *DOE Real Property: Better Data and a More Proactive Approach Needed to Facilitate Property Disposal* (2015).

Chapter 5
Secure Transportation Asset

Secure Transportation Asset Accomplishments

- *Completed more than 150 shipments without incident.*
- *Developed and implemented Safeguards Transporter risk reduction initiatives.*
- *Completed the Mobile Guardian Transporter (MGT) conceptual design review.*

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 to support nuclear security requirements. The components of the STA security concept are specialized vehicles, secure trailers, highly trained Federal agents, and leading-edge communication systems.

NNSA Defense Programs is STA's highest priority customer. STA also provides secure transport for several other NNSA and DOE programs and offices and other government agencies, such as the NNSA Nuclear Counterterrorism and Incident Response Program, the NNSA Office of Naval Reactors, the DOE Office of Nuclear Energy, and the National Aeronautics and Space Administration. STA also supports international shipments.

Since its formal creation in 1974, STA has a record of no loss of cargo and no radiological release on any shipment. To maintain that record, STA must replace aging transportation assets and communication systems for convoy safety and security. For example, STA has sustained its capability by implementing the risk-reduction initiative to extend the life of the Safeguards Transporter (SGT) until its replacement, known as the Mobile Guardian Transporter (MGT), becomes operational.

5.1 Secure Transportation Asset Program

Nuclear weapon LEPs, limited life component 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. STA supports the DOE goal to reduce the danger and environmental risk of domestic transport of nuclear cargo and consolidate storage of nuclear material.

STA 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, STA is government-owned and government-operated.

5.1.1 Core Components of the Secure Transportation Asset Program

5.1.1.1 Federal Agent Force

Federal agents go through a comprehensive selection process and complete intensive training to master a unique set of skills to defend a shipment from threat scenarios and address nonhostile emergencies without endangering the public or the cargo. Federal agents must be capable of responding to unpredictable situations across the full spectrum of threat scenarios. STA is focused on recruiting, stabilizing, and retaining the Federal agent workforce to keep pace with attrition and eligibility for retirement after 20-years.

5.1.1.2 Specialized Vehicle Fleet

STA maintains a variety of vehicles and tractors for convoy operations. STA procures commercial vehicles and components that are then modified and reconfigured to meet mission security and safety requirements. A vehicle remains in operation according to a “reliability life cycle” based on its maintenance history and the life expectancy of its mechanical and communications systems, rather than based on its age or mileage. The maintenance demands are three to four times that of a commercial vehicle, partly due to higher standards and partly due to specialized equipment.

5.1.1.3 Specialized Trailers

STA’s specialized trailer design, engineering, testing, production, and use span decades. The design and production addresses public safety and unique cargo configurations and protection systems. The SGT, a second-generation trailer for transporting nuclear warheads and weapon-grade materials, was designed for a 10-year life cycle. Working closely with the design agency, STA reviewed and extended the life cycle to 20 years. Risk reduction initiatives have been established to extend the life of the SGT further to continue reliable and safe operations until the new MGT is operational, currently anticipated in FY 2024.

5.1.1.4 Transportation Command and Control System

The command and control system provides multiple communication channels, capabilities for redundant and automated tracking, and robust data storage and processing. The essential elements are the primary and alternate Transportation Emergency Control Center, high-frequency relay stations, satellite services, and an overlapping integrated series of secure communication networks. The primary Transportation Emergency Control Center operates 24 hours per day to control and monitor convoy operations. STA continues to develop tactics, techniques, and procedures that take advantage of advances in the system. The nature of these communication channels mandates an Alternate Operations Facility to serve as a redundant capability at a backup location to ensure continuous communications during convoy missions and emergency situations.

5.1.1.5 Geographically Situated Facilities

STA manages a diverse portfolio of geographically dispersed facilities. The STA Headquarters in Albuquerque, New Mexico, manages over a dozen facilities that directly support operations throughout the United States. Multiple Federal Agent Commands include administrative support, mission operations, Federal agent training, firing ranges, and other direct support facilities such as radio maintenance, vehicle maintenance, armories, and logistic warehouses.

The principal training facility at Fort Chaffee, Arkansas, includes administrative offices, training classrooms, dormitories, and various support facilities. STA also manages communication relay stations in critical locations, as well as ammunition and explosive bunkers.

STA strives to ensure that facilities and related infrastructure do not put the primary mission at risk. This requires a long-term strategic view to ensure timely decisions with sufficient implementation and little or no impact on the mission. To maintain long-term viability of its facilities, STA will develop and implement an integrated plan that considers economic, strategic, and tactical implications, while providing recommendations for the integration and use of all STA facilities across the country.

5.2 Current State of Secure Transportation Asset Elements

5.2.1 Major Elements of Secure Transportation Asset

5.2.1.1 Vehicles

Modernizing and sustaining STA's vehicle assets require an integrated, strategic plan and a substantial investment for life cycle replacement. The STA strategy includes steady-state initiatives, elimination of outdated vehicles, refurbishing vehicles to extend their useful life, and procuring new vehicles.

The process of identifying, designing, procuring, and manufacturing these vehicles takes several years. The vehicle fleet is currently being updated with replacement armored tractors and escort vehicles. STA has also completed refurbishment of some of the armored tractors. Evaluating demands on vehicles is a never-ending effort to keep pace with operational threats.

5.2.1.2 Trailers

The trailer fleet is a critical asset for transporting nuclear weapons, weapon components, and SNM on public highways. The design, engineering, testing, production, and use of these trailers span several decades. The design and construction features address public safety, unique cargo configurations, and protection systems. The second-generation trailers will begin reaching the end-of-design life cycle in 2018, years before the first MGT will enter production. STA extended the design life cycle of the SGTs and implemented risk-reduction initiatives to maintain current capability until the new MGTs are produced and operational.

5.2.1.3 Aviation

The fleet of government-owned aircraft provides for the efficient and flexible airlift of limited life components, nuclear incident response elements, Federal agents, joint test assemblies, training assemblies, and personnel and equipment associated with national emergencies and disasters. STA is required to maintain an aircraft on continuous alert with a 4-hour response time to nuclear incidents. STA must also support evacuation and relocation of key personnel to maintain the continuity of government operations.

These aircraft are also the emergency response aircraft in support of the Nuclear Emergency Support Teams, which include the Joint Technical Operations Team, the Accident Response Group, and the Radiological Assistance program. Two of these are 737 aircraft manufactured in 1996. With both 737s already 20 years old, a plan must be developed to replace these aircraft as they age. In addition, the Office of Secure Transportation operates one DC-9, which was manufactured in 1969 and is 45 years old.

Currently, there is an aircraft replacement study underway. The analysis results would be used to identify a recommended alternative for aircraft replacement based on requirements validated prior to the start of the AoA. To maintain safe and secure operations, aging aircraft must be replaced.

5.2.1.4 Communications

Reliable, secure, real-time communication is essential to provide the crucial information necessary to ensure mission success. This includes information that is obtained, analyzed, and disseminated for mission planning; continuous monitoring and updating of that information during mission execution; and continuous communication during convoy operations. These various tiers of communication must be executed seamlessly in real time, while balancing the evolving need for cyber security to ensure system reliability and integrity.

STA achieved full deployment of the Advanced Radio Enterprise System in FY 2017, adding a unique dimension in communications and situational awareness that STA continues to refine. The overall operational communication architecture is an ongoing effort to ensure that leading-edge technology is employed to respond to normal and off-normal situations efficiently without communication delays and provide a complete picture of the operational environment.

5.2.1.5 Training

Federal agents receive training in full-scale emergency and tactical operational scenarios, tactical driving techniques, and a variety of weapons and explosives. Each Federal Agent Command has facilities and staff to refresh primary skills and accomplish the majority of qualification training. The Training Command at Fort Chaffee, Arkansas, supports special weapons, tactical scenarios, general Federal agent training, initial Nuclear Material Courier Basic Training and covers all aspects of convoy operations. The Federal Law Enforcement Training Center, at Glynco, Georgia, is an integral part of STA's training curriculum. The center provides basic law enforcement authority, tactics, and other specialized training for candidates as well as seasoned Federal agents. Federal agent law enforcement authority and specialized training are continually evaluated to respond to the dynamic operational environment. Based on these evaluations, STA has determined that Federal agents could better perform mission duties with additional law enforcement authority.

5.2.1.6 Safety and Security

Validation Force-on-Force exercises are assessments designed to test STA's Active Security Doctrine and determine system effectiveness for the STA's Site Security Plan. The vulnerability assessment team designs, performs, evaluates, and documents the conduct of these assessments; the training and logistical staff support the execution of Validation Force-on-Force exercises and integrate them with the emergency command and control elements to provide the most realistic convoy scenarios possible. The Site Security Plan and the Documented Safety Analysis outline compliance with security and safety orders and regulations as related to nuclear operations within DOE and NNSA.

5.2.1.7 Liaison and Domain Awareness

STA maintains a liaison program with agencies and organizations that may be in contact with a convoy or have to respond to an STA emergency. This interface extends across the 48 continental states, with the focus on primary and secondary convoy routes. The scope of the liaison function includes Federal, state, tribal, and local agencies and involves interactions with law enforcement officers, firefighters, emergency and hazardous materials responders, dispatchers, and military personnel.

STA has an Active Security Doctrine that is operationally focused, intelligence driven, and emphasizes realistic threat scenarios and specific environments on convoy routes. That doctrine provides options to adjust protection levels commensurate with real-time conditions and the technology to enhance domain awareness along transportation corridors. STA relies on extensive coordination and established data sharing with the DOE Office of Intelligence and Counterintelligence, the United States Northern Command, the Department of Homeland Security, and the Federal Bureau of Investigation. The doctrine, intelligence, reconnaissance, and liaison efforts allow STA to evaluate mission options and mitigate risks.

5.2.2 Secure Transportation Asset Goals

STA's overall goal is to be sized efficiently to support the projected workload with sufficient flexibility to adjust to unforeseen demands and changes in the security posture while maintaining a workforce and vehicle fleet capable of responding to the full security continuum.

Annual goals are to:

- strengthen mission support systems;
- foster an integrated and effective organization; and
- improve workforce capability and performance on a continuous basis.

Long-term goals are to:

- modernize mission assets and infrastructure;
- complete production and fielding of the replacement armored tractor by FY 2019;
- upgrade and replace aging vehicles on a continuous basis;
- continue SGT risk-reduction activities until the new MGT becomes operational;
- complete MGT final design and initiate activities for a first production unit;
- develop security strategies based on a design basis threat, and risk mitigation and management; and
- refurbish and maintain facilities and infrastructure.

5.2.3 Secure Transportation Asset Strategy

To meet changing customer needs within budget and to account for emerging threats, STA has developed an integrated, long-term plan to maintain, refurbish, modernize, and replace its critical transportation assets. The life cycles of these assets require significant investment and deliberate effort, spanning decades.

5.2.3.1 Program Planning and Management

STA strives to maintain the capacity to support the workload associated with dismantlement and maintenance of the stockpile and the initiative to consolidate storage of nuclear materials. STA will continue to implement operationally focused and intelligence-driven processes that concentrate on detection, deterrence, and disruption of potential threats while sustaining capabilities to defend, recapture, and recover nuclear weapons, weapon components, and SNM.

5.2.3.2 Strategic Management

STA will provide safe and secure transport of weapons, components, and SNM in support of national security. External factors that impact achieving that strategic goal are as follows:

- increased stockpile management operations tempo that reduces the life span of the vehicle fleet and the Office of Secure Transportation's ability to support NNSA missions
- the ability to train Federal agents in realistic over-the-road environments

5.2.3.3 Major Out-Year Priorities and Assumptions

The following four key strategies will guide STA over the next 5 to 10 years. These strategies are aligned with and support the key goals identified in the *Enterprise Strategic Vision* (NNSA 2015).

- **Modernize mission assets and infrastructure.** STA must maintain the transportation assets to support its mission in the face of changing customer needs, budgets, and threats. Modernizing and sustaining these assets requires an integrated, long-term strategy and a substantial investment. The STA strategy includes eliminating outdated assets, refurbishing transportation assets to extend their useful lives, and procuring new assets.
- **Improve workforce capability and performance.** Although STA's assets and infrastructure are essential to accomplishing the mission, the workforce is STA's most valuable asset. The nature of the work necessitates continuous recruitment, training, and retention efforts. This applies to everyone in the organization, from Federal agents to senior management. Initial and continued training and development will keep staff competent and proficient. STA focuses on recruiting and retaining experienced, innovative personnel, and supporting the development of personnel skills in future leaders.

- **Strengthen mission support systems.** The STA workforce needs proven state-of-the-art technology to support the mission, including reliable, redundant systems to plan, track, and communicate with convoys. STA is upgrading and enhancing the Transportation Command Control System and mobile integrated systems to provide a timely, common operating system and real-time situational awareness of weather, traffic, and potential threats to security and safety, especially in emergency situations. STA is enhancing the data and workflow application systems to support predictive vehicle maintenance as a management tool and to maximize efficiency.
- **Foster an integrated and effective organization.** STA will monitor, evaluate, and improve its operations to ensure secure transport is achievable in a changing environment. This includes activities directly related to the mission, such as safeguards and security requirements and business processes. STA will strive to eliminate redundancies, improve performance and efficiency, and streamline operations.

5.3 Secure Transportation Asset Challenges and Strategies

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

- **Replace the SGT trailer fleet**. STA implemented risk-reduction initiatives and allocated resources to extend the life and maintain the capability of the SGT fleet until the new MGTs are produced and operational.
- **Achieve stable and balanced vehicle production.** In the past, vehicle replacements were based on bulk purchases and accelerated production. To reach steady-state procurement and production, STA needs to sustain the number of required vehicles through extensive vehicle refurbishment to meet the secure transport missions.
- **Respond to sunset technology.** Resources reaching the end of their service life must be evaluated and replacement activities carefully managed so that, within a limited budget, 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 NNSA and DOE shipping forecasts, consolidation of requests, synchronization of site activities, the duration of various weapon activities, and handling and delivery missions for specific cargo.
- **Hire Federal agents.** To retain a highly qualified cadre of Federal agents, the focus is on career progression, job enrichment, and quality of life. The separation from family, long travel hours, and acute stress of the mission pose unique circumstances.
- **Maintain and update facilities.** Funds must be allocated for minor construction projects, life cycle replacements, repairs, and reduction of the deferred maintenance backlog to ensure cost-effective management. STA will implement industry best practices to maintain facilities in a safe and operable condition and meet all security requirements. STA's Facility Board prioritizes and matches mission needs to funding levels.
- **Aircraft.** STA currently owns three aircraft, one DC-9 and two B-737s. The DC-9 aircraft is over 48 years old, has limited performance, and is becoming difficult to maintain. With a small pilot and maintenance force, STA seeks to operate three of a similar type of aircraft to reduce training, maintenance, and aircraft part's supply costs. STA will conduct an AoA looking at options of new or used aircraft, types of aircraft, and lease *versus* buy options.

Chapter 6
Physical and Cyber Security

The Defense Nuclear Security and Information Technology and Cyber Security Programs ensure the security of the Nation's nuclear materials, physical infrastructure, workforce, and information assets at NNSA Headquarters and its field offices, the national security laboratories, the nuclear security production facilities, and the Nevada National Security Site. The Chief of Defense Nuclear Security is responsible to the NNSA Administrator and the Secretary of Energy for developing and implementing safeguards and security programs and activities. That responsibility includes protection, control, and accountability of SNM to prevent loss, theft, diversion, unauthorized access, misuse, or sabotage of radioactive materials and the physical security for all facilities in the nuclear security enterprise. Similarly, the NNSA Chief Information Officer is responsible for managing and protecting all electronic information and information assets created, processed, transmitted, and stored by NNSA and its M&O partners and coordinating with other government agencies to maintain strong cyber security defenses to ensure the information is not compromised or subjected to unauthorized access or malicious acts.

In previous years, the technologies employed within the nuclear security enterprise to address physical and cyber security threats were addressed in the SSMP including the following:

- A description of the technologies deployed at each site to address the physical and cyber security threats posed to that site
- The methods used by the Administration to establish priorities among investments in physical and cyber security technologies
- A description associated budget

These items are now being addressed in the *Physical and Cyber Security Technology Management Plan*, last released in January 2017.

Chapter 7
Sustaining the Workforce

The ability to meet its nuclear security missions, particularly in the weapons area, depends on a skilled, diverse workforce with expertise across a broad array of disciplines, including engineering, physical sciences, mathematics, and computer science. NNSA and the M&O partners[46] devote extensive effort to recruiting, training, sustaining, and revitalizing the workforce that supports the nuclear deterrent and other national security missions. This chapter provides an overview of the status, accomplishments, and challenges of the workforce and the approaches and strategies NNSA and its M&O partners use to address those challenges. Appendix E, Workforce and Site-Specific Information, includes the mission, mission capabilities, and workforce data for each of the eight NNSA sites. The M&O partners leverage the Strategic Partnership Program to sustain a stable nuclear weapons workforce and exercise the capabilities required to execute the nuclear weapons mission. The Strategic Partnership Program, in turn, supports site operating costs and can ensure sufficient workforce is available for increases in nuclear weapons activities.

Workforce Accomplishments

- *The national security laboratories cumulatively earned 25 R&D 100 awards in 2016. NNSA's management and operating (M&O) partners garnered more than 70 of these coveted awards in the last 5 years.*
- *The M&O partners filed more than 300 technical advances and invention disclosures in 2016.*
- *NNSA's M&O partners earned more than 400 patents in each of the last 3 years.*
- *Staff at all NNSA sites received national recognition and prestigious awards from technical and professional societies and diversity organizations.*
- *The national security laboratories published over 3,900 peer-reviewed technical papers during 2016.*

7.1 Introduction

The Weapons Activities workforce is composed of a diverse group of highly skilled, mission-focused technical and administrative staff and managers. The overall workforce has three basic components: the Federal workforce, the M&O partners, and the non-M&O entities, as illustrated in **Figure 7–1**. Under the M&O partner umbrella are the three national security laboratories, which operate as FFRDCs, the four nuclear weapons production facilities, and the Nevada National Security Site.[47] This government-owned, contractor-operated, nuclear weapons complex is assisted by non-M&O entities (support contractors, members of academia with technical expertise in specific areas, active duty military members, and industrial suppliers).

[46] M&O partners are consortiums of industrial and academic contractors that, depending on the site, are affiliates of well-known corporations like Honeywell, Bechtel, University of California, Fluor, BXWT, Battelle, and Lockheed.

[47] An FFRDC is an entity sponsored under a broad charter by one or several government agencies to perform, analyze, integrate, support, and/or manage basic or applied research and development. FFRDCs meet special long-term research or development needs that cannot be met as efficiently or effectively by existing in-house or contractor resources. FFRDCs operate in defense, homeland security, energy, aviation, space, health and human services, and tax administration.

Figure 7–1. Nuclear security enterprise workforce components

The effectiveness of this integrated workforce is enhanced by personnel exchange programs. For example, KCNSC may send technical staff to one of the national security laboratories to become familiar with new design changes to non-nuclear weapon components. Each year, personnel from the M&O partner sites are assigned on a temporary detail to NNSA Headquarters to participate in developing, implementing, and overseeing NNSA's nuclear weapons activities. Such exchange opportunities are mutually beneficial for the Federal staff and the M&O partners.

The M&O partners perform the technical activities in support of NNSA's nuclear security missions, such as R&D, design, production, test, manufacturing, surveillance, *etc.*, with oversight by the Federal workforce. The M&O workforce also partners with the Federal workforce to develop and implement strategic planning for the nuclear security enterprise.

NNSA's outreach for the requisite skill set also uses the expertise of non-M&O partners to provide materials, components, and specialized services; access supplemental experimental assets; and use the R&D resources of academia. In a number of areas, NNSA is becoming more reliant on the non-M&O workforce, including vendors, subcontractors, and other service providers, to meet the mission requirements and production efficiencies of the U.S. Government, including War Reserve parts.

NNSA and its M&O partners are responsible for managing the workforce to address future missions and emerging needs. To do so, NNSA and partners use a talent management life cycle approach. **Figure 7–2** depicts the major phases in an employee's career from recruitment to separation, tailored to NNSA and M&O needs. The challenges and strategies related to developing, retaining, and sustaining the workforce are discussed in Sections 7.6 and 7.7.

Figure 7–2. Three basic components of the talent management life cycle process

7.2 Workforce Planning

The role of NNSA Headquarters in workforce planning is to:

- Plan for the Federal workforce.
- Provide annual work scope guidance.
- Monitor the M&O partners' management of the workforce in executing work scope.
- Collect NNSA workforce demographics for annual reports to Congress.
- Work with the M&O partners to identify and resolve cross-cutting issues affecting multiple sites.

NNSA's M&O partners develop and implement workforce plans and approaches to manage staffing to maintain a stable workforce across the full spectrum of nuclear weapon capabilities.

Each NNSA site has workforce planning processes tailored to its unique needs, to include:

- using resources from other programs (*e.g.*, the Strategic Partnership Program);
- parent company reach-back;[48]
- deferring purchases, maintenance, travel, *etc.*, to preserve headcount;
- prioritizing work against available funding;
- relying on the flexibility of exempt staff[49] and
- limited-term and staff augmentation employment.

The workforce projections reflect minimal growth over the FYNSP period (see **Figure 7–3**).

[48] Parent company reach-back is the ability of operating contractors to leverage certain knowledge, skills, abilities, and business practices to respond to M&O partner needs, such as best practices, technical capabilities, or access to specialized resources and talent.
[49] Exempt employees are those who are excluded from *Fair Labor Standards Act* minimum wage and overtime pay requirements.

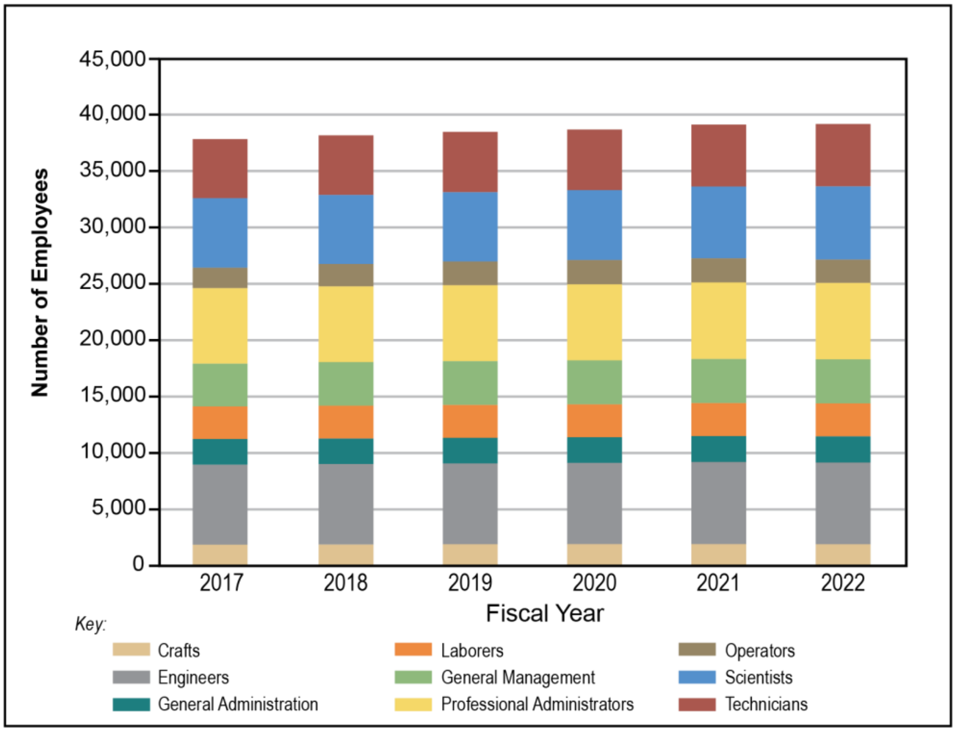


Figure 7–3. Management and operating partner workforce projections by Common Occupational Classification System for the current Future Years Nuclear Security Program period[50]

7.3 Current Status

7.3.1 Workforce Size and Composition

7.3.1.1 Overall Workforce

At the end of FY 2016, the overall Federal and M&O workforce included 39,290 employees. This number excludes the Naval Reactors workforce and includes employees in Defense Nuclear Nonproliferation activities and the Office of Secure Transportation. Collectively, the sites reported an increase of 2,138 employees over the last two fiscal years. This is consistent with increases in programs, balanced by retirements and separations. SNL had the largest net increase of 650, while the Nevada National Security Site had the only net decrease at 109.

7.3.1.2 Federal Workforce

The Federal workforce consists mostly of civilians along with small numbers of active-duty military members on special assignment. This workforce plans, manages, and oversees the nuclear security enterprise and is accountable to the President, Congress, and the public. The Federal workforce performs key planning functions, as outlined in Section 7.2, and performs fiduciary oversight; risk prioritization; product acceptance; and environmental, safety, and health oversight duties (see **Figure 7–4**). The Federal workforce resides primarily at NNSA Headquarters (Washington, DC, Germantown, Maryland, and Albuquerque, New Mexico) and at field offices across the eight NNSA sites. At the end of FY 2016, there

[50] Common Occupational Classification System (COCS) categories are detailed in *Environmental Restoration/Waste Management Activities Common Occupational Classification System*, Revision 3, May 1996, by Pacific Northwest National Laboratory.

were 2,144 on-hand Federal employees (1,622 employees under the NNSA Federal Salaries and Expenses (FSE) and 522 employees in the Office of Secure Transportation).

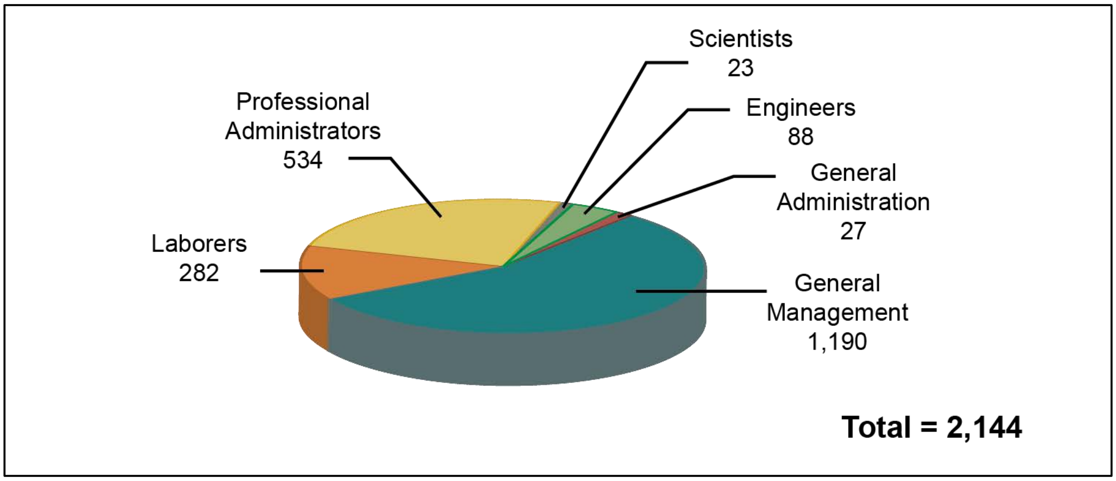


Figure 7–4. NNSA Federal workforce by Common Occupational Classification System[51]

There is a cadre of approximately 25 to 30 active-duty military members at NNSA within the Office of Defense Programs. The senior military leader in Defense Programs is a flag officer whose position is established by the *Atomic Energy Act of 1954*, as amended. These military personnel bring a service perspective to weapons activities and return to DOD at the end of their assignments with an understanding of NNSA and the nuclear security enterprise.

The NDAA for FY 2015 capped the total Federal employees under NNSA FSE at 1,690 full-time equivalents (FTEs), excluding the Office of Secure Transportation and the Office of Naval Reactors. That 1,690 cap on FTEs represents a 17 percent reduction in FTEs since FY 2011, while the program and project management portfolio has increased by 18 percent during the same period. NNSA conducted internal staffing level reviews based on overall succession planning goals, current staffing ratios, organizational retirement trends, retirement eligibility data, and opportunities to address skills-mix issues in the workforce. Though currently unmet, the authorization cap in the future may limit NNSA's ability to address the pending retirement bow wave and manage the increased work scope in major mission areas, particularly for LEPs and major construction projects. In FY 2017, NNSA partnered with the Office of Personnel Management's (OPM's) Strategy and Evaluation Branch to conduct an objective review of NNSA's staffing level. The OPM effort is a phased approach. The first phase includes four Program Offices and one Field Office (Defense Programs, Defense Nuclear Nonproliferation, Acquisition and Project Management, Management and Budget, and the Los Alamos Field Office) which, in sum, represent roughly half of the FSE population (823 of the 1,690 FTEs). The second phase, which started in June 2017, includes the balance of the Program and Field Offices. The OPM study is based on objective quality evidence and is conducted by the U.S. Government's most qualified personnel staffing analysis experts. The first phase of the OPM study affirmed that the NNSA Federal workforce in the offices that were assessed is understaffed by 19 percent.

[51] In this document, workforce data are reported using COCS. Federal and M&O workforce data are reported in the standardized COCS categories to allow consistent comparison among the sites. However, these categories are not completely descriptive of the functions within each category. For example, the broad COCS category "General Management" also includes technical and scientific management functions, and the "Professional Administrators" category includes technical analysis and drafting design functions.

7.3.1.3 Management and Operating Workforce

The M&O workforce resides at eight government-owned or leased nuclear security enterprise sites. Roll-ups of the workforce under Common Occupational Classification System (COCS) categories for the national security laboratories (as well as for the Nevada National Security Site) and the nuclear weapons production facilities are shown in **Figures 7–5** and **7–6**, respectively. The composition of the workforce has been relatively consistent since the FY 2016 SSMP. In the NNSA nuclear security enterprise workforce, the number of scientists, engineers, and technicians is highest at the national security laboratories, as would be expected for their NNSA R&D roles. The nuclear weapons production facilities also have engineers and scientists on staff, although the proportion of operators and craftspeople is higher in order to fulfill the manufacturing missions.

Although professional administrative and general management percentages are lower for the M&O partners than for the Federal staff, they still represent a substantial portion of the M&O workforce. This is a byproduct of the COCS code definitions, as explained in footnote 5 above. The COCS codes are established by job function, not by degree held. The COCS categories mask the number of scientists and engineers functioning as technical managers or as program or project managers.

7.3.1.4 Non-Management and Operating Workforce

NNSA continues to build connections with academic alliances and to develop long-term vendor relationships while seeking to maintain a skilled, versatile, knowledgeable, and experienced workforce to supplement the Federal and M&O partner workforce. The firms that fabricate TPBARs and the Laboratory for Laser Energetics at the University of Rochester are examples of the non-M&O workforce for which NNSA needs to be aware of the skills, experience levels, and availability. NNSA continues to identify additional suppliers, researchers, and technical and management consultants to reduce the risk of relying on single-source providers with capabilities not duplicated or retained within the M&O workforce.

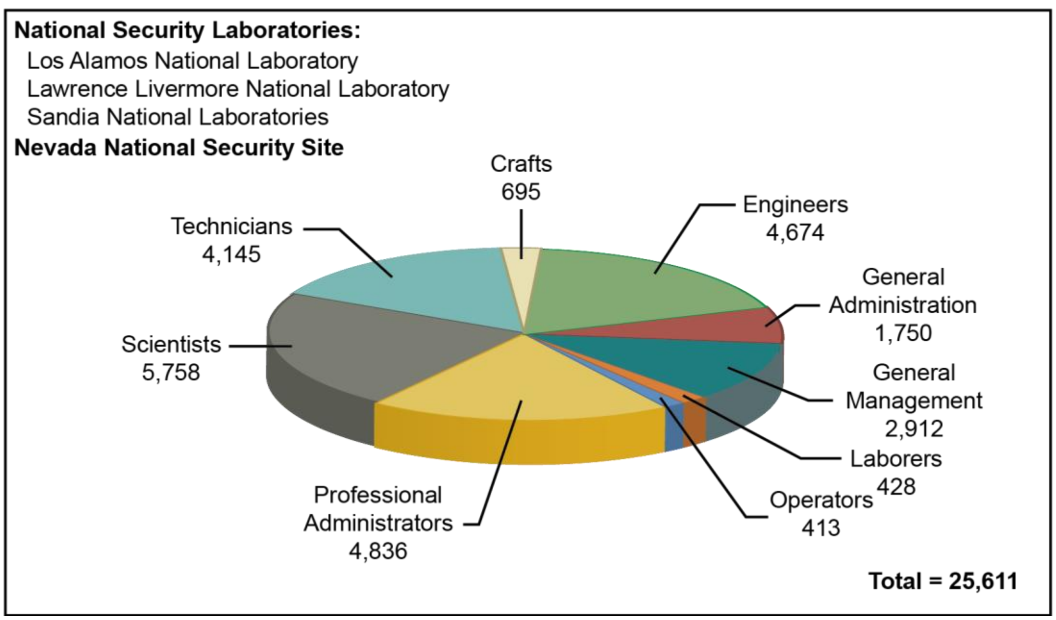


Figure 7–5. Total workforce of national security laboratories and the Nevada National Security Site by Common Occupational Classification System

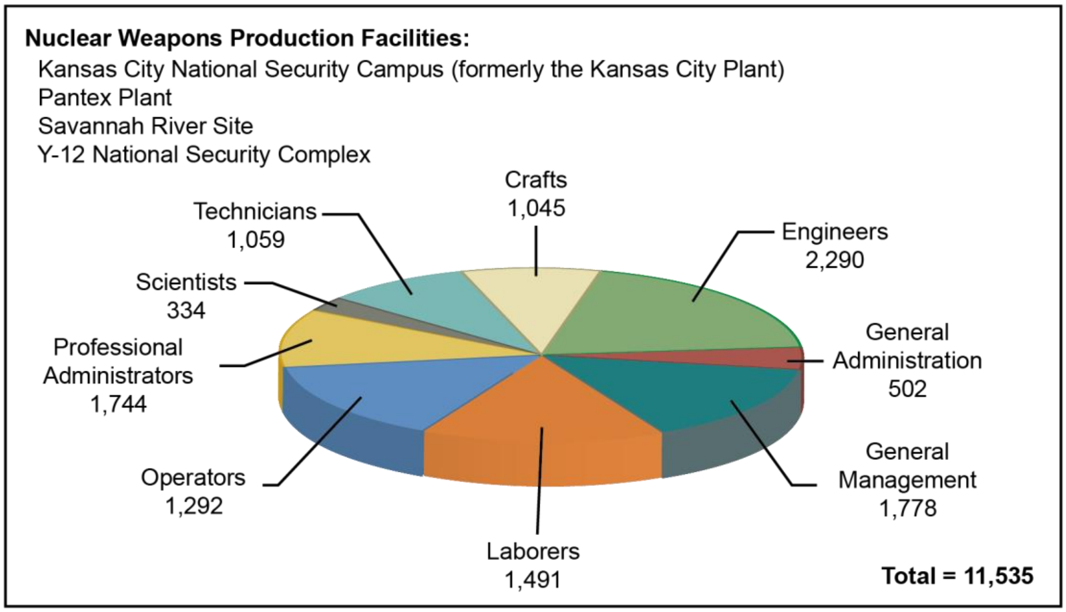


Figure 7–6. Total workforce of nuclear weapons production facilities by Common Occupational Classification System

7.3.2 Age and Other Demographics of the Workforce

Figure 7–7 provides an illustration of the M&O workforce distribution by age.

- The average age of the workforce at the eight sites varies from 46 to 50 years, with the percentage of retirement-eligible employees ranging from 15 to 51 percent.
- Some sites (see Appendix E) have a bimodal age distribution for the workforce, with a large number of employees in the youngest and especially in the oldest age ranges and fewer in the mid-range.
- NNSA and M&O partners monitor the high number of retirement-eligible employees at specific sites.

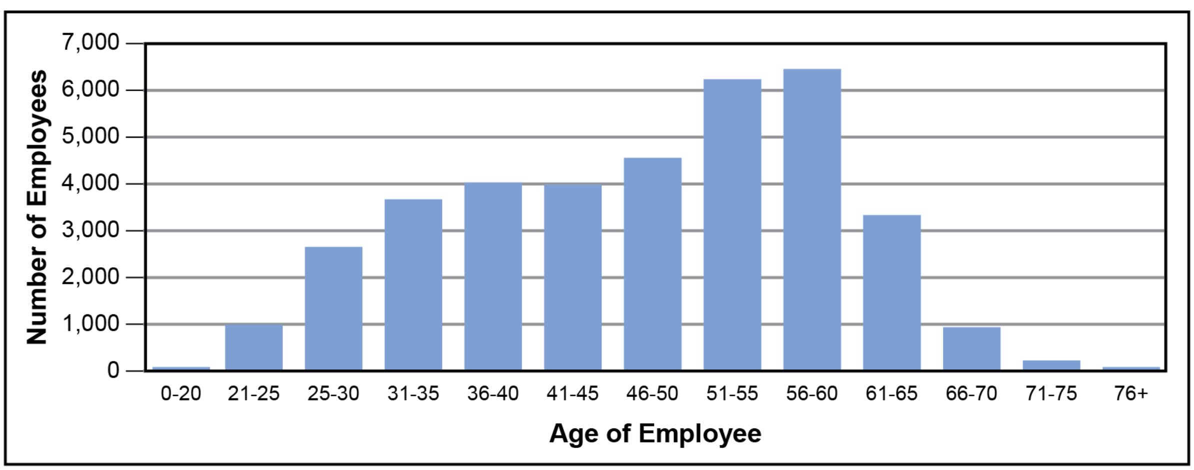


Figure 7–7. Management and operating partner headcount distribution by age

Figure 7–8 illustrates NNSA's M&O partner workforce distributed by years of service (*i.e.,* the period from the date an employee was hired to the present).

- A large number of employees have 1 to 15 years of service, and a lesser number have service greater than 15 years.
- The average length of service at the sites ranges from 12 to 18 years. These numbers demonstrate the overall increased hiring in recent years to replace retirees and staff programs such as the B61-12 LEP, the W88 Alt 370, and the W80-4 LEP.
- Several sites have experienced increases in voluntary separation for the 25- to 35-year-old age group and for those with 5 to 15 years of service. While the voluntary separation rates are still low, the affected sites are monitoring these trends among essential skill employees.
- The percentage of the workforce in the later stage of a career has remained relatively stable or even decreased as a result of increased hiring combined with retirements, shifting the distribution toward early career employees. This trend is accurate for all the sites, being most evident at the nuclear weapons production facilities.

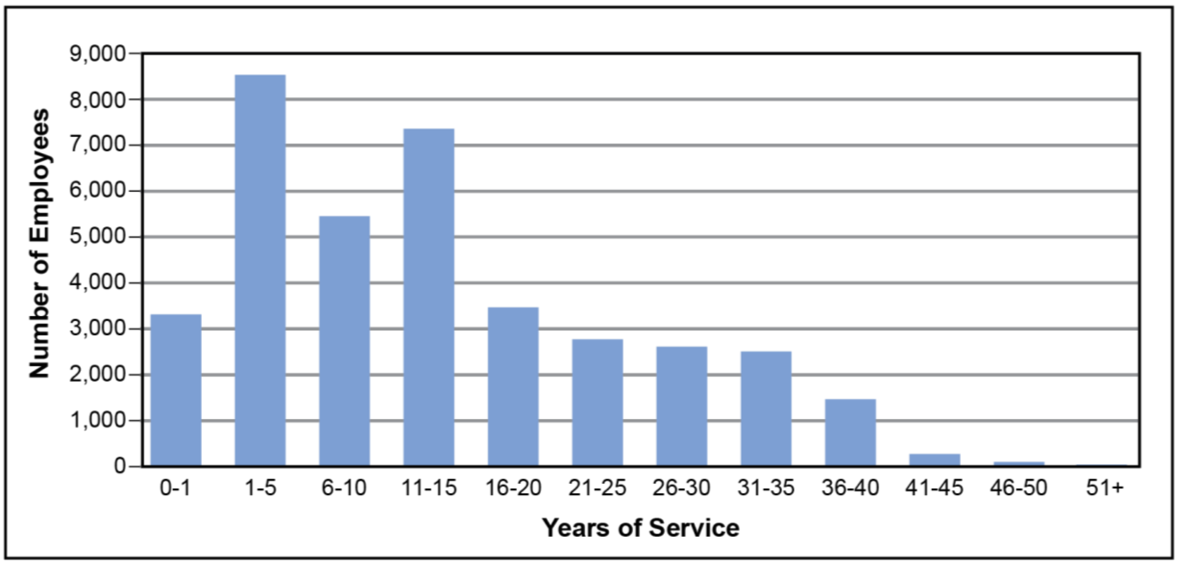


Figure 7–8. Management and operating partner headcount distribution by years of service

7.4 Accomplishments

The members of the nuclear security enterprise workforce collectively have a history of outstanding technical and professional excellence and dedication, as demonstrated by numerous awards and recognition for technical achievements and contributions to professions and communities. More detailed information on these accomplishments is listed in Appendix E.1. Accomplishments include the following:

- The three national security laboratories cumulatively earned or partnered in 25 R&D 100 awards in 2016 (the laboratories have earned nearly 70 of these coveted awards over the last 5 years).[52] Y-12 and the Nevada National Security Site earned or partnered in five additional awards in this same 5-year period.

[52] Widely recognized as the "Oscars of Invention," the R&D 100 Awards identify and celebrate the top technology products of the year. Past winners have included sophisticated testing equipment, innovative new materials, chemistry breakthroughs, biomedical products, consumer items, and HED physics. The R&D 100 Awards span industry, academia, and government-sponsored research.

- NNSA's M&O partners have cumulatively been granted close to 400 patents in each of the last 3 years. This compares with 280,000 U.S. patents (about 0.14 percent) granted to U.S. citizens or organizations in the each of the last 3 years. More than 300 technical advances and invention disclosures were filed across the sites in 2016.
- The national security laboratories jointly published over 3,900 peer-reviewed technical papers across a broad variety of science and engineering fields in 2016. Some of these publications received international recognition and earned prestigious awards.
- NNSA sites also have robust technology transfer programs with dozens of Cooperative Research and Development Agreements and partnership agreements. Technological advances that result from these agreements benefit local communities and society at large by extending the innovation of the workforce to applications within and beyond national security applications.
- Dozens of scientists and engineers were named as Fellows of their technical societies for technical achievement in their respective fields and dedication to their profession in 2016, joining hundreds of colleagues on staff who have received similar recognition in the past. Societies granting fellow status included Institute of Electrical and Electronic Engineers, American Physical Society, and many other specialized technical societies.
- Several members of the workforce received prestigious awards for outstanding technical achievement in 2015 to 2016. These included DOE's E. O. Lawrence Award, the American Chemical Society's Glenn T. Seaborg Award for Nuclear Chemistry, American Physical Society's Joseph F. Keithley Award for Advances in Measurement Science, and a Presidential Early Career Award for Science and Engineering.[53, 54]
- Several other professional societies recognized members of the workforce in 2016 for technical accomplishments and contributions to professional societies, as listed in **Table 7–1**.

Table 7–1. Professional society awards recognizing diversity and excellence in the NNSA

Professional Organization	*Award*
National Society of Black Engineers	Black Engineer of the Year
Society of Women Engineers	Upward Mobility Award and Prism Award
Hispanics in Science, Technology, Engineering and Mathematics (formerly Hispanic Engineer National Achievement Awards Conference)	Great Minds in STEM awards
Award given by the Asian American Engineer of the Year committee	Asian American Engineer of the Year Award
American Indian Science and Engineering Society	One of the Top 50 Workplaces for Native STEM Professionals

STEM = science, technology, engineering, and math

[53] The Ernesto Orlando Lawrence Awards honor U.S. scientists and engineers at mid-career for exceptional contributions in R&D supporting DOE and its mission to advance the national, economic, and energy security of the United States. The awards are given in nine categories: atomic, molecular, and chemical sciences; biological and environmental sciences; computer, information, and knowledge sciences; condensed matter and materials sciences; energy science and innovation; fusion and plasma sciences; high energy physics; national security and nonproliferation; and nuclear physics.

[54] The Seaborg Award is given by the American Chemical Society to recognize and encourage research in nuclear and radiochemistry or their applications.

7.5 Challenges

NNSA and the M&Os face many challenges in planning and managing the multifaceted workforce. These challenges are a near-term increase in the workload to accomplish weapons modernization through LEPs, along with a subsequent longer-term strategy as the LEP workload decreases starting in the 2030s (see Figure 2–5) for several decades.

7.5.1 Recruiting and Hiring

The nature of the nuclear security enterprise mission requires a highly skilled and highly educated workforce that must undergo security background investigations and retain security clearances for the duration of employment. As with much other Federal and federally contracted defense work, for this workforce, new hires must:

- Meet requirements of U.S. citizenship and clearances not required in conventional non-defense industry.
- Wait for appropriate clearances after being hired before beginning the specific tasks for which hired.
- Undergo lengthy training and hands-on experience and mentoring to become proficient.
- Be willing to work in stringent safety and security environments.
- Forego access to personal electronics and social media during the workday.

7.5.2 Developing, Retaining, and Sustaining the Workforce

Many of the challenges in developing, retaining, and sustaining the workforce are similar to those in the private sector. Sharing many issues with large portions of the defense industry, additional challenges exist within the nuclear security enterprise in retaining employees and training them to be productive throughout their careers:

- Prospective hires are often not aware of career opportunities in the nuclear security enterprise.
- The nuclear security enterprise has difficulty communicating the advantages of a nuclear weapons career to prospective employees, compared to private industry.
- There is a limited availability of U.S. citizens earning advanced engineering and science degrees.[55]
- Some sites are geographically remote, resulting in difficulty recruiting nationally.
- Uncertain budget environments and hiring freezes can affect internal recruiting and hiring decisions.
- Candidates may lose interest and find other opportunities because of extended hire cycle times.
- Candidates at some sites may be frustrated by long security clearance approval times prior to hiring.
- Retaining millennial employees is a common concern in the private sector and a growing concern in the private sector and a growing for the nuclear security enterprise.
- Engaging new hires during the security clearance process is a challenge for hiring managers, particularly in the weapons programs.
- Retaining new hires in mid-career is as challenging as recruiting them. Some private sector employers offer attractive compensation packages and hiring incentives to lure employees. These

[55] The percentage of M.S. and Ph.D. candidates eligible to work in national security positions remains relatively low for advanced degree levels in engineering. At the end of 2015, the proportion of permanent U.S. residents receiving M.S. degrees in engineering was 53.0 percent; U.S. residents received 45.3 percent of Ph.D. degrees (Brian L. Yoder, "Engineering by the Numbers," *The American Society for Engineering Education*, 2016).

incentives may be difficult for early-career employees to resist, even when satisfied with nuclear security enterprise work. The end result is a loss of early- and mid-career employees. The phenomenon is especially true for the following:

- Science and engineering disciplines with the highest demand, such as computer science
- Locations with a large established high-tech business base, such as Silicon Valley
- Locations with especially high cost-of-living indices

7.5.3 Unique Set of Essential Skills for Nuclear Weapons Work

Essential skills are a subset of the human capital aspect of capabilities that must be exercised and sustained to support the nuclear weapons mission. These essential skills are integral to multiple enabling capabilities. For example, the capability for simulation codes and modeling in Figure 1–3 in Chapter 1 is deployed at several M&O sites to address aspects of nuclear weapon design, production, and certification and requires the following:

- Materials behavior subject matter experts working with software developers to create models that describe weapon effects in certain environments
- Plutonium physicists working with software developers to develop nuclear implosion models
- Engineering analysis and modeling subject matter experts to produce IDCs to advance predictive capability

Manufacturing process subject matter experts are needed to work with software developers to simulate, design, and refine processes and perform failure analysis for the production of weapon components.

7.5.4 Training and Knowledge Transfer to the Next Generation

The transfer of knowledge and training enough to stay ahead of the wave of retirement-eligible employees is an area of emphasis for NNSA and its M&O partners.

The heavy stockpile modernization workloads have provided an opportunity for new employees to "learn directly by doing," although this must be accompanied by sufficient mentoring and guidance to be optimal.[56] Challenges facing NNSA and its M&O partners include the following:

- Managing the high percentage of employees eligible for retirement among the sites and NNSA.
- Hiring sufficient staff to replace the projected retirements and staff the increase in modernization programs.
- Training and transfer of knowledge and skills to the next generation workforce prior to the departure of retirees.
- Reducing the time needed to bring early-career scientists and engineers up to basic technical competency and then promote them to technical leadership positions. Getting employees to that level in the nuclear weapons field has traditionally taken several years.
- Documenting, managing, and preserving subject matter expertise and maintaining critical technical skills and key processes prior to the expected wave of retirements for knowledge preservation for future nuclear weapons designers, engineers, and component manufacturers.

[56] See Chapter 2, Figure 2–5 and Section 2.3, Stockpile Sustainment and Modernization through the 3+2 Strategy.

7.6 Approaches and Strategies

To address the near- and long-term challenges mentioned in Section 7.5, NNSA and its M&O partners employ a variety of approaches and strategies.

7.6.1 Recruiting and Hiring

NNSA and its M&O partners have increased hiring to meet mission deliverables. To mitigate challenges in recruitment, multiple strategies have been employed as appropriate for the individual sites. **Table 7–2** summarizes the strategies to address the challenges.

Examples of Programs to Attract and Retain Personnel

- *LLNL received a Gold 2016 Optimas Award for Recruiting from Workforce Magazine to recognize the excellence in its military internship programs, including the Military Academic Research Associates Program, the Reserve Officers' Training Corps Internship Program, and the Newly Commissioned Officer Program.*
- *Each year, the three national security laboratories visit the military academies and provide briefings and technical talks to cadets and midshipmen.*

Table 7–2. Strategies for recruiting and hiring

Challenges	*Strategies*
• Limited awareness of career opportunities in the nuclear security enterprise • Less attractive compensation packages compared to industry • Proximity to high-tech industries, sparking intense competition for high-demand disciplines	• Increase outreach programs. • Attend career fairs. • Increase social media presence. • Establish long-term university partnerships. • Focus on robust, focused college recruiting. • Capture interest through initial student internships and subsequent conversion to permanent employee status.
• Competition for high-demand disciplines, such as electrical engineering and computer science	• Promote access to unique, world-class research, development, science, technology, and engineering capabilities and facilities. • Develop postdoctoral programs with opportunity to become career employees. • Emphasize stable employment, even during economic downturns, with long-term financial stability.
• Difficulty finding and hiring technical specialists in emerging disciplines, such as nanotechnologies, advanced manufacturing technologies, and high performance computing	• Develop partnerships with universities that offer specialization in these emerging disciplines.
• Limited availability of U.S. citizens earning advanced engineering and science degrees	• Increase military and veteran recruitment. • Target U.S. citizen students in university partnerships.
• Remote geographic location of some sites, resulting in difficulty recruiting nationally	• Target willing candidates *via* university partnerships. • Emphasize local hiring. • Increase emphasis on internships and apprenticeships to increase the local pool of technologists and craft workers, particularly at the nuclear weapons production facilities.
• Loss of candidates because of extended hire cycle time	• Work on processes to decrease hire cycle time. • Use innovative hiring strategies (*e.g.*, hiring on the spot, hiring pools).
• Lower quality work environment because of aging infrastructure issues	• Continue efforts to increase capital investments in modern facilities with collaborative space and enhanced digital communications access.
• Failure to demonstrate the differentiating advantages of a nuclear weapons career to prospective employees	• Increase the emphasis on the uniqueness and state-of-the-art research opportunities in recruiting materials, university technical talks, recruiting events, *etc*.

7.6.2 Developing, Retaining, and Sustaining the Workforce

NNSA and its partners also employ a number of strategies for development and retention, especially for early- and mid-career employees.[57] **Table 7–3** illustrates the approach for the challenges.

Table 7–3. Strategies for developing, retaining, and sustaining the workforce

Challenges	*Strategies*
• New hires awaiting security clearances • Feelings of isolation while awaiting clearance	• Increase pre-clearance training programs. • Offer opportunity to work on unclassified R&D or other projects. • Use priority and interim clearance processes to shorten clearance times for new hires with essential skills.
• Attrition rates for early-career employees • Retaining new hires in mid-career, especially those in high-demand disciplines and in locations with large high-tech base and a high cost of living • Ensuring Federal technical employees possess the necessary knowledge, skills, and abilities to perform their duties and responsibilities (*e.g.,* safe operation of defense nuclear facilities) • Making available to Federal employees across the nuclear security enterprise the wide range of programmatic and technical oversight tasks to advance NNSA's mission	• Offer advanced education, training, leadership, and mentoring. • Emphasize total compensation benefits (*i.e.*, flexible work arrangements, royalty sharing, educational assistance, and work and life balance). • Emphasize stable employment with long-term financial stability. • Provide rotational development opportunities. • Explore possibilities for specific skill incentives (*e.g.*, bonuses and pay for market differential). • Analyze exit interviews and employee satisfaction surveys to obtain additional insight. • Use the Technical Qualification Program, a structured training and development program, to ensure that employees maintain technical competencies and identify those competencies that employees must possess. • Use the Nuclear Weapon Acquisition Professional Certification Program, which was established to combine education, training, and mentoring, to ensure the workforce meets current Federal program management standards in key technical areas (*i.e.,* engineering, program management and science, and technology).

7.6.3 Training and Knowledge Transfer to the Next Generation

The knowledge and expertise of seasoned employees approaching retirement has to be documented and preserved for future weapon designers. In particular, efforts to gather weapons knowledge prior to the retirement of late-career employees must be improved through enhancement of existing programs and development of additional programs.[58]

The nuclear security enterprise sites have deployed programs that reflect their strategies to address the knowledge transfer challenges. **Table 7–4** summarizes those strategies.

[57] This section includes examples of programs that have been implemented by at least one site but that may not be available or feasible at other sites, because the M&Os are operated under seven different contracts; moreover, each M&O has its own business model, which may or may not be compatible with a particular approach.
[58] In FY 2015 and FY 2016, the NNSA Defense Programs sites and the UK's Atomic Weapons Establishment participated in Joint Working Group-sponsored workshops on knowledge preservation and knowledge management to share approaches and challenges.

Table 7–4. Strategies for knowledge transfer and preparing the next-generation workforce

Challenges	Strategies
• Transfer of knowledge and skills prior to expected wave of retirements	• Provide programs to transfer experience of weapon mentors and leaders to new hires, such as lunch and learn sessions. • Digitize and catalogue weapon system-specific artifacts. • Design and implement education and training programs for weapons engineers and scientists. • Implement increased internship and postdoctoral opportunities for students and recent graduates. • Provide formal mentoring in weapon programs and in research, development, test, and evaluation to accelerate on-the-job training. • Put in place succession planning to identify critical skill personnel and replacement candidates for key positions.
• Amount of time required to bring early-career scientists and engineers to technical and leadership competency	• Incorporate introductory live and web-based self-study modules. • Design education and training programs for weapons engineers and scientists. • Implement new hire orientation programs. • Design programs specifically for new employees within 6 months of hire.
• Documenting, managing, and preserving subject matter expertise, critical technical skills, and key processes prior to an expected wave of retirements	• Develop or expand programs to identify, track, and manage mission-critical subject areas, essential skills, and key processes. • Develop data virtualization and interactive online tools to capture knowledge, improve collaboration, and expand the weapons knowledge base. • Enhance video and process documentation of weapon surveillance, annual assessment, life extension program, and alteration expertise and processes and role descriptions for designers and engineers.

7.7 Strategic Partnership Projects

NNSA's Strategic Partnership Projects[59] play a significant role in addressing enterprise workforce challenges.[60] The highly specialized and unique technical expertise available in Strategic Partnership Projects offers the ability to take advantage of additional capabilities when new challenges arise. Through the Strategic Partnership Projects, the Federal, state, and local governments, universities, and private industry collaborate with NNSA to:

- Accomplish goals that may otherwise be unattainable and avoid potential duplication of research efforts.
- Access highly specialized or unique facilities, services, or technical expertise when private sector facilities are inadequate.
- Increase R&D interactions between NNSA and industry by providing opportunities to transfer technology originating at NNSA facilities to industry for further development or commercialization.

Strategic Partnership Projects assist NNSA in maintaining core competencies through enhancing the science and technology base at NNSA sites with the scientific expertise to solve local, state, national, and global challenges.

[59] Formerly known as "Work for Others," Strategic Partnership Projects are work performed for non-DOE entities by DOE/NNSA personnel and/or their respective contractor personnel or the use of DOE/NNSA facilities for work that is not directly funded by DOE/NNSA appropriations.

[60] NNSA's appropriations for Weapons Activities work has recently been levied a 5 percent tax to pay for Strategic Partnership Projects. Neither Naval Reactors, also doing nuclear work with M&O contractors, nor DOD's FFRDCs, also doing defense R&D work on contract, require such a tax to buy similar support. They pay for it out of their fees.

Chapter 8
Budget and Fiscal Estimates

Chapter 8 provides an overview of the key programmatic elements proposed in the Weapons Activities budget request for FY 2018 and displays the budgetary information, based on the program of record. Out-year (FY 2019 through 2022) budget amounts have not been included in this chapter. The Administration will make a policy judgment on amounts for NNSA's FY 2019 through FY 2023 topline in the FY 2019 budget, in accordance with the Nuclear Posture Review and National Security Strategy currently under development.

Each programmatic section in this chapter compares the FY 2018 budget request to the FY 2017 enacted budget and contains a milestones and objectives chart that projects long-term strategies. There is also a section describing the budget estimates for Weapons Activities to include LEPs, major Alts, and major construction projects to ensure an effective deterrent in the absence of full-scale underground nuclear explosive testing over that 25-year period.

8.1 Fiscal Year 2018 Nuclear Security Program Budget

Table 8–1. Overview of Future Years Nuclear Security Program budget estimates for Weapons Activities in fiscal years 2017 through 2018[a]

Activity	Fiscal Year (dollars in millions)					
	2017 Enacted	*2018 Request*	*2019 Request*	*2020 Request*	*2021 Request*	*2022 Request*
Directed Stockpile Work	3,308.0	3,977.0	Estimates for the FY 2019–FY 2022 base budget topline for NNSA do not reflect a policy judgment. Instead, the Administration will make a policy judgment on amounts for NNSA's FY 2019–FY 2023 topline in the FY 2019 Budget, in accordance with the National Security Strategy and Nuclear Posture Review currently under development. For FY 2019 – FY 2022, the FY 2018 Budget Request for Weapons Activities was increased by 2.1 percent annually above the FY 2018 request level.			
Science	436.5	487.5				
Engineering	132.5	193.1				
Inertial Confinement Fusion Ignition and High Yield	523.0	532.9				
Advanced Simulation and Computing	663.2	734.2				
Advanced Manufacturing Development	87.1	80.5				
Secure Transportation Asset	248.9	325.1				
Infrastructure and Operations	2,808.4	2,803.1				
Defense Nuclear Security	685.5	687.0				
Information Technology and Cyber Security	176.6	186.7				
Legacy Contractor Pensions	248.5	232.1				
Adjustments [b]	(-77.4)					
Weapons Activities Total	***9,240.7***	***10,239.3***				

[a] Totals may not add because of rounding.
[b] Adjustments include rescissions.

Figure 8–1 illustrates the level of funding proposed for FY 2018 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 apples-to-apples 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, all programmatic construction was moved to Infrastructure – Construction. In the early years of the Stockpile Stewardship Program, programmatic construction was funded by the sponsoring program.

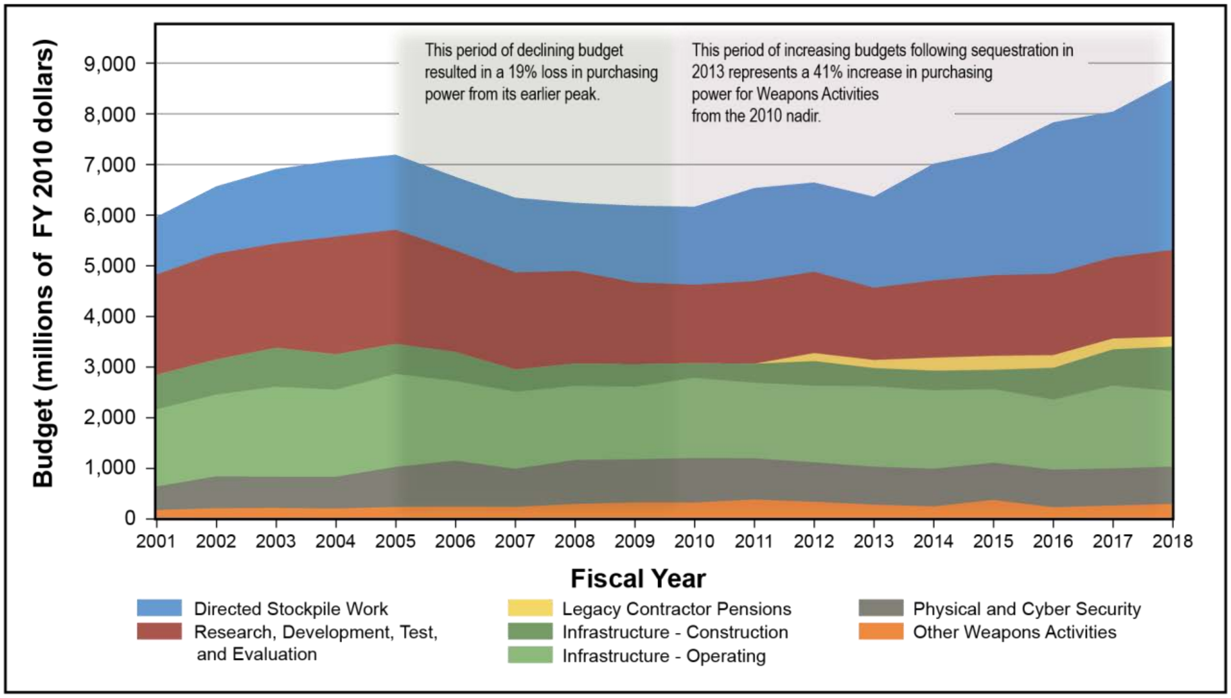


Figure 8–1. Weapons Activities historical purchasing power – fiscal years 2001 through 2018

The most significant change over the period displayed in Figure 8–1 is the increase in purchasing power for DSW, which, as of the FY 2018 request, is almost triple what it was in FY 2001. Part of this increase is the result of changes to the budget structure over the intervening years. For example, pit production activities, originally funded as a campaign, became part of DSW as Plutonium Sustainment in FY 2008. In addition, funding for Tritium Sustainment, part of Uranium Sustainment, and Domestic Uranium Enrichment were added to DSW in the FY 2016 FYNSP.[61] A significant amount of this increase can be attributed to funding for multiple LEPs and the DSW activities that support those LEPs.

The pie charts that follow in each section are of the FY 2018 budget request and tables of the FY 2018 breakdown, as compared to the FY 2017 enacted budget.

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

8.2 Directed Stockpile Work

8.2.1 Directed Stockpile Work Budget

The Stockpile Systems and Stockpile Services lines in **Figure 8–2** include the Surveillance program funding as listed in **Table 8–2**.

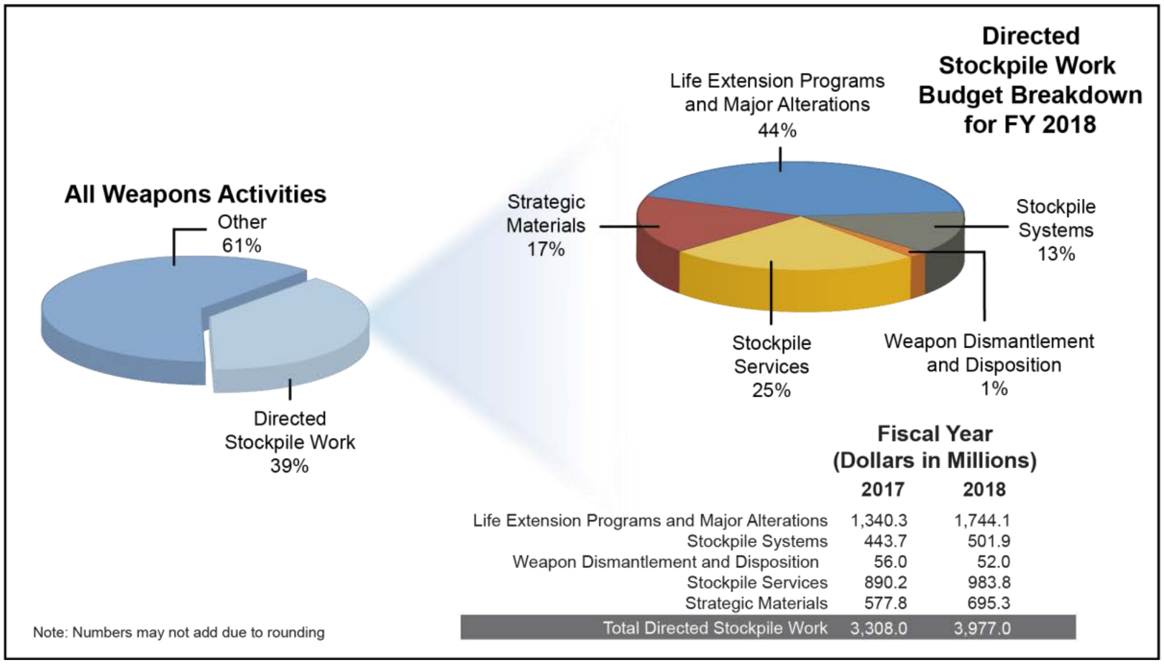


Figure 8–2. Directed Stockpile Work funding schedule for fiscal years 2017 through 2018

Table 8–2. Surveillance program funding for fiscal years 2013 through 2018

	Fiscal Year (dollars in millions)					
	2013	***2014***	***2015***	***2016***	***2017***	***2018***
Surveillance Program Funding [a]	217	225	236	217	230	240

[a] The surveillance numbers for FY 2017 and FY 2018 represent current planning estimates. Prior year numbers reflect actual expenditures.

8.2.2 Directed Stockpile Work Accomplishments

Major DSW accomplishments since the FY 2017 SSMP, in addition to the Annual Assessment Reports, the Laboratory Director Letters to the President, and scheduled replacements of limited life components, are detailed in the following sections.

8.2.2.1 Life Extension Programs

W76-1 Life Extension Program

- Exceeded the cumulative production goal of 70 percent by the end of FY 2016.
- Exceeded the FY 2016 warhead delivery quantity and delivered required refurbished warheads on schedule to the Navy.

- Produced and delivered required JTAs for surveillance flight tests.
- Executed required retrofit evaluation system test and stockpile surveillance activities to facilitate completion of Annual Assessment and Weapon Reliability activities.

W88 Alteration 370

- Completed all remaining War Reserve component Baseline Design Reviews.
- Completed System Baseline Design Review in March 2016.
- Completed Integrated Baseline Reviews in August 2016.
- Completed the Preliminary Addendum to the Final Weapon Development Report in September 2016.
- Participated in and passed the Preliminary Design Review and Acceptance Group Review in September 2016.
- Completed the Inter-Laboratory Peer Reviews by June 2016.
- Conducted the fourth successful development flight test on Demonstration and Shakedown Operations test 26 in November 2015.
- Initiated pre-production engineering activities ahead of Phase 6.4 authorization for testers and tooling development.
- Completed the Baseline Cost Report.

B61-12 Life Extension Program

- Completed the third system-level test of a Development Flight Test Unit, a guided flight, at the Tonopah Test Range in October 2015.
- Completed integration tests with the F-15E, F-16, PA-200, F-35, and B-2A. These included tests conducted at aircraft simulation laboratories as well as on the aircraft.
- Completed the System Baseline Design Review in January 2016.
- Completed a DOD Preliminary Design Review and Acceptance Group design review, which resulted in a DOD determination that the baseline design meets all requirements.
- Authorized for entry into Phase 6.4 (Production Engineering) in June 2016.
- Completed the Baseline Cost Report.
- Maintained 11 Interface Requirements Agreements with other programs to document the B61-12 dependencies on programmatic deliverables.

W80-4 Life Extension Program

- Continued advanced design of feasibility concepts.
- Developed program controls.
- Continued development of implementation documents (including the Risk Management Plan, Requirements Management Plan, Configuration Change Control Plan, Systems Engineering Management Plan, Program Controls Plans, and Integrated Phase Gate Implementation Plan).

8.2.2.2 Stockpile Systems

- Conducted surveillance activities for all weapon systems using data collection from flight tests, laboratory tests, and component evaluations to assess stockpile reliability without nuclear explosive tests.
- Completed the W80-1 detonator first production unit.
- Completed final design review for W87 Alt 360 GTS.
- Qualified and executed B61, B83, and W80 tests on new safety mechanism tester.
- Renewed the B61 Nuclear Explosive Safety Study for disassembly operations.
- Completed the B83 Operational Safety Review to allow continued nuclear explosive operations.
- Exceeded DOD requirements for the W87 small ferroelectric neutron generator retrofits.
- Executed development activities according to the schedule for W87 GTS replacement.
- Initiated a W78 JTA instrumented test body refresh effort.

8.2.2.3 Weapons Dismantlement and Disposition

- Exceeded FY 2016 goal for dismantlement of CSAs.
- Executed the first surveillance disassembly and inspection of a W84 warhead since FY 2012.

8.2.2.4 Stockpile Services

- Improved detonator cable assembly manufacturing and inspection processes to improve yield while producing one lot of 1E33 assemblies at LANL.
- Launched a multi-year project to modernize the LANL production plant from a paper-based plant to one based on digital data.
- Completed 112 percent of required neutron generator builds and shipped 100 percent of required neutron generator shipments at SNL.
- Completed procurement of an additional ion mill for electronics fabrication and a focused ion beam microscope for supplier product verification at KCNSC.
- Created and deployed a common Stockpile Program Production Baseline that merges Pantex and Y-12 production commitments.
- Completed conceptual designs and planning estimates for two projects at SRS: Replacement of Production Unloading Lasers and Function Test Station Data Acquisition System Upgrades. Both projects are critical to sustain the LLC exchange loading and GTS surveillance missions.
- Acquired an additional mass spectrometer from Idaho National Laboratory to serve as a critical spare at SRS.
- Completed actions to support deployment of Product Realization Information Management and Exchange in first quarter of FY 2017 to replace the nuclear security enterprise's Image Management System.
- Upgraded and/or replaced multiple machine tools and other equipment throughout the nuclear security enterprise.
- Resumed operations after the PF-4 shutdown resulted in a 2-year backlog of power supply surveillance work. All required FY 2016 shelf-life units were completed.

- Provided diagnostics on key flight testing end event for both ICBM and cruise missiles. This included support for the first JTA3-CR W80 Mission and the Utah Test and Training Range.
- Provided weapons response services for continued operations at Pantex and several high-visibility events, including W84 disassembly and inspection.
- Deployed capability to share real-time telemetry data between Tonopah Test Range and Albuquerque.
- Procured Life of Program Buy parts for the Code Management System to reduce program and schedule risk.
- Deployed Quality Evaluation Requirements Tracking System versions 4.1 and 4.2 to better manage surveillance data.
- Exceeded goals for function test equivalents and destructive examinations of GTS at SRS.
- Completed corrective maintenance on the rolling mill under the Studies and Initiative element, restoring it to operation. The machine press has been reconfigured for hot forming with practice operations conducted at Y-12.

8.2.2.5 Strategic Materials

Uranium

- Completed the first Building 9212 capability relocation by transitioning radiography operations to Building 9204-2E.
- Approved CD-2/3 on several Uranium Processing Facility subprojects.
- Initiated electrical investments in Building 9215 and Building 9204-2E.
- Achieved TRL 6 on the calciner, electrorefining, and microwave technologies.
- Transferred multiple metric tons of enriched uranium material to the Highly Enriched Uranium Materials Facility for secure storage.

Plutonium

- Resumed all PF-4 operations paused in June 2013; the facility is able to conduct surveillance activities and manufacture pits.
- Fabricated a W87 production development unit in August 2016 at LANL.
- Approved the baseline and start of construction execution for the first two subprojects of the CMRR project.

Tritium

- Published the Tritium Strategy document, which outlines a long-term supply plan.
- Obtained NRC approval to increase the maximum number of TPBARs irradiated in Watts Bar Unit 1.
- Shipped 300 TPBARs to SRS's Tritium Extraction Facility.
- Issued the WesDyne 9-year contract modification to continue fabrication and assembly of TPBARs.
- Prepared and issued Supplemental Environmental Impact Statement, and issued Record of Decision.
- Issued contract to restart lithium-6 powder and pellet manufacturing.

Domestic Uranium Enrichment

- Demonstrated centrifuge R&D reliability improvements to the AC100 Centrifuge.
- Began component design for a smaller, national security centrifuge that, based on Oak Ridge National Laboratory's Optimization Model, maximizes performance and minimizes overall construction and operational costs.
- Completed updated analysis of uranium inventory availability to support tritium production.
- Approved CD-0, Approve Mission Need, for a domestic uranium enrichment capability.

Lithium

- Conducted a formal AoA for a lithium production capability.

Strategic Materials Sustainment

- Completed the recycle and recovery of tritium ahead of schedule in support of DSW demands.
- Exceeded production goal at Y-12 to meet Defense Programs requirements, replenish metal, and provide a risk mitigation inventory.
- Exceeded expectations for activities at LANL associated with TRU waste management at TA-55 for the High Efficiency Neutron Counter-3 and mobile loading demonstration and obtained an additional 25 kilograms of MAR storage.
- Accomplished risk reduction activities and vault material disposition, including reducing MAR on the PF-4 main floor by 22 percent.

8.2.3 Directed Stockpile Work Changes from the FY 2017 SSMP

8.2.3.1 Life Extension Programs and Major Alterations

NNSA released a revised Baseline Cost Report for the B61-12 LEP as part of the requirement to enter Phase 6.4. The new program total cost is $8,253 million, which is a 1.2 percent increase from the FY 2013 baseline SAR.[62] The increase addresses a shortfall in the technology and production maturation campaigns initially funded by other programs within NNSA now funded by the B61-12 LEP. Other increases are a result of better estimates based upon improved design definition and the increased cost of labor at Pantex.

The W88 Alt 370 program recently completed the Baseline Cost Report, which provides a high-fidelity cost estimate. The report provides an updated estimate to the first SAR, sent to Congress in FY 2013. The Baseline Cost Report estimate for the program is $2,618 million; this is approximately $255 million or 11 percent higher than the previous estimate, reported in the 2015 SAR. The increased costs were primarily due to increases in test and qualification, increased rigor in program management, increased planning margins for the treatment of program technical risks, and some offsetting reduction in scope associated with nuclear components. This estimate represents the new program baseline and will be reflected in future SARs.

[62] This total includes Other Program Monies. Without those included, the then-year dollar cost total is $7,605 million.

8.2.3.2 Stockpile Systems

- No substantive changes from the FY 2017 SSMP.

8.2.3.3 Weapons Dismantlement and Disposition

Section 3125 of the FY 2017 NDAA limits expenditures and obligations for dismantlement activities to $56,000,000 for FY 2017 to FY 2021 and limits the dismantlement rate to that contained in the FY 2016 SSMP.

8.2.3.4 Stockpile Services

Production Support

- No substantive changes from the FY 2017 SSMP.

R&D Support

- No substantive changes from the FY 2017 SSMP.

R&D Certification and Safety

- No substantive changes from the FY 2017 SSMP.

Management Technology and Production

- No substantive changes from the FY 2017 SSMP.

8.2.3.5 Strategic Materials

Uranium Sustainment

- No substantive changes from the FY 2017 SSMP.

Plutonium Sustainment

- No substantive changes from the FY 2017 SSMP.

Tritium Sustainment

- No substantive changes from the FY 2017 SSMP.

Domestic Uranium Enrichment

- No substantive changes from the FY 2017 SSMP.

Strategic Materials Sustainment

- No substantive changes from the FY 2017 SSMP.

8.2.4 Directed Stockpile Work Milestones and Objectives

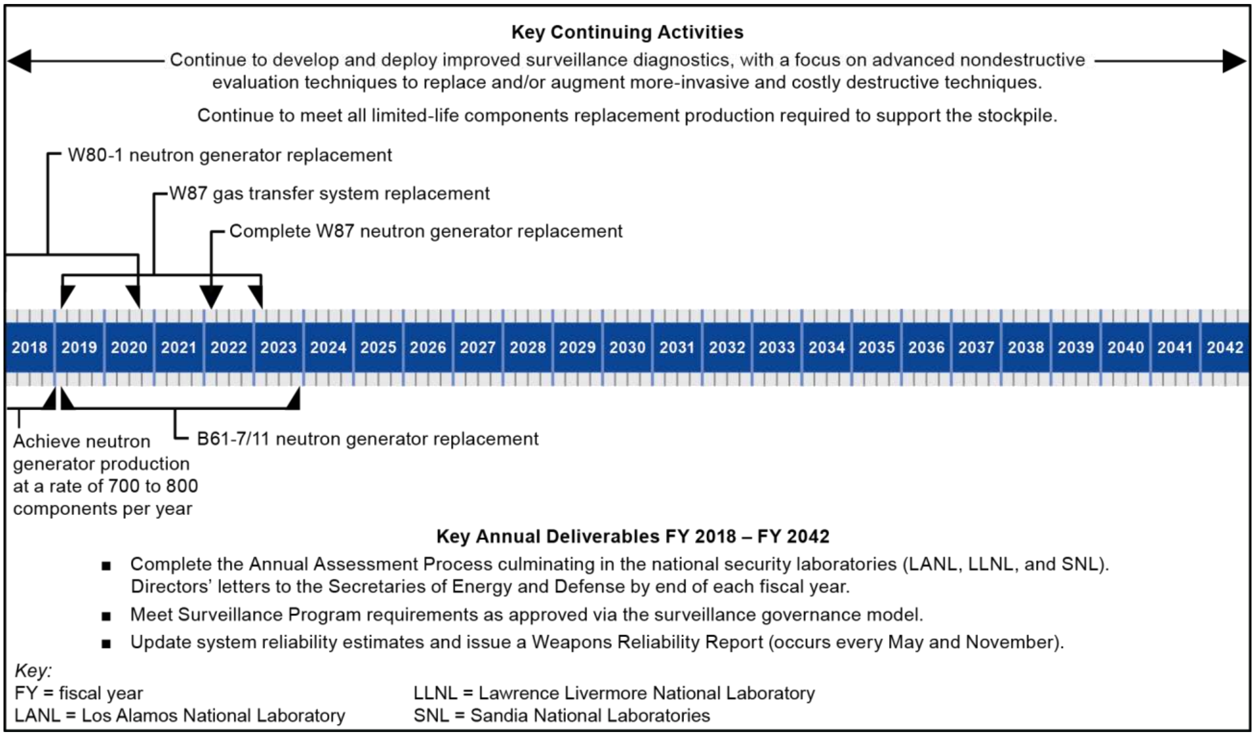


Figure 8–3. Goals, milestones, and key annual activities for weapon assessment, surveillance, and maintenance

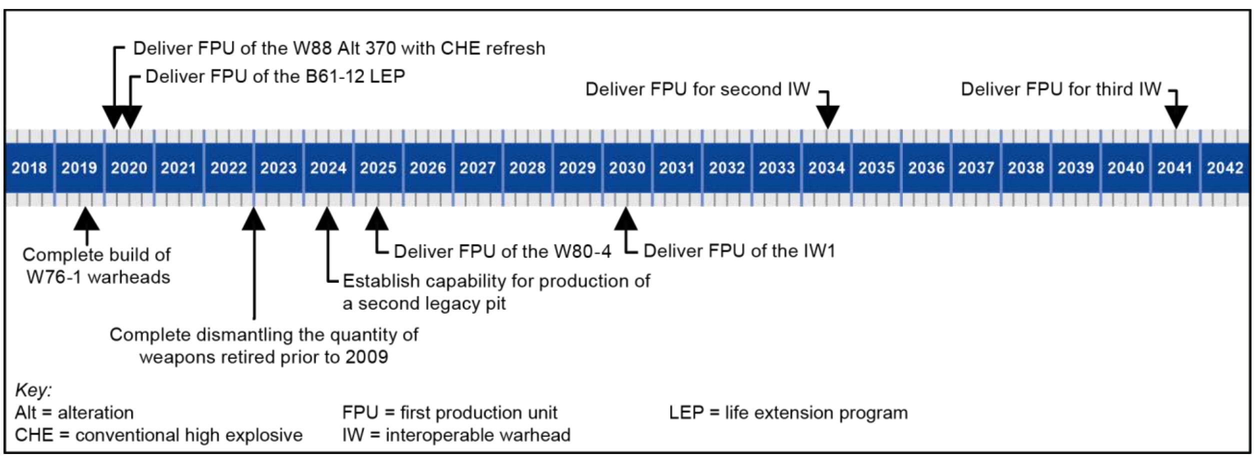
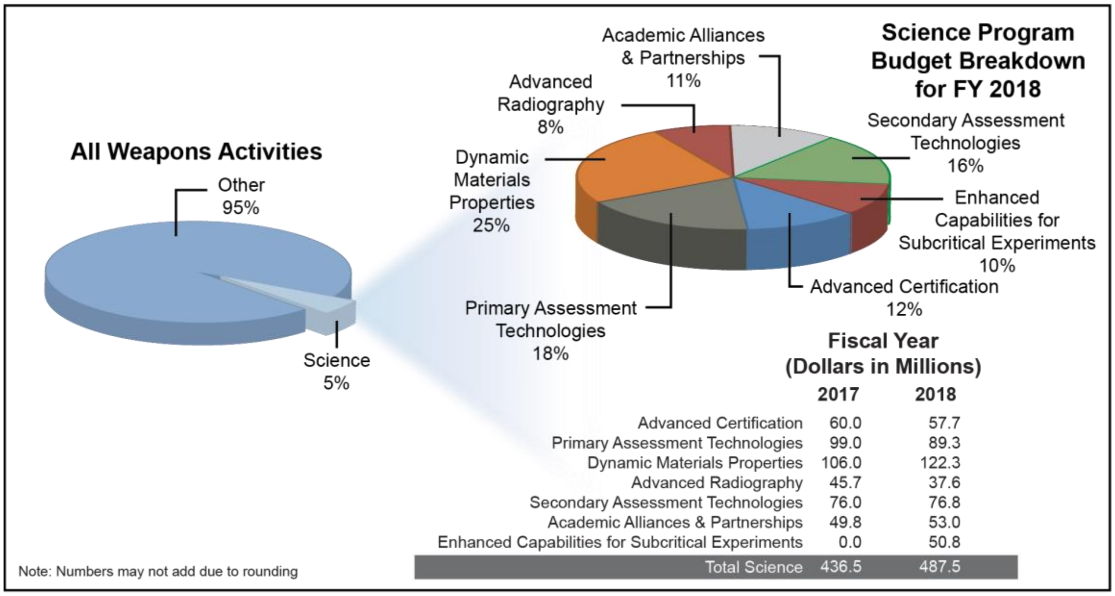


Figure 8–4. Milestones for life extension programs, major weapons component production, and weapons alteration and dismantlement

8.3 Research, Development, Test, and Evaluation

8.3.1 Science Program

8.3.1.1 Science Program Budget



Fiscal Year (Dollars in Millions)	2017	2018
Advanced Certification	60.0	57.7
Primary Assessment Technologies	99.0	89.3
Dynamic Materials Properties	106.0	122.3
Advanced Radiography	45.7	37.6
Secondary Assessment Technologies	76.0	76.8
Academic Alliances & Partnerships	49.8	53.0
Enhanced Capabilities for Subcritical Experiments	0.0	50.8
Total Science	436.5	487.5

Figure 8–5. Science Program funding schedule for fiscal years 2017 through 2018

8.3.1.2 Science Program Accomplishments

Major accomplishments and significant contributions from the Science Program and its subprograms since the FY 2017 SSMP are detailed in this section.

Advanced Certification

- Advanced future LEP options through completion of the Secondary LEP PCF Pegpost/Level 1 milestone, the initial Certification Readiness Exercises, and LANSCE experiments on additive manufacturing of new parts and restoration of aged components.
- Designed and experimentally validated an innovative concept using an additively manufactured component that significantly improves primary performance for future LEP applications, including the W80-4.

Primary Assessment Technologies

- Published a joint LLNL, LANL, and SNL update to the 10-year boost science plan that integrates theoretical, computational, and experimental efforts in support of LEPs and stockpile modernization.
- Examined the primary performance impact of features that arise as a result of warhead production, birth defects, aging, and LEPs using the DARHT facility and LANSCE.
- Developed an intelligent-retrieval archive base for radiochemical nuclear test data.
- Completed evaluation of experimental data associated with a potential proliferant design.

Dynamic Materials Properties

- Executed an experiment at Z that compared the properties of new and aged plutonium to support the B61-12 LEP certification.
- Conducted a Z experiment that yielded higher-pressure data in previously inaccessible regimes, using a shock ramp platform.
- Completed 11 experiments on JASPER; 5 of these were graded density impactor experiments with plutonium to obtain phase transitions data.
- Delivered plutonium phase and strength data at high-pressure regimes previously only accessible through models and theory.

Advanced Radiography

- Acquired double pulse radiographic images on LLNL's Flash X-Ray; a new three-frame camera acquired two pulse radiographs in separate frames.
- Conducted static experiments using a dense plasma focus pulsed neutron source, relevant to an Advanced Reactivity Measurement Subcritical Experiment being proposed for the NDSE concept.

Secondary Assessment Technologies

- Advanced development of test platforms for warm x-rays (10 to 100 kiloelectronvolts) and greater than 1 million electron volt neutron sources on Z, obtaining several record x-ray and neutron yields that resulted in record fluences on test objects with low noise.

Academic Alliances and Partnerships

- Dedicated the Dynamic Compression Sector at the Advanced Photon Source at Argonne National Laboratory.
- Hired 22 program-supported graduate students into the nuclear security enterprise; 19 were hired by other government laboratories.
- Supported participants of Academic Alliances publishing 522 peer-reviewed publications in disciplines relevant to the Stockpile Stewardship Program.

8.3.1.3 Science Program Changes from the FY 2017 SSMP

Several changes to the milestones and objectives have occurred, as indicated in **Figure 8–6**.

- As part of the PCF realignment, the FY 2017 pegpost *PCF Advanced Safety Baseline Capability* was changed to *One Point Safety Baseline Capability*; the milestone will be completed in FY 2017.
- The FY 2018 milestone c*omplete hydrodynamic and subcritical experiments supporting our understanding of ejecta* was moved to FY 2020 to insert safety experiments into the schedule, in accordance with the Subcritical Experiments Council revision of the overall schedule to achieve better alignment with national priorities.

8.3.1.4 Science Program Milestones and Objectives

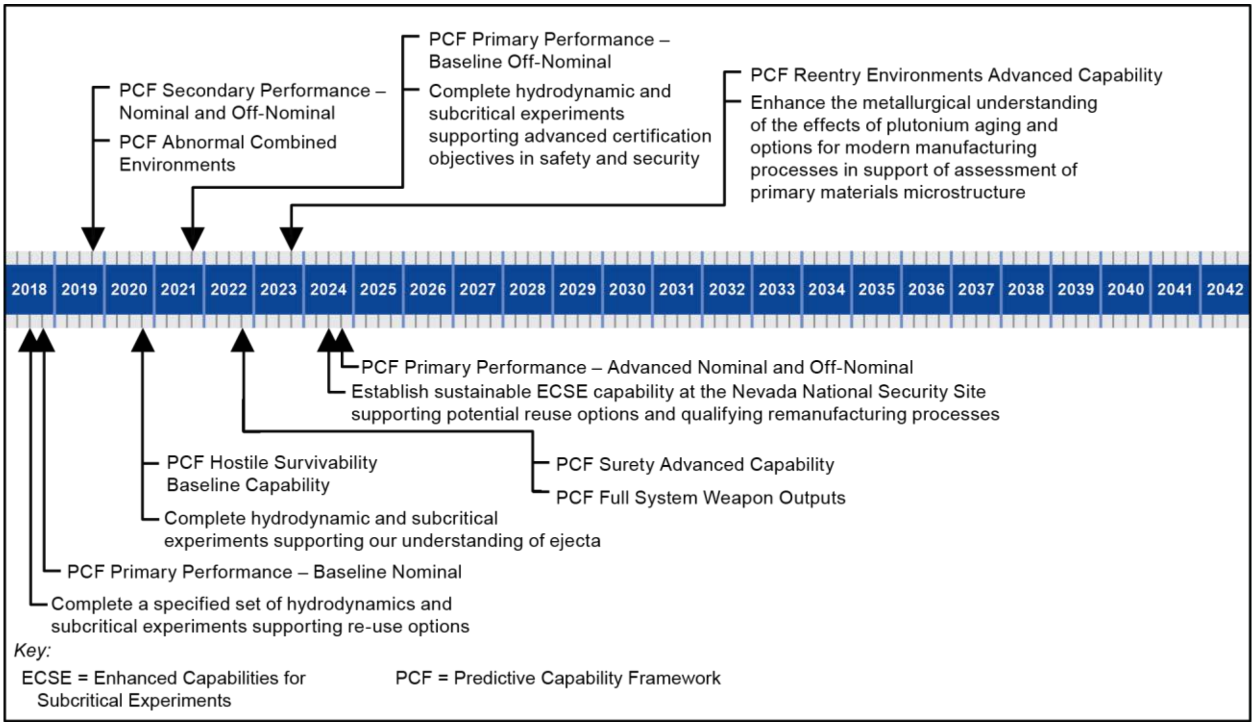


Figure 8–6. Experimental and analysis milestones and objectives led by the Science Program

8.3.2 Engineering Program

The Stockpile Responsiveness Program was added as a new subprogram in the FY 2018 President's Budget Request for this congressionally directed program.

8.3.2.1 Engineering Program Budget

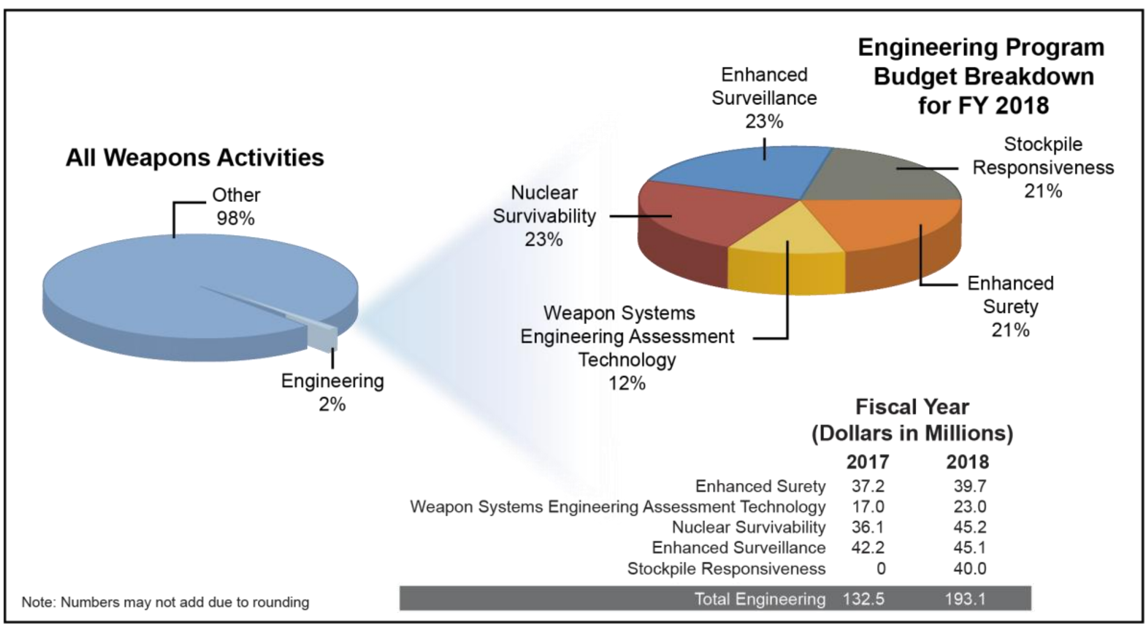


Figure 8–7. Engineering Program funding schedule for fiscal years 2017 through 2018

8.3.2.2 Engineering Program Accomplishments

Major accomplishments and significant contributions from the Engineering Program and its subprograms since the FY 2017 SSMP are detailed in this section. Information regarding Enhanced Surety can be found in Chapter 2, Section 2.2.6.2 (Research and Development Certification and Safety). The remaining subprograms are described in Chapter 3, Section 3.2.3 (Engineering, Stockpile Assessment, and Responsiveness).

Enhanced Surety

- Used recently established x-ray computerized tomography techniques to discover significant technical findings that promise increased manufacturing yields and cost savings for the highest priority mechanical component.
- Performed advanced use control technology qualification testing on schedule to meet B61-12 LEP needs. This B61-12 qualification testing also benefits computer codes used for future qualification and surveillance.
- Conducted compatibility testing with real materials and shared legacy system characterization; additional collaborations under Phase 3 will benefit both the UK and the United States.

Weapons Systems Engineering Assessment Technology

- Improved the prediction of material failure as part of the Livermore Insensitive High Explosives Damage model development by incorporating the effect of strain rate and hydrostatic strengthening, as determined from mechanical properties experiments on IHE specimens.
- Developed new test case for the plastic-bonded explosive 9502 by integrating lessons learned on confinement, geometry, morphology, and temperature state of HE necessary to produce a deflagration-to-detonation transition for the B61 LEP and the nuclear security enterprise-wide effort to refine the definition of an IHE.

Nuclear Survivability

- Completed delivery of six unique high-voltage pulsers for electromagnetic environment testing, allowing qualification of hardware of 30 simultaneous conductors for W88 Alt 370 and W87 system qualification.
- Debuted a newly designed and survivable in-chamber gas handling system for use on system-generated electromagnetic pulse tests on Z for complex geometries and a range of gas pressures.
- Used 11 device part numbers in the W76-1 Arming and Fuzing subsystem to undergo continued irradiation at 1X and 50X fielded intrinsic radiation exposure levels. The irradiation tests were part of a multi-year intrinsic radiation and pure-gamma exposure sequence to assess the ability of accelerated test procedures to capture and predict the effects of long-term intrinsic radiation exposure for commercial-off-the-shelf silicon technologies.

Enhanced Surveillance

- Deployed the first 12 x 12-inch square praseodymium-doped gadolinium lutetium oxide advanced x-ray scintillator in CoLOSSIS-I of the x-ray computed tomography system at Pantex. The increased brightness and resolution afforded by this material will increase the throughput on CoLOSSIS, which scientists use to look for anomalies in warheads.

- Delivered age-aware specifications and design for gold electrical contact coating on MC5008 and developed solutions for mechanically induced degradation of electrical contacts for the W88 Alt 370, the W76-1, and the W87.
- Matured the weapons model to include spatially aware uranium corrosion predictability with real-time feedback. This involved a major upgrade of the uranium materials model and its implementation. The program began implementing the uranium and associated models designed for multidimensional applications in FY 2017.
- Completed developmental work on thermal battery materials aging, detonator material aging, aluminum corrosion-resistant coating, and plastic ball grid underfill material to support the B61 LEP.

8.3.2.3 Engineering Program Changes from the FY 2017 SSMP

NNSA expects to develop additional milestones as a result of the upcoming Stockpile Responsiveness Program. Several changes to the milestones and objectives have occurred already, as indicated in **Figure 8–8**.

- Scope in the FY 2018 milestone *Weapon Component Performance Capability* was moved from the Engineering Program.
- The FY 2030 milestone *Predictive capabilities for requirements definition and weapon design needs for responsive stockpile* was deleted. Another existing milestone *Deploy next generation predictive capabilities for CSAs, cases, HE, detonators, and non-nuclear components and materials to support assessment and certification* (FY 2025) more accurately describes the current state of efforts and capabilities.

8.3.2.4 Engineering Program Milestones and Objectives

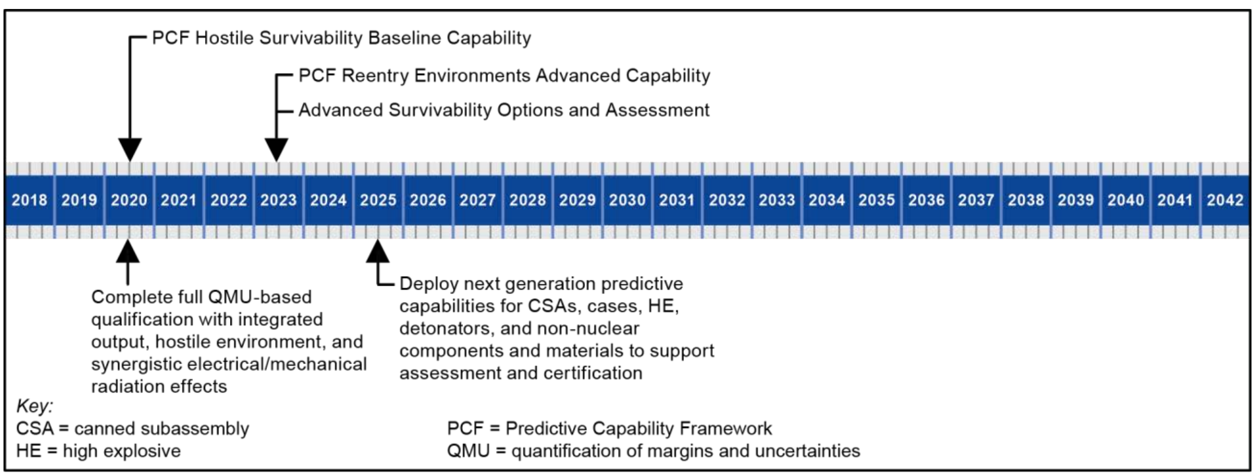
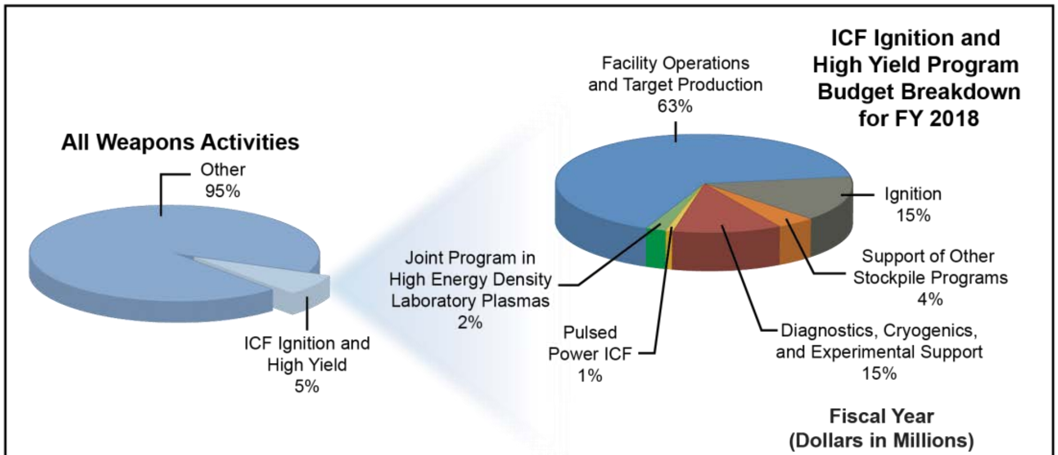


Figure 8–8. Engineering and technological milestones and objectives led by the Engineering Program

8.3.3 Inertial Confinement Fusion Ignition and High Yield Program

8.3.3.1 Inertial Confinement Fusion Ignition and High Yield Program Budget



Fiscal Year (Dollars in Millions)	2017	2018
Ignition	77.9	79.6
Support of Other Stockpile Programs	23.4	23.6
Diagnostics, Cryogenics, and Experimental Support	64.2	77.9
Pulsed Power ICF	5.6	7.6
Joint Program in High Energy Density Laboratory Plasmas	9.5	9.5
Facility Operations and Target Production	342.4	334.8
Total ICF Ignition and High Yield	523.0	532.9

Key:
ICF = Inertial Confinement Fusion

Note: Numbers may not add due to rounding

Figure 8–9. Inertial Confinement Fusion Ignition and High Yield Program funding schedule for fiscal years 2017 through 2018

8.3.3.2 Inertial Confinement Fusion Ignition and High Yield Program Accomplishments

Major accomplishments and significant contributions from the ICF Program and its subprograms are detailed in this section.

Ignition

- Qualified new high spatial and temporal resolution x-ray imaging for implosions on the NIF and developed a symmetric, high-convergence implosion platform for code validation.
- Executed the first experiment on Z using trace tritium (0.1 percent) in a gas-filled target and measured record neutron yields on magnetic direct-drive experiments.
- Performed the first integrated laser-based magnetized liner inertial fusion experiments on Omega.
- Experimented with the first liquid layer capsule at NIF that forms the hot spot in a novel way to study convergence and hot spot formation issues. Initial experiments exhibited problems and did not suggest that this approach will lead more successfully to ignition. Also began experimental development of the double shell platform on NIF.
- Improved the beam timing accuracy on target to 3 picosecond root mean square on Omega and used new facility co-timing capabilities to radiograph a deuterium and tritium fuel layer in flight at a convergence ratio of 10.
- Identified—and developed approaches to mitigate—two significant obstacles to obtaining ignition with the NIF: the time-dependent symmetry of the implosion and the perturbations arising from capsule support mechanisms.
- Demonstrated a new high case-to-capsule ratio target using beryllium capsules that will mitigate the effects of asymmetric drive and tent features.

- Established the National Direct-Drive Program at the Laboratory for Laser Energetics, University of Rochester and developed its two Integrated Experimental Campaigns: the 100-gigabar campaign on OMEGA and the Megajoule Direct-Drive campaign on the NIF.

Support of Other Stockpile Programs

- Conducted high-impact stockpile stewardship experiments of relevance to pit reuse options.
- Obtained critical data on plutonium phase, mix, radiation transport on NIF, including the first plutonium strength experiment.
- Developed new NIF platforms enabling studies of plutonium equation of state, complex hydrodynamics, boost, radiation effects, and identified two critical issues hindering development of a robust burning platform.
- Conducted plutonium experiment on Z in support of the B61-12 LEP certification. The data will be used to characterize material property differences between new and aged plutonium.
- Produced record x-ray yields and fluences on Z using new z-pinch sources. These warm x-ray sources extend the energy range of useful radiation effects environments on Z.

Diagnostics, Cryogenics, and Experimental Support

- Commissioned and qualified the Advanced Radiographic Capability at LLNL, the world's most energetic short pulse laser.
- Developed the Virgil high-resolution x-ray spectrometer at the Naval Research Laboratory.

Pulsed Power Inertial Confinement Fusion

- Executed first experiment using trace tritium (0.1 percent) in a gas-filled target and measured record neutron yields on magnetic direct-drive experiments at Z facility.

Joint Program in High Energy Density Laboratory Plasmas

- This joint program with the DOE Office of Science continues to support the NNSA's stockpile stewardship mission by conducting HED physics research and strengthens NNSA's RDT&E activities. The subprogram provides support for external users at Omega through the National Laser Users' Facility program and a joint solicitation with the Office of Science for High Energy Density Laboratory Plasmas research at universities and DOE laboratories. It also supports academic programs to steward the study of laboratory HED plasma physics, maintain a cadre of qualified HED researchers, and develop the next generation of stockpile stewards.

Facility Operations and Target Production

- Reached a stable, efficient operating point for the NIF. Over the last 2 years, NIF has met the goals of the congressionally mandated 120-day study by performing a record 417 experiments in FY 2016 (more than twice the 191 experiments in FY 2014).

8.3.3.3 Inertial Confinement Fusion Ignition and High Yield Program Changes from the FY 2017 SSMP

- Completed the milestone *Obtain boost relevant data required to support the FY 2018 PCF pegpost.*
- Completed the milestone *Measure the effect of shell mixing on deuterium-tritium burn.*

Several changes to the milestones and objectives have occurred, as indicated in **Figure 8–10**.

- The remaining FY 2017 milestone *Demonstrate operation of Z facility at 95 kilovolts* was deleted because it is no longer consistent with ICF Program planning.
- The wording of the FY 2018 milestone *Assess requirements for a high yield (>100 megajoule) platform to support LEP stockpile modernization* was changed to *Assess requirements for a high*

yield platform to support LEP and long-term stockpile modernization in order to update expectations of high yield to be in line with current physics extrapolations.

- The FY 2018 milestone *Use symmetrically driven implosions to investigate performance scaling and cliffs* was added.
- The FY 2019 milestone *Deliver the Optical Thompson Scattering Transformative Diagnostic* was removed; the effort is continuing at levels below those qualifying as a milestone.
- The FY 2020 milestone *Obtain time-resolved diffraction data at a scale that can support high-pressure, high-Z material studies* was added.
- The FY 2021 milestone *Deliver Hybrid Complementary Metal Oxide Semiconductor Diagnostic Capability* was removed; the effort is continuing at levels below those qualifying as a milestone.
- The FY 2022 milestone *Establish mission need for a high yield platform to support LEP and long-term stockpile modernization* was added.
- The FY 2023 milestone *Deliver multi-layer Wolter optic diagnostic* has been deleted as it is no longer consistent with ICF Program planning.
- The wording of the FY 2024 milestone *Complete the research program outlined in the 10-year HED Strategic Plan. Revise and update the 10-year plan* was significantly weakened to say *Assess the results of the research program outlined in the 10-year HED Strategic Plan* to convey a more outcome-oriented assessment of research performed rather than noting the completion of a program.

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

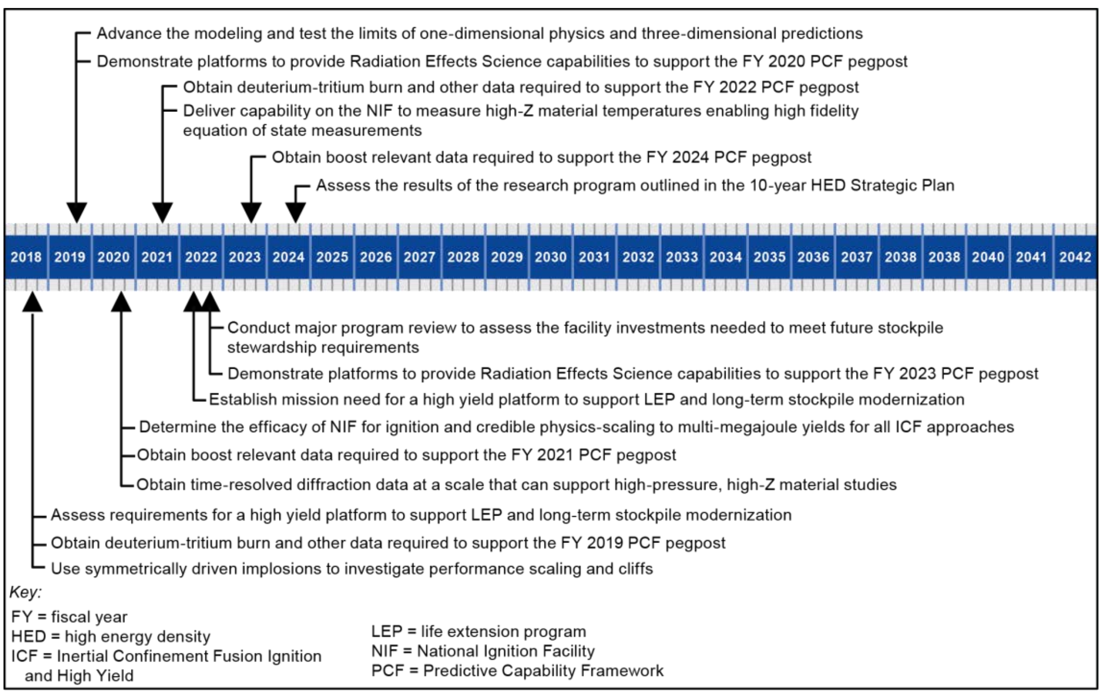
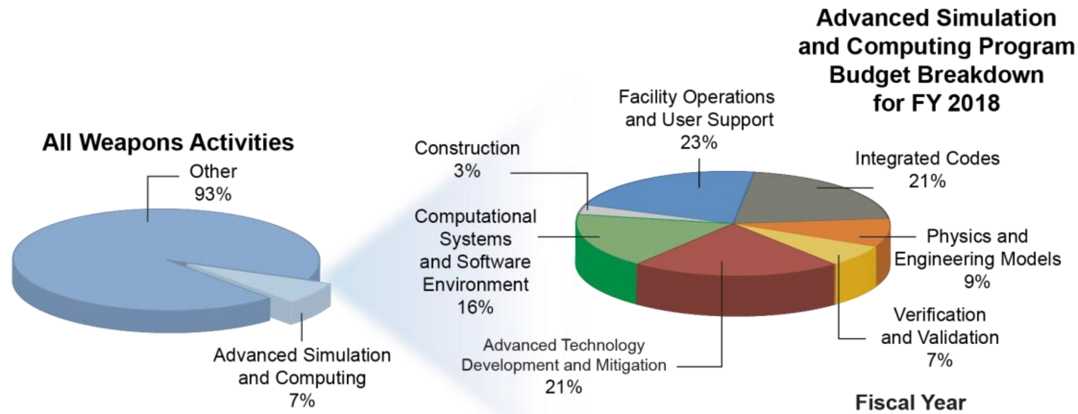


Figure 8–10. Milestones and objectives based on experiments on NNSA's high energy density facilities led by the Inertial Confinement Fusion Ignition and High Yield Program

8.3.4 Advanced Simulation and Computing Program

8.3.4.1 Advanced Simulation and Computing Program Budget



Fiscal Year (Dollars in Millions)

	2017	2018
Integrated Codes	149.6	151.8
Physics and Engineering Models	67.1	66.9
Verification and Validation	52.0	51.1
Computational Systems and Software Environment	130.6	121.5
Facility Operations and User Support	168.8	160.0
Advanced Technology Development and Mitigation	95.0	158.0
Construction	0	25.0
Total Advanced Simulation and Computing	663.2	734.2

Note: Numbers may not add due to rounding

Figure 8–11. Advanced Simulation and Computing Program funding schedule for fiscal year 2017 and fiscal year 2018

8.3.4.2 Advanced Simulation and Computing Program Accomplishments

Major accomplishments and significant contributions from the ASC Program and its subprograms since the FY 2017 SSMP are detailed in this section.

Integrated Codes

- Upgraded safety modeling capabilities that contributed to resumption of plutonium R&D activities at LANL's PF-4.
- Delivered support for both transient and steady-state adjoint sensitivity analysis for uncertainty quantification studies of circuits that have a large number of parameters.
- Optimized performance of deterministic neutron transport on Trinity Phase II (Knights Landing) for scaling and runtime performance using multilevel threading and vectorization for Single Instruction, Multiple Data architecture2.
- Deployed first release of the Rapid Optimization Library package, which performs large-scale optimizations for design, control, and inversion problems in large-scale engineering applications. This technology is also used for mesh optimization and image analysis.

Physics and Engineering Models

- Improved models for dynamic compaction of advanced manufacturing materials by reducing the computational cost in simulating struts in a lattice-structured material. Additive manufacturing materials are of interest for LEP designs because of the high stiffness-to-weight ratio.
- Developed an equation of state for products of a HE to study effects of material aging.

- Discovered a new mechanism by which foam-filled parts age that provides a better understanding of the polyurethane foam that protects electronics in the W76, W88, and B61. This new understanding improves the ability to predict material decomposition in stockpile-to-target sequence and abnormal environments.

Verification and Validation

- Performed full sensitivity study for hostile and blast engineering model and benchmarked model results to experimental data.
- Resolved a long-standing discrepancy between theory and plutonium experiments performed at JASPER, thereby improving confidence in plutonium equation of state data.

Computational Systems and Software Environment

- Installed first partition of Trinity (ATS-1) at LANL for classified use. The final partition of ATS-1 was installed and made available for unclassified applications to complete the 41-petaFLOPS system.
- Used Trinity's burst buffers for checkpoint-restart in integrated code applications.
- Took delivery of the Sierra early access system and provided technical coordination and contractual management for the Collaboration of Oak Ridge, Argonne, and Livermore (CORAL) effort development and Sierra contracts.

Facility Operations and Use Support

- Integrated Tri-Lab Operating System stack onto the first-deployment CTS-1 machine.
- Deployed CTS-1 HPC platforms at LLNL, LANL, and SNL during FY 2016 third quarter and fourth quarter.
- Completed a new building at LLNL to house unclassified CTS machines.

Advanced Technology Development and Mitigation

- Advanced abstraction layer definitions and implementations for mesh topology, parallelism, data management, and checkpoint restart, which together enable portable efficient software construction.
- Released open-source version of the Flexible Computer Science Infrastructure toolkit, which provides data, programming, and execution model abstractions for physics application development.
- Performed a series of multidimensional implosion calculations using a next-generation nuclear performance code, which includes a high-order hydrodynamic option, and compared outputs from a production nuclear performance code.
- Collaborated with the DOE Office of Science to support the DOE/NNSA exascale computing goals and the National Strategic Computing Initiative, as directed by Executive Order 13702.[63]

[63] See Presidential Executive Order 13702, Creating a National Strategic Computing Initiative, July 29, 2015.

8.3.4.3 Advanced Simulation and Computing Program Changes from the FY 2017 SSMP

- Completed the FY 2017 milestone *Exascale System Readiness – Deliver Trinity (ATS-1)*.

Several changes to the milestones and objectives have occurred, as indicated in **Figure 8–12**.

- The FY 2020 milestone *Meet ATDM 5-year code objectives* was deleted since it was redundant with two milestones: *Exascale Code Assessment – on ATS-1 and ATS-2* (FY 2019) and *Exascale Code Performance – Single Simulation on ATS-3* (FY 2023).
- The wording of the latter two milestones [*Exascale Code Assessment – on ATS-1 and ATS-2* (FY 2019) and *Exascale Code Performance – Single Simulation on ATS-3* (FY 2023)] has been modified to more precisely convey their intent and their timeframes have changed. The revised milestones are *Code Assessment – on ATS-1* (FY 2018) and *ATS-2* (FY 2020) and *Code Performance – on ATS-3* (FY 2022).

Several milestones have been added as plans have matured:

- *Exascale System Readiness – Deliver ATS-4* (FY 2023)
- *Exascale System Readiness – Deliver ATS-5* (FY 2025)
- *Code Assessment – On ATS-4* (FY 2025)
- *Code Assessment – On ATS-5* (FY 2027)

8.3.4.4 Advanced Simulation and Computing Program Milestones and Objectives

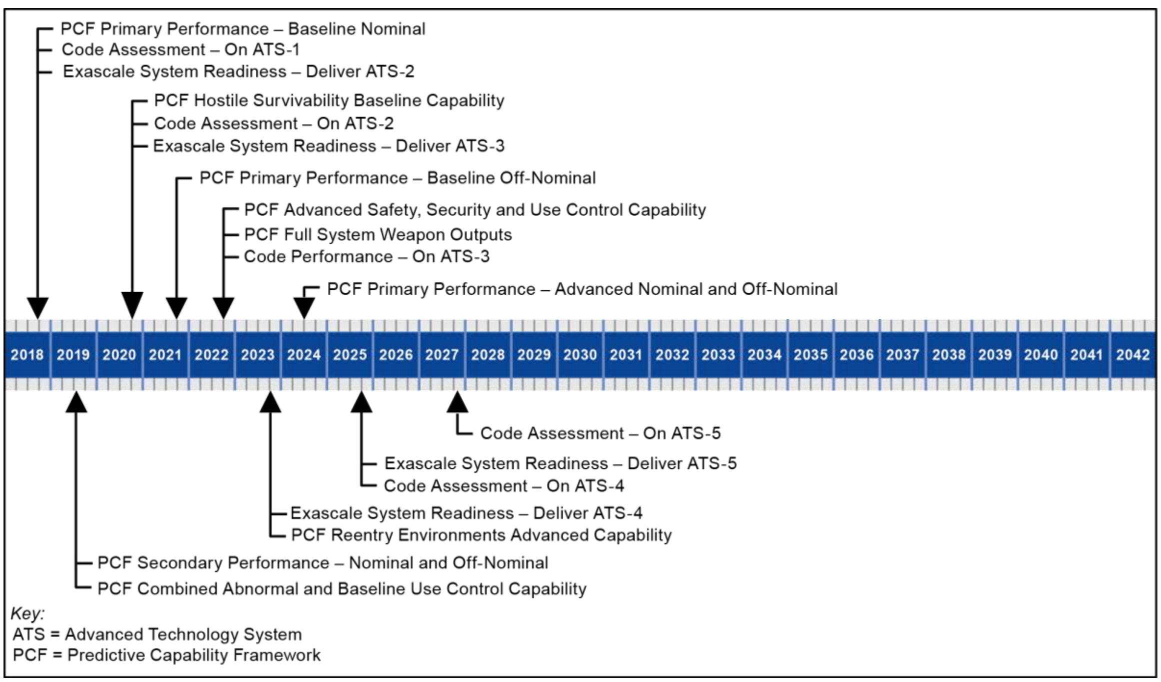


Figure 8–12. Milestones and objectives of the Advanced Simulation and Computing Program

8.3.5 Advanced Manufacturing Development Program

8.3.5.1 Advanced Manufacturing Development Program Budget

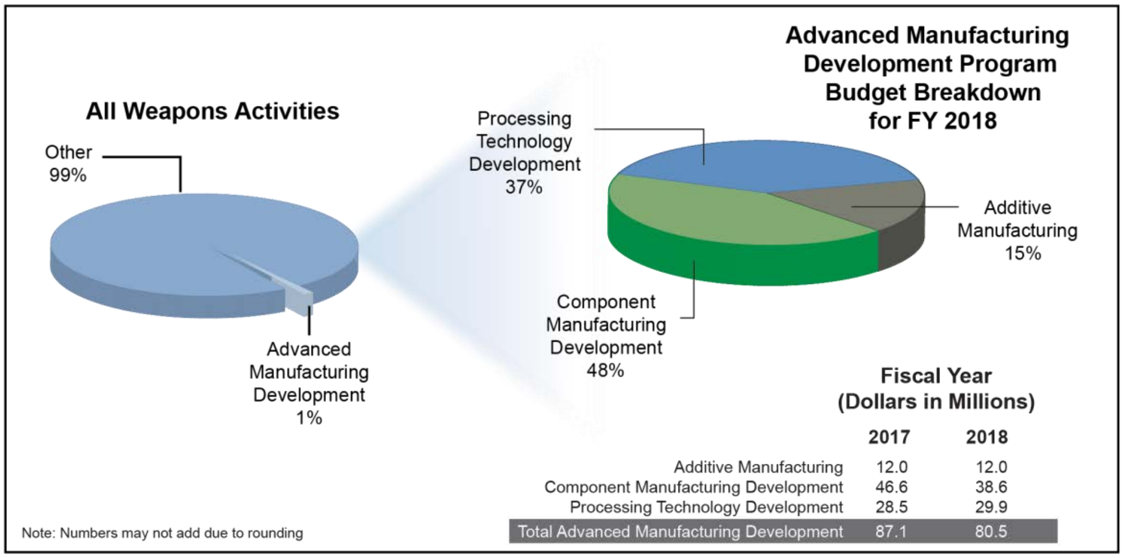


Figure 8–13. Advanced Manufacturing Development Program funding schedule for fiscal years 2017 through 2018

8.3.5.2 Advanced Manufacturing Development Program Accomplishments

Major accomplishments and significant contributions from the Advanced Manufacturing Development Program and its subprograms since the FY 2017 SSMP are detailed in this section.

Additive Manufacturing

- Printed more than 25,000 developmental tools, fixtures, and molds at KCNSC in support of LEPs, resulting in a cost avoidance of $45 million as part of the Digital Manufacturing initiative targeted at driving radical improvements to mission success.
- Recognized Pantex with a Defense Programs Award of Excellence for Additive Manufacturing for its rapid iteration of design to production for tools and fixtures that significantly reduce cost and time associated with scoping work to outside vendors.
- Completed three design iterations for a B61-12 support and alignment fixture using topology optimization and additive manufacturing, enabling them to meet B61-12 requirements while avoiding costs and down times associated with sourcing the fixtures to outside vendors.

Component Manufacturing Development

- Developed and employed the Electronic Production Control System that tracks parts through the post-fab process, collects all the electronic data generated, and incorporates many defect prevention strategies. This automated, flow tracking, defect prevention, and quality control tool will result in a savings of $17.6 million, assuming approximately 25,000 parts will be delivered for the B61, W88, and W87.
- Continued development and testing of the technologies associated with the Joint Radar Module for the B61 and the W88; system requirement tests in FY 2016 resulted in no failures, enabling the transfer of the Joint Radar Module technology to the B61 and W88 programs.

Processing Technology Development

- Initiated tritium exposure and aging studies to determine if aluminum is a viable alternative material for reservoirs in future weapon systems; two units will be removed annually from storage until FY 2020 and tests performed to determine if aluminum is suitable.

8.3.5.3 Advanced Manufacturing Development Program Changes from the FY 2017 SSMP

- The milestone *Complete W80-4 technology development PCF pegpost* has been rephrased to *Finish manufacturing development leveraged by the W80-4 LEP per the Interface Requirements Agreement* to be more specific.
- The milestone *Submit technology development for the enduring stockpile* (FY 2024) has been rephrased to *Transfer advanced manufacturing development tech from design agencies to production agencies* to be more specific. The date of this milestone has been moved to FY 2023.

The following milestones have been added as plans have matured:

- *Expand the use of additively manufactured tools, fixtures, and molds for production lines* (2019).
- *Develop manufacturing prototypes to support the Multi-Application Transportation Device for Integrated Surety Architecture* (2020).
- *Transfer tritium processing technologies to Tritium Sustainment Program* (2020).
- *Develop trusted and secure manufacturing diagnostics to support advanced manufacturing processes to assure supply chain integrity* (2022).
- *Deliver major items of equipment: calciner, electro-refiner, and machine chip processing furnace(s)* (2025).

8.3.5.4 Advanced Manufacturing Development Program Milestones and Objectives

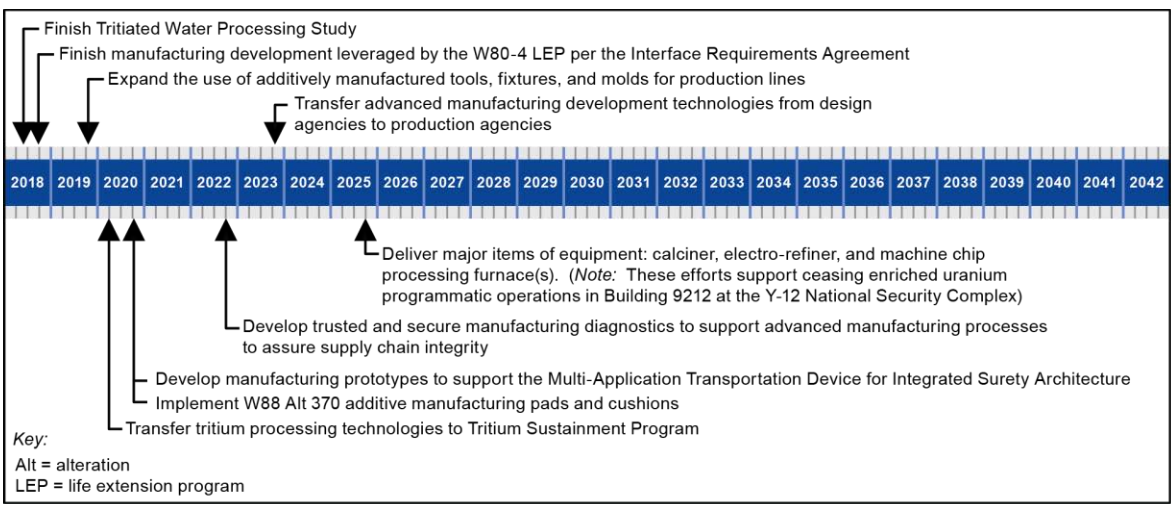


Figure 8–14. Milestones and objectives for Advanced Manufacturing Development Program

8.4 Secure Transportation Asset

8.4.1 Secure Transportation Asset Budget

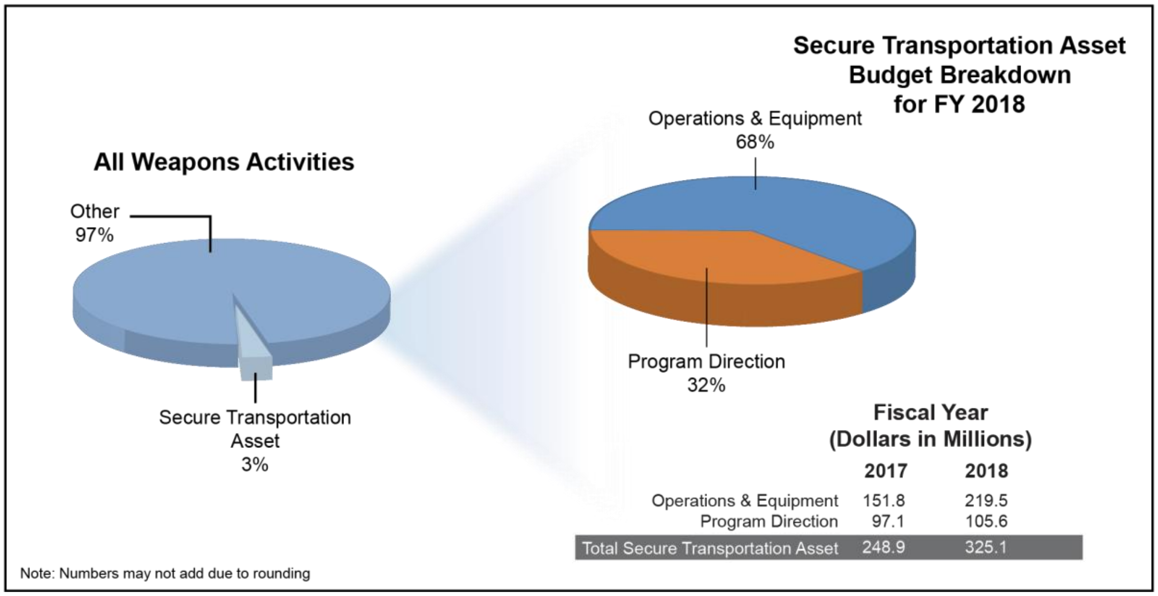


Figure 8–15. Secure Transportation Asset funding schedule for fiscal years 2017 through 2018

8.4.2 Secure Transportation Asset Accomplishments

Major accomplishments of the STA since the FY 2017 SSMP are detailed in this section.

Operations and Equipment

- Completed more than 150 shipments without compromise or loss of nuclear weapons or components or release of radioactive material.
- Produced 14 Escort Vehicle Light Chassis.
- Accomplished SGT annual risk management goals and developed and implemented systems extension plan.
- Completed the MGT conceptual design review.
- Completed MGT structural design for ¼-scale evaluation.
- Refreshed the Transportation and Emergency Control Center Information Technology equipment software.
- Conducted Force-on-Force operational validation exercise.
- Completed the facilities plan for aviation, Federal Agent Western Command, and long-term STA facilities.

Program Direction

- Graduated two Nuclear Material Courier Basic classes.

8.4.3 Secure Transportation Asset Changes from the FY 2017 SSMP

- Replacement Armored Tractor I production completion moved from FY 2018 to FY 2019.
- In FY 2018 the Replacement Armored Tractor II design will be completed with production beginning in 2019.
- Objective *Aviation fleet reaches its life span* was changed and made more specific by including 3 objectives for replacement of aircraft (FY 2020, FY 2024, and FY 2025).

8.4.4 Secure Transportation Asset Milestones and Objectives

In support of the milestones in **Figure 8–16**, the activities described will move STA toward defined goals. The key strategies are unchanged, and STA continuously evaluates the operational environment to ensure safe and secure transport of the Nation's weapons and SNM. To stabilize operating budgets and support steady-state production, STA has adjusted out-year plans for all escort vehicles and armored tractors and reevaluated plans to maintain a high-frequency communication system. Design and production of the MGT will be challenging throughout the FYNSP.

Vehicle Fleet

- Continue production of Support Vehicle 2.
- Complete a new STA vehicle performance requirements document.

Trailer Fleet

- Continue SGT risk-reduction initiatives to include a consistent supply chain of parts, logistics, and SGT expertise to extend the life of the trailers.
- Complete the trailer communication upgrade project.
- Complete an MGT ¼-scale structural performance assessment and complete the crash unit manufacturing readiness review.
- Establish design and evaluation criteria for the enhanced cargo restraint system.

Facilities

- Complete STA training facilities plan.
- Coordinate STA responses to the NNSA Albuquerque Complex Project initiative.

8.4.4.1 Secure Transportation Asset Milestones and Objectives

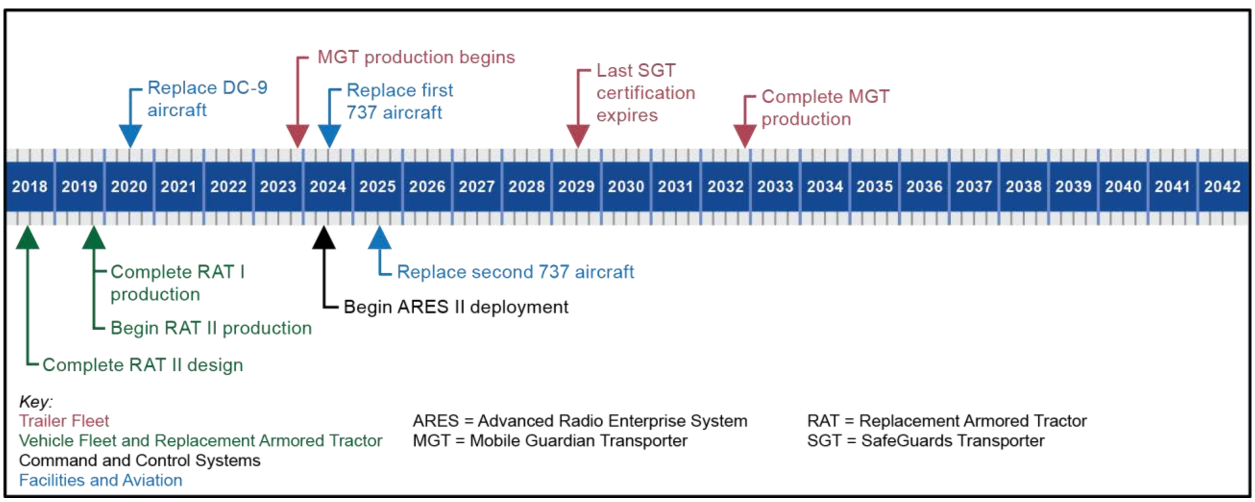
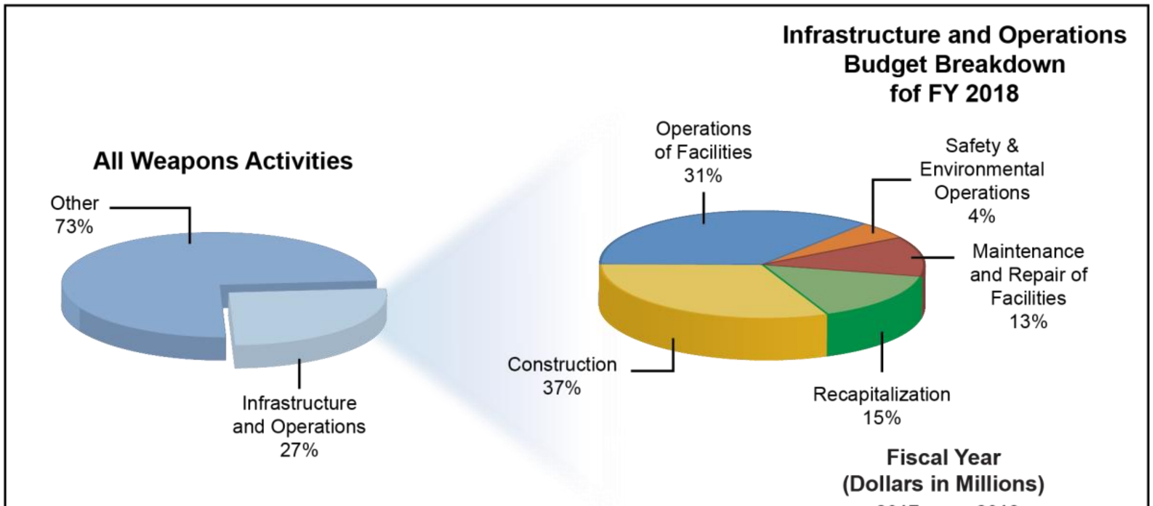


Figure 8–16. Secure Transportation Asset Program milestones and objectives

8.5 Infrastructure and Operations

NNSA has made significant progress in improving its infrastructure planning and management tools. These efforts include implementing tools to reshape the nuclear security enterprise and improve infrastructure investment planning and implementation for future needs. (The program management tools and processes are summarized in Chapter 4, "Physical Infrastructure," Section 4.3.3.)

8.5.1 Infrastructure and Operations Budget



Fiscal Year (Dollars in Millions)	2017	2018
Operations of Facilities	824.0	868.0
Safety & Environmental Operations	110.0	116.0
Maintenance and Repair of Facilities	324.0	360.0
Recapitalization	743.1	427.3
Construction	807.2	1,031.8
Total Infrastructure and Operations	2,808.4	2,803.1

Figure 8–17. Infrastructure and Operations funding schedule for fiscal years 2017 through 2018

In response to GAO recommendations, the following information is provided to improve transparency in the budget. **Table 8–3** compares investments in Maintenance and Recapitalization to benchmarks (based on the percentage of Replacement Plant Value) derived from the DOE Real Property Asset Management Plan and associated guidance. To address these benchmark shortfalls, NNSA has increased the maintenance by $38.2 million from FY 2017 to FY 2018 and continues to use the asset management programs that use supply chain management practices to increase purchasing power for common building components across the nuclear security enterprise (*e.g.*, roofs and heating, ventilating, and air conditioning). Recapitalization investments reflect a net $115 million decrease (excluding the one-time $200 million disposition in FY 2017) that is partnered with a $139 million increase in general purpose line item construction that is part of NNSA modernization. Recapitalization continues to include deactivation and demolition of excess and underutilized facilities to reduce the NNSA footprint.

Table 8–3. Projected fiscal year 2018 NNSA infrastructure maintenance and recapitalization investments

		FY 2016	FY 2017 [a]	FY 2018
Replacement Plant Value (RPV) ($B)		46.5	47.3	48.2
Maintenance Benchmark 2 to 4% RPV	Infrastructure & Safety Maintenance Investments ($K)	277,000	324,000	360,000
	Other NNSA Maintenance Investments (direct and indirect funded) ($K)	517,825	492,395	494,604
	Total NNSA Maintenance Investments ($K)	794,825	816,395	854,604
	Maintenance as % RPV	1.71%	1.63%	1.67%
Recapitalization Benchmark 1%	Infrastructure & Safety Recapitalization Investments ($K)	253,724	630,509	312,492
	Other NNSA Recapitalization Investments ($K)	98,800	112,639	114,850
	Total NNSA Recapitalization Investments ($K)	352,524	743,148	427,342
	Recapitalization as % RPV	0.76%	1.48%	0.84%

$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 Federal Complex, which is not included in RPV estimates for FY 2016–2021.

8.5.2 Infrastructure and Operations Accomplishments

General Purpose Infrastructure

- Conducted roll-out of new analysis tools and risk management methodologies to guide consequence-driven decision making.
- Halted the growth of Deferred Maintenance through prioritized maintenance and recapitalization investments and standardized definition across the complex.
- Broke ground on the Pantex Administrative Support Complex.

Programmatic Infrastructure

- Continued to consolidate the management of long-term, stockpile-wide capabilities at multiple NNSA sites through the Capability Based Investments program.

Disposition of Facilities

- Funded the disposition of several facilities across the nuclear security complex, including two of NNSA's top-10 high-risk facilities.

8.5.3 Infrastructure and Operations Changes from the FY 2017 SSMP

The Kansas City Bannister Federal Complex Disposition effort requires no further funding.

8.5.4 Infrastructure and Operations Milestones and Objectives

The construction project schedules are reflected in the Construction Resource Planning List in Section 8.7.5.

8.6 Other Weapons Activities

8.6.1 Other Weapons Activities Budget

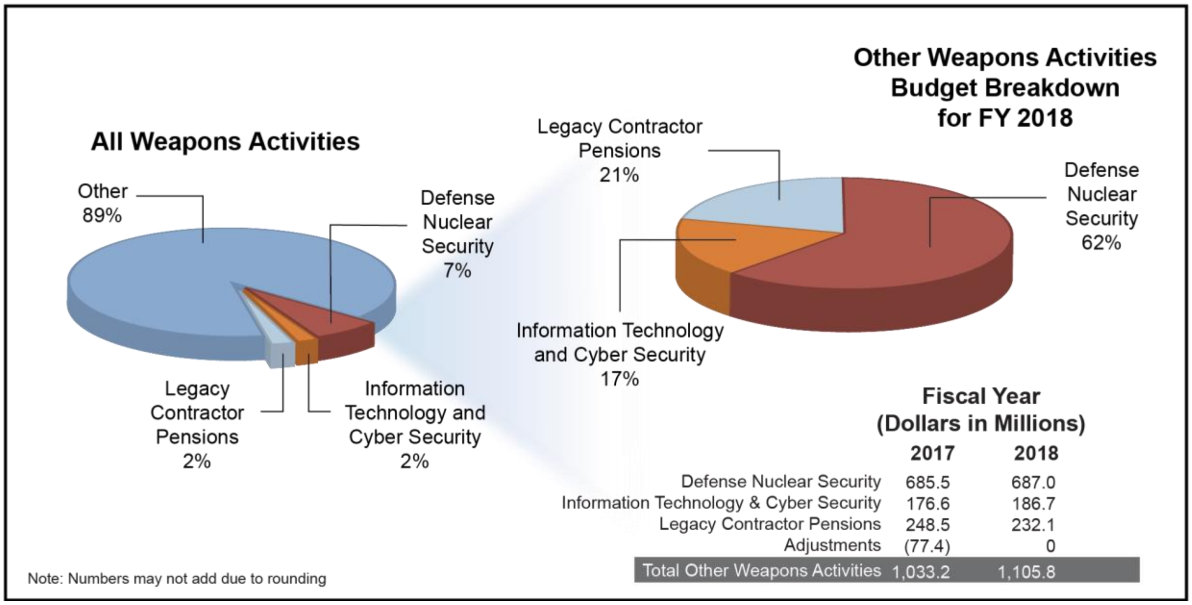


Figure 8–18. Other Weapons Activities funding schedule for fiscal years 2017 through 2018

8.6.2 Other Weapons Activities Changes from the FY 2017 SSMP

Detailed information regarding the Defense Nuclear Security Program and the Information Technology and Cyber Security Program is now addressed in the *Physical and Cyber Security Technology Management Plan* (January 2017).

8.7 Budget Estimates Beyond Fiscal Year 2018

8.7.1 Estimate of Weapons Activities Program Costs

Figure 8–19 depicts updated Weapons Activities funding based on the program in the FY 2018 President's Budget request. As noted at the beginning of this chapter, no policy decision has been made on the topline totals for Weapons Activities for FY 2019–FY 2022. These will be further refined in the 2019 budget, in accordance with the National Security Strategy, National Defense Strategy, and Nuclear Posture Review that are currently under development. Figure 8–19 displays, for the 24 years beyond FY 2018, NNSA's budget estimates based on the program of record as described in Chapters 1 through 7. The figure displays the relative makeup of the Weapons Activities Program in terms of major portfolios for the period from FY 2017 through FY 2042 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 2017–FY 2018.

The projected future cost for the program for FY 2019–FY 2042 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. This range of total cost is necessary due to the uncertainties in the individual components that comprise the estimates, in particular, for the LEPs and construction costs which are described further in this chapter.

The blue line in Figure 8–19 represents the nominal total from Figure 8–22 in the FY 2017 SSMP and portrays the relative magnitude of the funding changes. As can be seen in this year's figure, the budget estimates for the FY 2018–FY 2022 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 2022–FY 2026 period. This is for the construction of facilities for which planning and estimates have matured within the past year.

The nominal cost of the program from FY 2017–FY 2018 increases by approximately 10.8 percent, and over the FY 2018–FY 2022 period, it increases at an annual rate of approximately 3.3 percent. After FY 2022, the nominal cost declines through FY 2024 and resumes an increase of approximately 2.1 percent per year over FY 2025–2042. The greater-than-inflation increases to the program estimated over the FY 2018–FY 2022 period reflect the execution of a number of programs or efforts for which funding over that period increases at more than a current services rate due to planned increases in work scope. These efforts include the LEPs, a number of construction projects, and increases to strategic materials to meet demands.

Over the FY 2019–FY 2022 period, the uncertainty around the middle values varies from +6.6 to +3.3 percent above on the redline to 1.1 to −3.6 percent below on the green line. The increase in the high range starting in FY 2028 reflects a ramp-up in funding for a potential domestic uranium enrichment facility.

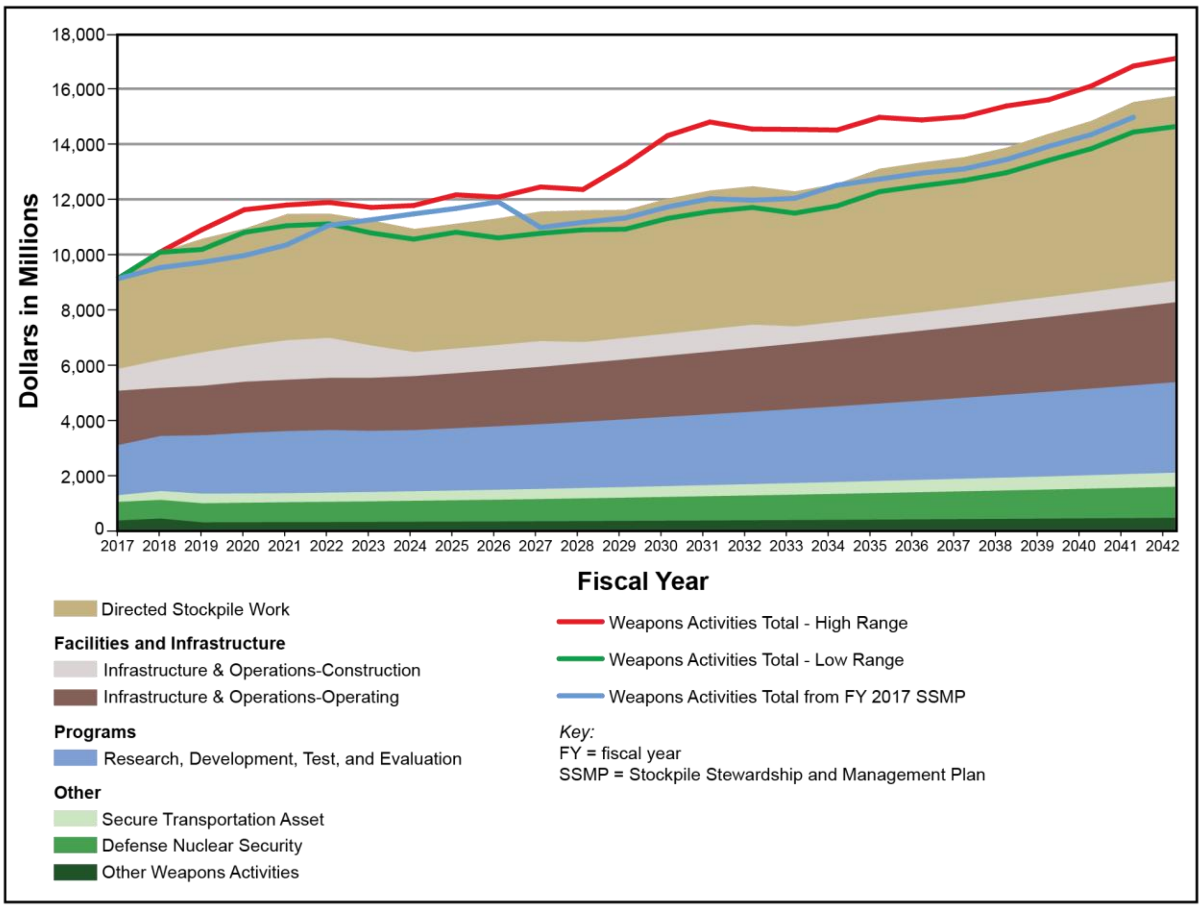


Figure 8–19. Estimated out-year budget estimates for NNSA Weapons Activities in then-year dollars

8.7.2 Basis for Cost Estimates

As noted in Section 8.7.1, Figure 8–19 displays both the request for FY 2018 and an estimate of program costs for the 24 years beyond FY 2018. The FY 2018 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 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 2019–2022, although no policy or prioritization decisions were made. The budget estimates for this period reflect the costs for continuation of 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.[64] For these projections, escalation factors based on numbers provided by OMB for 2017 were used.

Some portions of the program will not proceed at the same level of effort for FY 2023 through FY 2042. These changes in annual projections from year to year apply to major construction projects, LEPs, and, because of the future evolution in the current stockpile to a 3+2 Strategy 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.

8.7.3 Stockpile Sustainment

Sustainment costs include warhead-specific assessment activities, limited life component exchanges, required and routine maintenance, safety studies, periodic repairs, resolution and timely closure of SFIs, 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 8–20 shows, in then-year dollars, the annual sustainment cost for FY 2018 through FY 2022 attributable to a particular warhead type based on updated FY 2018 numbers and an estimate of the total sustainment cost by year for warheads of all types for FY 2023 through FY 2042. The FY 2023 through FY 2042 costs account for the increased sustainment costs to be incurred during the transition from the current stockpile to one that reflects the 3+2 Strategy.

8.7.4 Life Extension Programs and Major Alterations

LEPs are undertaken separately from stockpile sustainment with the goal of extending the lives of warheads for several additional decades. Major Alts also make component changes but do not address all the aging issues in a warhead that would require an LEP.

[64] 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, typically, is represented by the funding level of the last year of the FYNSP.

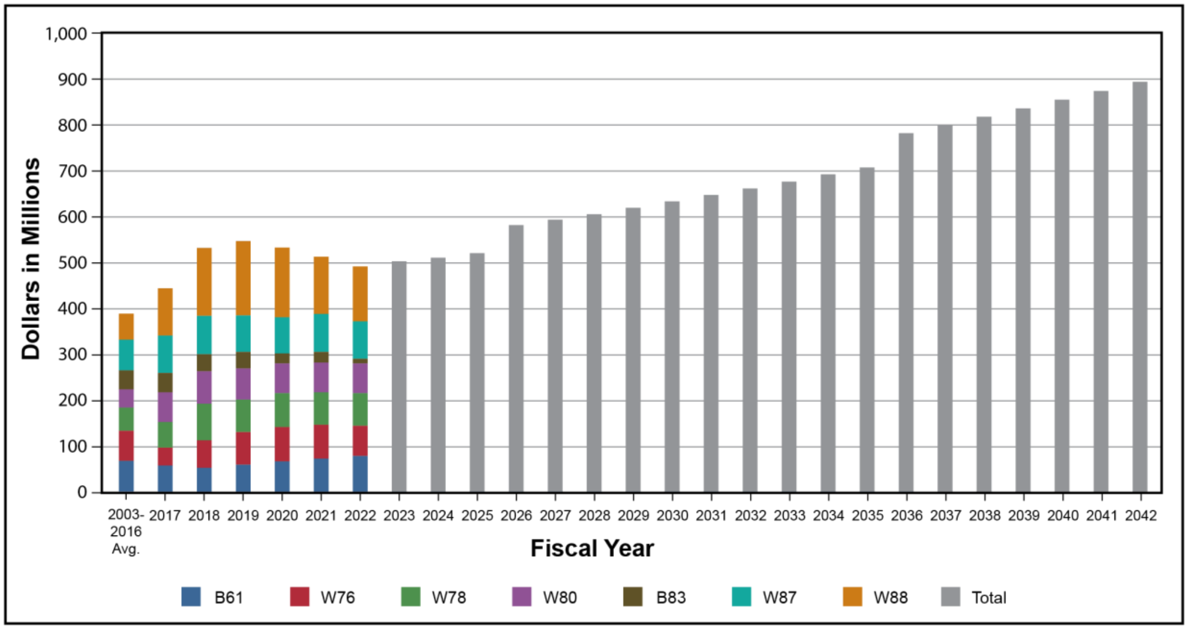


Figure 8–20. Estimate of warhead-specific sustainment costs

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

Throughout the *Phase 6.x Process,* NNSA elements perform multiple cost estimates for each LEP and major Alt. The initial LEP or major Alt independent cost estimate (ICE)[65] is generated by Defense Programs as input to the SSMP.[66] Since initial ICEs may be performed at a very early stage when the proposed LEP or Alt may be more than a decade before a feasibility study (such as the IW3), these are considered "planning" estimates and are not a bottoms-up program cost estimate, which would be used to baseline the program. These early-stage SSMP Defense Programs ICEs are important for long-term planning and budget deliberations and are notably:

- performed by an organization different than the Federal program office that will oversee the LEP when initiated;[67]
- use a different cost estimating methodology (top down) than follow-on estimates conducted by the responsible program office (bottoms up);
- occurs before a program baseline, which happens later in the *Phase 6.x Process* when the scope is better refined and more fully understood;[68] and
- updated annually and published in the SSMP.

[65] NNSA Policy Letter (NAP-28A) Paragraph 6.c. CEPE will conduct the NNSA independent cost estimate (ICE) and independent cost reviews for programs meeting the definition for a Major Atomic Energy Defense Acquisition (MAEDA) program where the total project or program cost is greater than $500 million or the total lifetime cost is greater than $1 billion (see process in Appendix 2). The appropriate Deputy Administrator or Associate Administrator may perform their own independent cost estimate as needed, such as for the annual Stockpile Stewardship and Management Plan (SSMP, or its successor). CEPE conducts NNSA ICE independent of Defense Programs ICE or planning estimates.

[66] 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.

[67] Defense Programs planning estimates are independent cost estimates performed by Defense Program's Office of Cost Policy and Analysis.

[68] Since planning estimates begin years before even early-stage feasibility studies, they assume scope generally 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 this single assumed point solution, rather than the range of *every* possible solution.

When complete, the program Weapons Design and Cost Report estimate supersedes previous estimates and typically is the basis for the initial LEP baseline.

LEPs and major Alts are also required to send SARs to Congress. Quarterly SARs begin in the first quarter following entry into Phase 6.3 and constitute the first official performance baseline (previous published estimates are considered pre-baseline). Still, Defense Programs continues to update and publish ICEs annually to inform the Deputy Administrator for Defense Programs and provide transparency in the SSMP throughout the entire lifetime of the program.

8.7.4.2 Fiscal Year 2017 through Fiscal Year 2042 Estimates

Figures 8–21 through **8–28** and **Tables 8–4** through **8–11** enumerate cost profiles for each LEP and major Alt for FY 2017 through FY 2042. Each figure and table displays the results of a top-down estimate (Defense Programs ICE) as well as the more detailed bottom-up estimate completed by the program at the end of Phase 6.2A. The Defense Programs ICE profiles include a high and low estimate range, and check estimates against published program estimates (W76-1, B61-12, and W88 Alt 370) and estimates for programs in early stages of planning (W80-4, IW1, IW2, IW3, and next B61 program). The Defense Programs ICEs are also produced independent of future budget availability and, as a result, may differ from proposed budgets, which are affected by funding constraints. The funding amounts on the bars in these figures are the values used in the FYNSP or, for the out-years, as the nominal values for LEPs as part of the DSW total in Figure 8–19.

Defense Programs ICEs are based on:

- LEP or major Alt actual program costs to date
- Historical analogous development costs (W76-1 and B61-12), as well as actual production costs (W76-1)
- A standard work breakdown structure used for every LEP and major Alt
- Comparative evaluations of LEP scope and complexity by independent program and subject matter experts
- Estimates of non-LEP line-item costs critical to the program success (namely Other Program Money and DOD costs)[69]
- Development costs distributed using standard, well-known Rayleigh profiles (based on historical major defense acquisition programs)
- Production costs distributed using a nonlinear cost growth profile similar to the W76-1 program, adjusted for relative complexity and uncertainty

These Defense Programs ICEs for planning purposes reflect complexity factors evaluated by both the program managers and teams of subject matter experts across the nuclear security enterprise. This integrated team provides technical expertise on each LEP and major Alt by evaluating the relative scope complexity between the near-complete W76-1, the B61-12, the W88 Alt 370 and future LEPs. Coupled with the scope and scheduling experience of the Federal program managers, LEP planning estimates

[69] Execution of all LEPs and major Alts are dependent on the availability of an adequately funded base of capabilities and activities funded by Weapons Activities programs other than LEPs and major Alts. The costs reflected in LEP and major Alt estimates are incremental to that base and reflect not only each program's budgeted line item but also 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.

reflect a range of cost uncertainty based on the best information available. The published cost ranges are to account for unforeseen technical issues, budget fluctuations, and even the level of component maturity available at a future date.[70]

For early-stage programs that do not have a detailed bottoms-up estimate (such as the W80-4 and the IWs), the midpoint between the high and low planning estimates is used as the nominal cost value. In cases where a program has published its SAR baseline, the figures reflect the SAR values.

Each figure also contains an associated table (Tables 8–4 through 8–11) with the high, low, and nominal (Budget Requirement or SAR Value) estimated total cost to NNSA and DOD in both constant FY 2017 and then-year dollars.[71] The total estimated cost is provided because the portions of all the LEP profiles fall outside the 25-year window for the FY 2018 SSMP. While figures are in then-year dollars, total estimated costs in current constant-year (FY 2017) dollars are also provided to assist in comparing LEPs over different timeframes. When comparing LEP costs, consideration should be given to the different quantities of warheads being refurbished. Production costs, following development and production engineering, are influenced by the total number of warheads undergoing refurbishment. The classified Annex to the SSMP provides information on production quantities.

Of importance is that early-stage LEPs and major Alts occasionally experience significant scope changes, which in turn can affect the cost estimate. This occurs primarily because each *Phase 6.x Process* contains design uncertainty, and design options are down-selected by the Nuclear Weapons Council during the process, the scope may change significantly. This occurred recently with the W80-4 program when NNSA, based on available information at the time, assumed a moderate NEP refurbishment. An extensive design options study and subsequent discussions with the Nuclear Weapons Council increased this NEP refurbishment scope substantially. Such changes may occur in the future, and NNSA will update the following year's SSMP, along with an explanation of change.

The figures and tables display both the bottom-up, program-based and the top-down, model-based (high and low) independent cost ranges, to show transparently the degree of consistency between the two estimates and the underlying methodologies. If the total estimates contained in the tables are comparable and profiles are generally similar, there is confidence that the baseline bottom-up estimate is reasonable. If total costs are similar, and there is a year-by-year profile discrepancy, there is greater confidence in the bottom-up baseline estimate because it is based on a project-specific integrated schedule, rather than on an idealized distribution based on historical projects. For this reason, NNSA does not perform or encourage additional year-by-year comparisons between the two published estimates beyond what is described above.

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

[71] The DOD costs are for weapon components for which DOD is responsible, such as arming and fuzing. While not budgeted or executed by NNSA, these estimated costs are published for transparency as they better reflect anticipated all-in costs. These estimates reflect the program's best understanding of the costs but, since they are outside NNSA, are not at the same rigor.

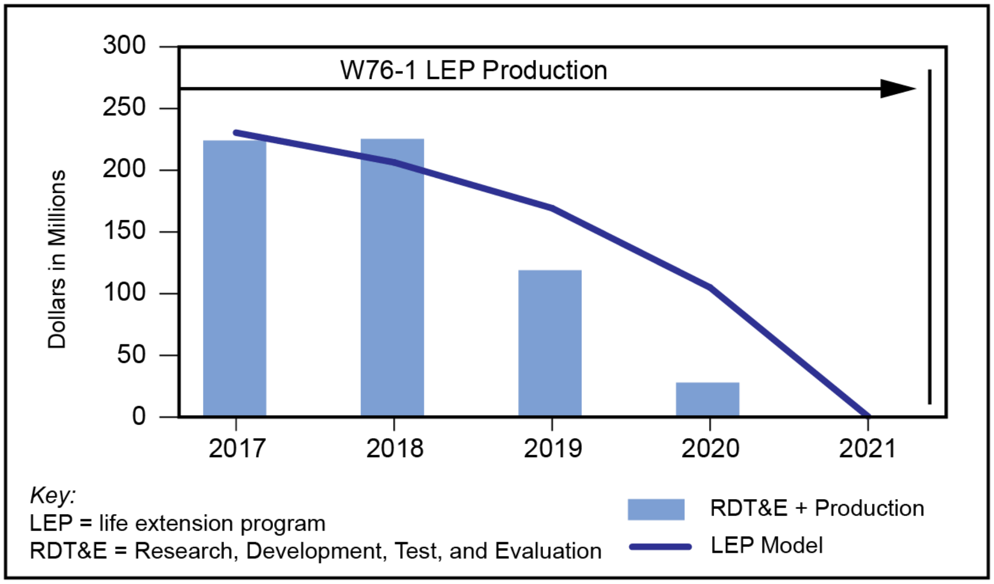


Figure 8–21. W76-1 Life Extension Program cost fiscal year 2017 to completion

Table 8–4. Total estimated cost for W76 Life Extension Program

FY 1999 – FY 2020 (Dollars in Millions)	*NNSA*		*DOD*	
	FY 2017 Dollars	*Then-Year Dollars*	*FY 2017 Dollars*	*Then-Year Dollars*
SAR Value	4,146	3,611	Not in NNSA SAR	Not in NNSA SAR

SAR = *Selected Acquisition Report*

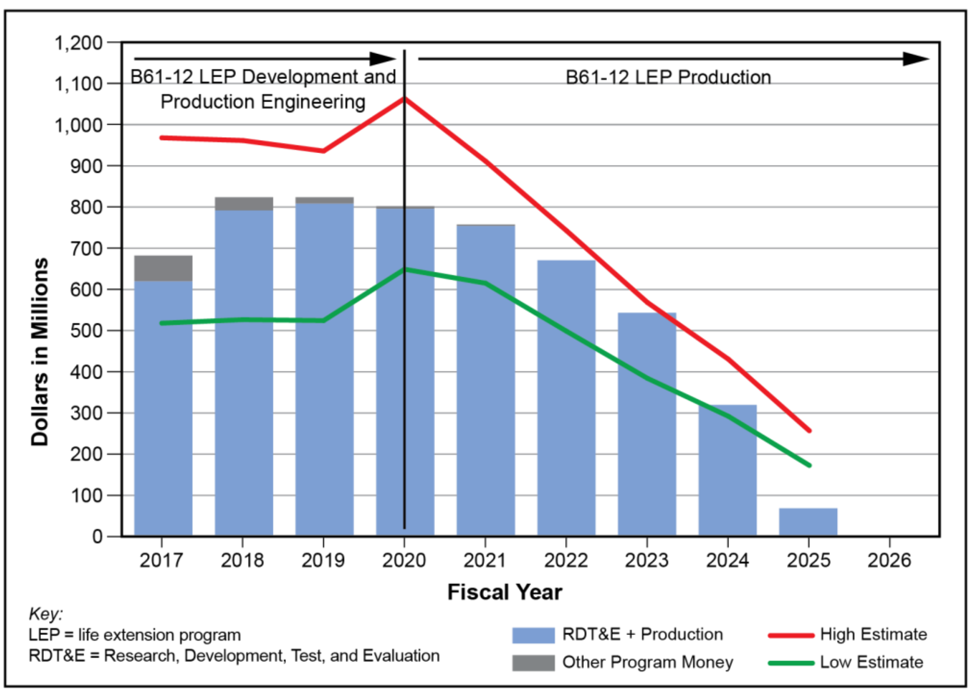


Figure 8–22. B61-12 Life Extension Program cost fiscal year 2017 to completion

The nominal values for RDT&E and production in Figure 8–22 and Table 8–5 reflect NNSA's recently completed Baseline Cost Report as the B61-12 LEP enters Phase 6.4 (Production Engineering).

Table 8–5. Total estimated cost for B61-12 Life Extension Program

FY 2009 – FY 2025 (Dollars in Millions)	*NNSA*		*DOD*	
	FY 2017 Dollars	*Then-Year Dollars*	*FY 2017 Dollars*	*Then-Year Dollars*
High Total	9,743	10,033	214	218
Low Total	7,240	7,371	117	114
SAR Total	7,346	7,605	Not in NNSA SAR	Not in NNSA SAR

SAR = *Selected Acquisition Report*

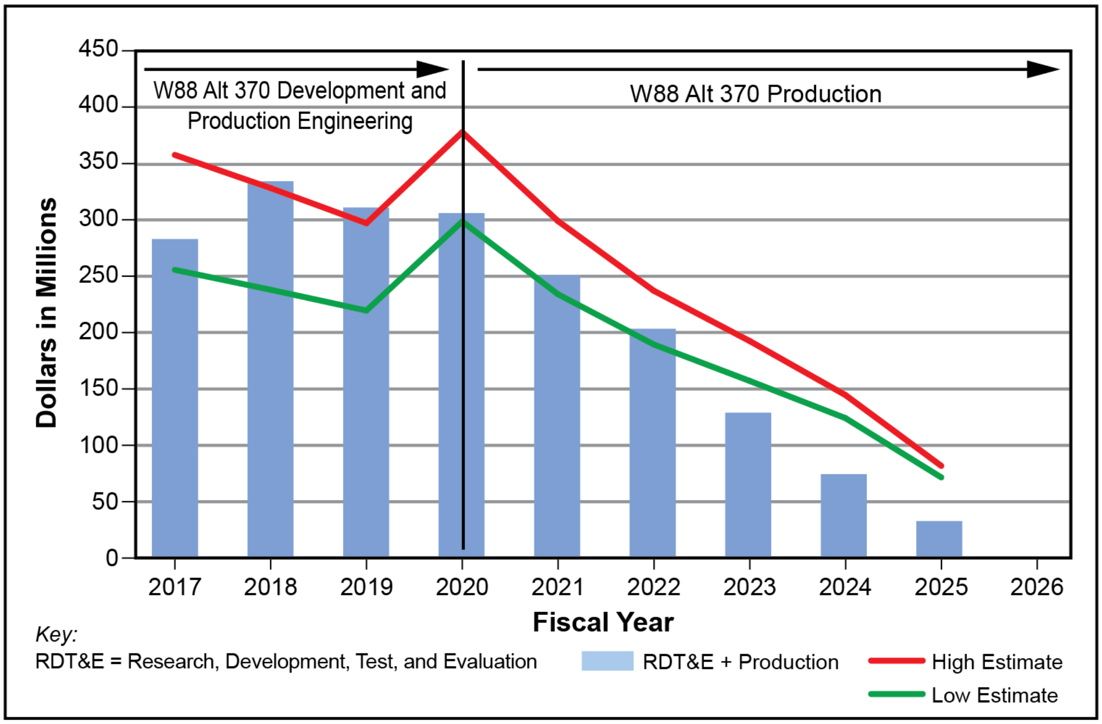


Figure 8–23. W88 Alteration 370 (with conventional high explosive refresh) cost fiscal year 2017 to completion

In November 2014, the Nuclear Weapons Council approved the addition of scope for the CHE refresh as part of the W88 Alt 370. NNSA has completed a Baseline Cost Report that includes the CHE refresh and other changes. The numbers in Figure 8–23 and Table 8–6 reflect this updated baseline.

Table 8–6. Total estimated cost for W88 Alteration 370 (with conventional high explosive refresh) Program

FY 2010 – FY 2025 (Dollars in Millions)	*NNSA*		*DOD*	
	FY 2017 Dollars	*Then-Year Dollars*	*FY 2017 Dollars*	*Then-Year Dollars*
High Total	3,038	3,150	880	900
Low Total	2,542	2,624	876	895
SAR Total	2,586	2,618	Not in NNSA SAR	Not in NNSA SAR

SAR = *Selected Acquisition Report*

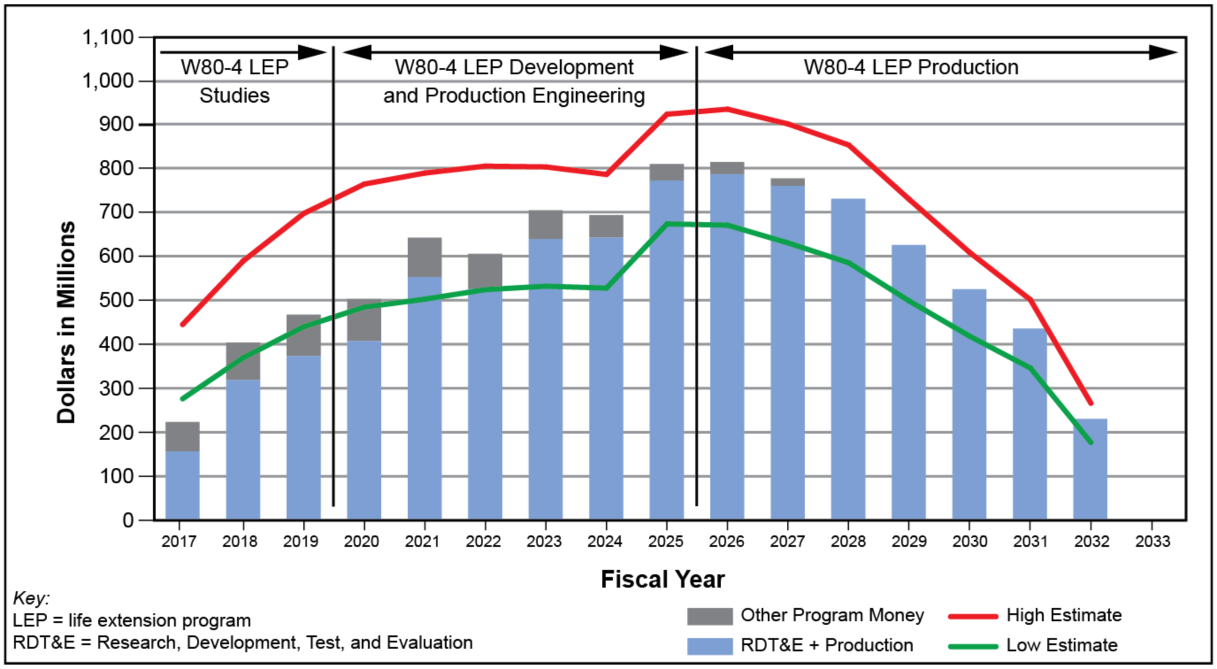


Figure 8–24. W80-4 Life Extension Program cost fiscal year 2017 to completion

Table 8–7. Total estimated cost for W80-4 Life Extension Program

FY 2015 – FY 2032 (Dollars in Millions)	*NNSA*		*DOD*	
	FY 2017 Dollars	*Then-Year Dollars*	*FY 2017 Dollars*	*Then-Year Dollars*
High Total	9,945	11,606	214	252
Low Total	6,841	7,998	56	67
Budget Estimate	NA	9,287	NA	159

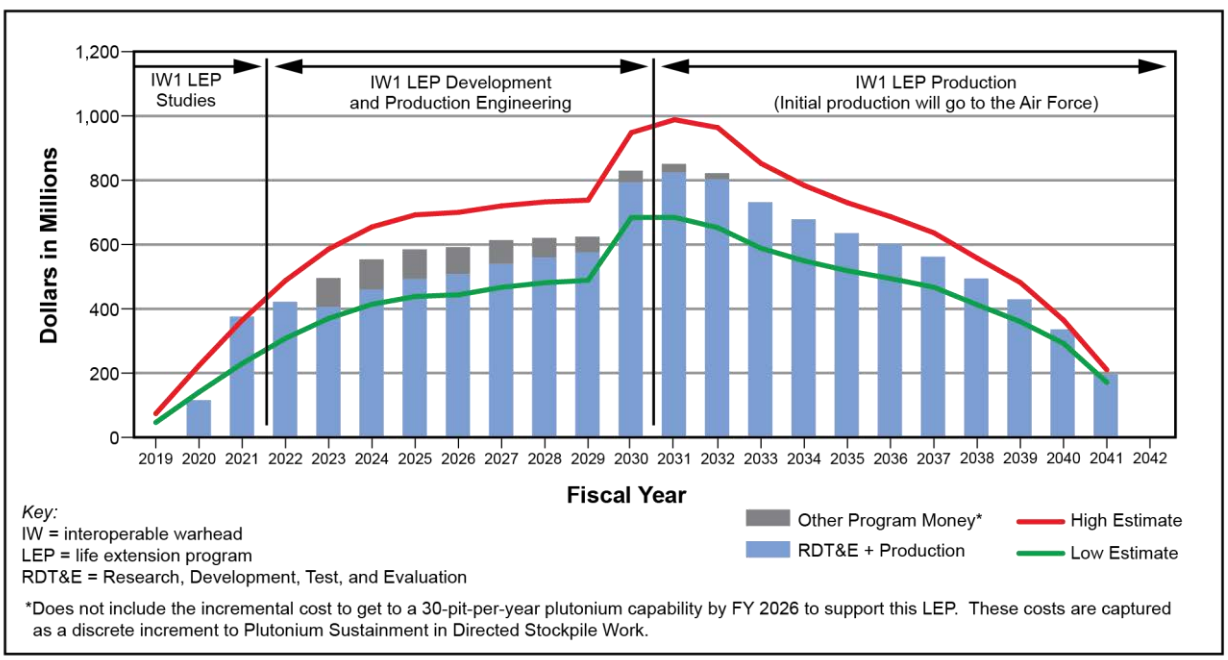


Figure 8–25. IW1 Life Extension Program cost fiscal year 2021 through fiscal year 2042

The Defense Programs independent cost estimate models assume a standard 12-year study and development period in advance of the first production unit. The IW1 LEP is slated to recommence in FY 2020, compressing that period, in part to account for the work accomplished in FY 2014 and before. To avoid an unexecutable ramp in funding from FY 2020 through FY 2021, additional funding has been added in the FY 2022 through FY 2029 period to provide a nominal funding profile with the required amount of funding in advance of the first production unit.

Table 8–8. Total estimated cost for IW1 Life Extension Program

FY 2013-2014, FY 2020-2043 (Dollars in Millions)	*NNSA*		*DOD*	
	FY 2017 Dollars	*Then-Year Dollars*	*FY 2017 Dollars*	*Then-Year Dollars*
High Total	10,641	14,233	3,254	4,385
Low Total	7,234	9,747	1,085	1,471
Budget Estimate	NA	11,990	NA	2,928

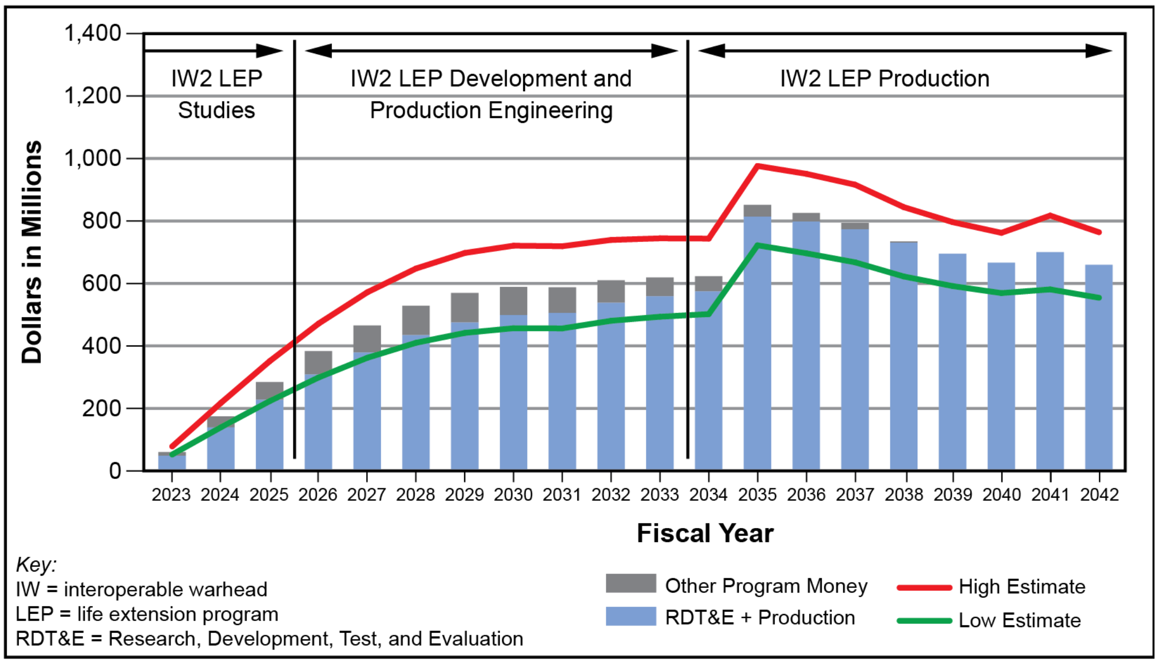


Figure 8–26. IW2 Life Extension Program cost fiscal year 2023 through fiscal year 2042

Table 8–9. Total estimated cost for IW2 Life Extension Program

FY 2023 – FY 2049 (Dollars in Millions)	*NNSA*		*DOD*	
	FY 2017 Dollars	*Then-Year Dollars*	*FY 2017 Dollars*	*Then-Year Dollars*
High Total	11,506	17,705	3,254	5,055
Low Total	8,059	12,551	1,085	1,704
Budget Estimate	NA	15,128	NA	3,379

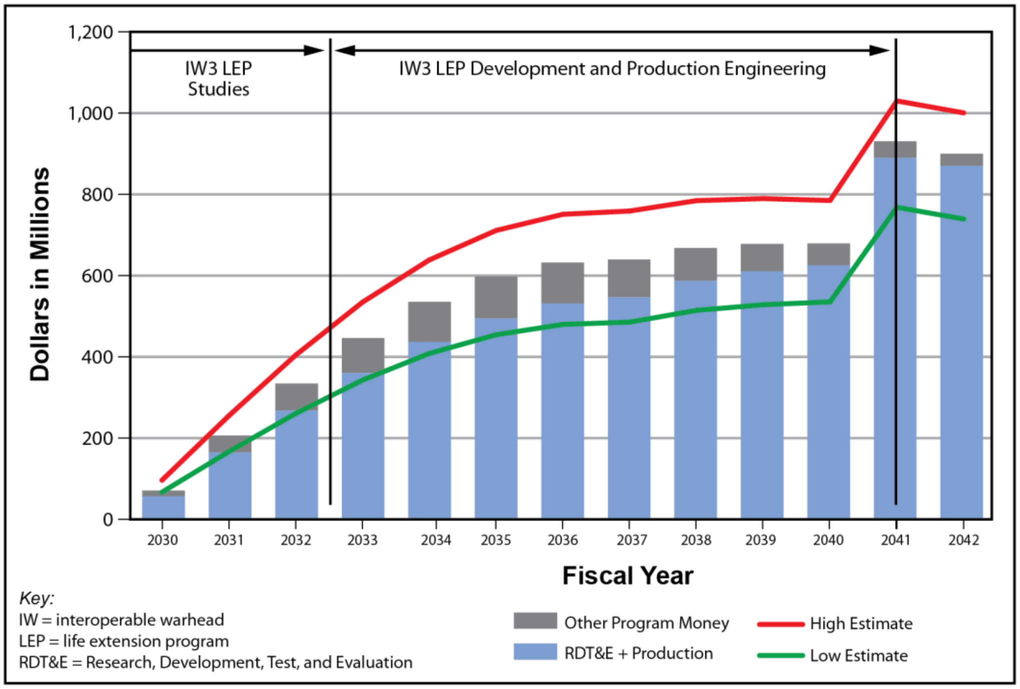


Figure 8–27. IW3 Life Extension Program cost fiscal year 2030 through fiscal year 2042

Table 8–10. Total estimated cost for IW3 Life Extension Program

FY 2030 – FY 2057 (Dollars in Millions)	NNSA		DOD	
	FY 2017 Dollars	Then-Year Dollars	FY 2017 Dollars	Then-Year Dollars
High Total	10,934	19,555	3,254	5,858
Low Total	7,844	14,232	1,085	1,980
Budget Estimate	NA	16,894	NA	3,919

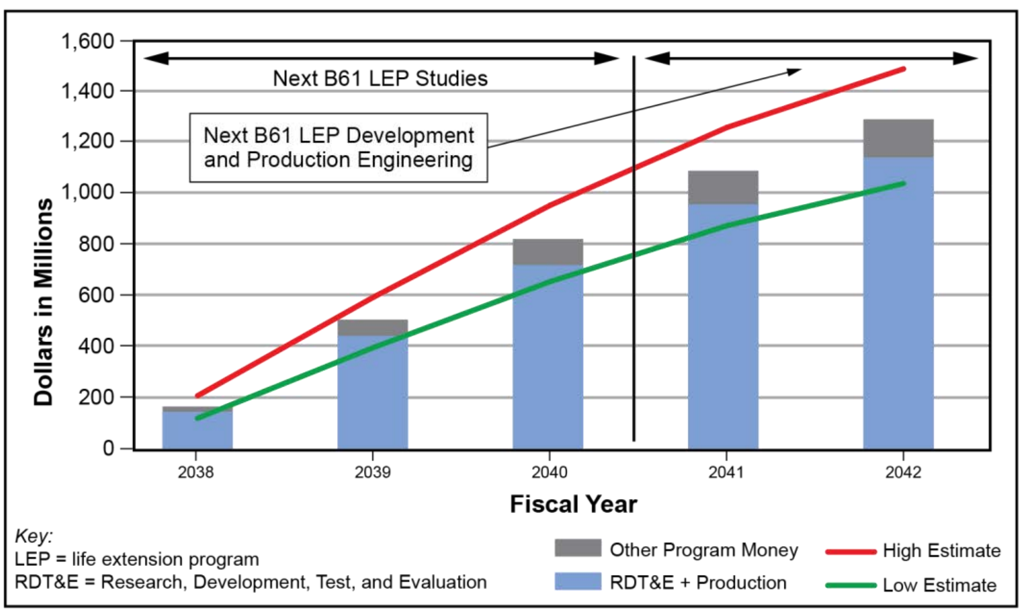


Figure 8–28. Next B61 Life Extension Program cost fiscal year 2038 through fiscal year 2042

Table 8–11. Total estimated cost for next B61 Life Extension Program

FY 2038 – FY 2057 (Dollars in Millions)	NNSA		DOD	
	FY 2017 Dollars	Then-Year Dollars	FY 2017 Dollars	Then-Year Dollars
High Total	13,373	26,251	214	421
Low Total	9,293	18,282	56	111
Budget Estimate	NA	22,267	NA	266

Figure 8–29 is a one-chart summary of the total projected nuclear weapons life extension costs from FY 2017 through FY 2042, based on the LEP schedule reflected in Chapter 2, Figure 2–5, of this FY 2018 SSMP and the nominal LEP costs shown in Figures 8–21 through 8–28.[72] The dotted line shows the total projected LEP cost reflected in the FY 2017 SSMP.

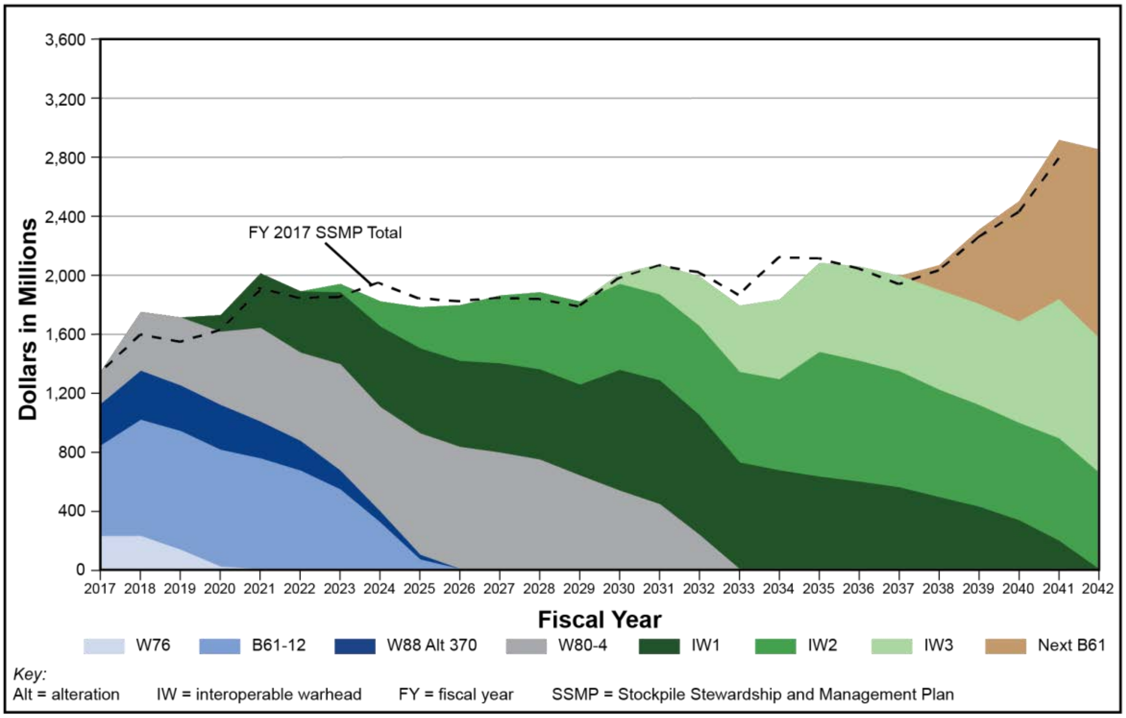


Figure 8–29. Total U.S. projected nuclear weapons life extension costs for fiscal year 2017 through fiscal year 2042 (then-year dollars)

Two adjustments to the LEP Defense Programs independent cost estimate model this year have affected the costs in Figure 8–29. Changes to the cost estimate model have also affected the high and low lines in Figures 8–23 through 8–29. The changes are:

- The W76-1 cost basis, used to estimate RDT&E, was adjusted to reflect an improved understanding of historical work scope and costs. This change led to an increase in both the high and low estimates of all the LEPs.
- Uncertainty parameters have been added to the production model, for greater fidelity and more accurate range.

[72] Nominal costs are used to allow for comparison of 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.

The principal differences between the FY 2017 and FY 2018 LEP cost estimates are:

- **SAR values.** The W76-1 LEP decreased slightly based on current execution. The increases in the B61-12 LEP and the W88 Alt 370 are primarily the result of the model changes described above.
- **LEPs that use Defense Programs independent cost estimates.** The W80-4 program cost reflects more work than anticipated for the secondary than was assumed in the FY 2017 SSMP. The IWs reflect a decrease in production costs due to a more cost-efficient proposed production schedule.

The total side-by-side differences between this year's and last year's estimates are in **Figure 8–30** below.

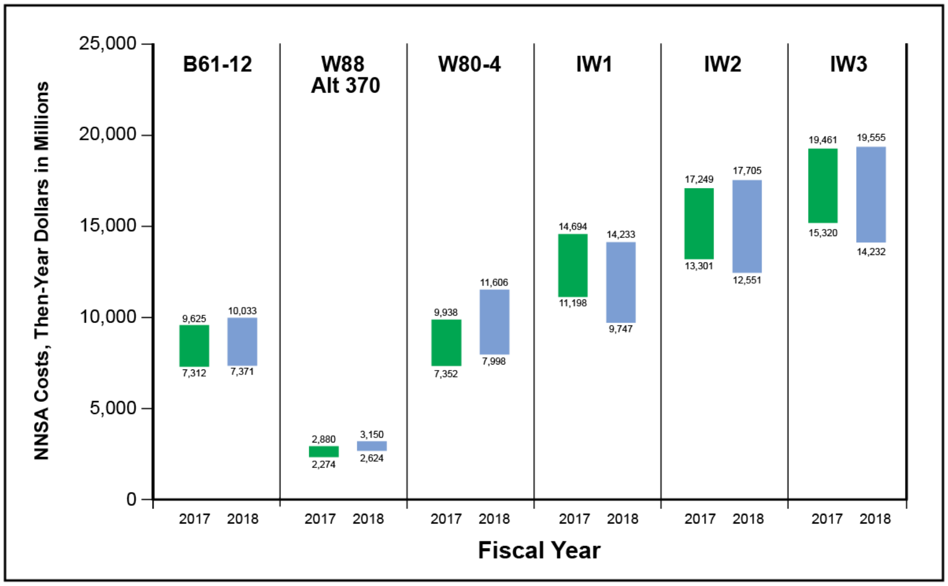


Figure 8–30. Fiscal year 2017 versus fiscal year 2018 SSMP Defense Program independent cost estimates

8.7.5 Construction Costs

The budget estimate for construction in FY 2023 and beyond, as part of the Infrastructure construction total included in Figure 8–19, is based on the set of projects in the NNSA Construction Resource Planning List, a portion of which is in **Figure 8–31**. That list was assembled by a Construction Working Group that includes representatives from all the sites and the responsible NNSA offices. Because of the preliminary planning status for most of these projects, many have been binned in one of three cost ranges. For projects estimated to cost more than $500 million, upper bounds were estimated based on the best available data. The projects in the Construction Resource Planning List that start beyond the FYNSP have been binned in the 5-year period in which each is expected to start, based on detailed estimates for completion and general priority. Those projects are listed in alphabetical order and are not in priority order within the bin. Construction funding for each of these periods is based on the total cost of the projects started (*i.e.*, achieving CD-1, Approve Alternative Selection and Cost Range) in that period, spread over the 5 years of the period.[73] Only a portion of the list is shown this year reflecting projects prioritized for funding during FY 2018 programming activities. Some projects received funding in the FY 2018 request while the others were included in the budget estimates for the periods indicated. Projects not shown were used to generate the construction budget estimates for FY 2028–FY 2042.

[73] For projects for which the construction period exceeds 5 years, the project cost was split over two 5-year periods.

Project	10-Year Project List					
	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023-2027
Uranium Processing Facility, Y-12						
Chemistry and Metallurgy Research Replacement, LANL						
Tritium Production Capability, SRS						
Technical Area 55 Reinvestment Project III, LANL						
Transuranic Liquid Waste, LANL						
U1a Complex Enhancements, NNSS						
Exascale Computing Facility Modernization						
Exascale Class Computing Cooling Equipment, LANL						
Fire Station, Y-12						
Albuquerque Complex Project						
Emergency Operations Center, Y12						
Expand Electrical Distribution System, LLNL						
Trusted Rad-Hard Microelectronics, SNL [a]	←					
Plutonium Modular Approach, LANL [a]	←					
Lithium Production Capability, Y-12						
138 kilovolt Power Transmission, NNSS						
Emergency Operations Center, LLNL		→				
Emergency Operations and Response Center, SNL			→			
Domestic Uranium Enrichment Capability						
Electrical Transmission/Distribution Capacity Upgrade, LANL						
Energetic Materials Characterization, LANL						
Fire Station Replacement for Older 1 and 5, LANL						
High Explosive Formulation, Pantex						
High Explosive Science and Engineering, Pantex						
Los Alamos Canyon Bridge Upgrade, LANL						
MaRIE (Science Tool), LANL						
Materials Staging, Pantex						
Production Support Fire Suppression Lead-ins, Pantex						
Seismic Risk Mitigation Project, LLNL						
Site 300 Nuclear Security Infrastructure Stabilization						
Technical Area IV District Chilled Water Loop, SNL						
Underground Electrical Distribution Replacement, Pantex						
Utility Distribution System, LLNL						
Weapons Engineering Facility, SNL						

Key:
- Total Project Cost $10M – $100M
- Total Project Cost $100M – $500M
- Total Project Cost > $500M
- → Project Delayed from SSMP 2017
- ← Project Accelerated from SSMP 2017
- New Projects in Red Type

LANL = Los Alamos National Laboratory
LLNL = Lawrence Livermore National Laboratory
MaRIE = Matter-Radiation Interactions in Extreme
NNSS = Nevada National Security Site
Pantex = Pantex Plant
SNL = Sandia National Laboratories
SRS = Savannah River Site
Y-12 = Y-12 National Security Complex

[a] Estimates for the FY 2019–FY 2022 base budget topline for NNSA do not reflect a policy judgment. Instead, the Administration will make a policy judgment on amounts for NNSA's FY 2019–FY 2023 topline in the FY 2019 Budget, in accordance with the National Security Strategy and Nuclear Posture Review currently under development. As a result of this, planning estimates in Figure 8–31 should be considered notional and may not exactly reflect the FY 2018 President's Budget Request.

Figure 8–31. NNSA Construction Resource Planning List

Table 8–12 contains the low, high, and midpoint total costs for executing all the projects on the Construction Resource Planning List scheduled for FY 2023 and beyond. Uncertainty exists in these construction cost estimates because of the immaturity of planning for these projects. Most have not achieved CD-0 (Approve Mission Need) under DOE Order 413.3 nor have AoA studies been conducted, which could result in decisions to pursue nonconstruction solutions to the mission need or significant changes to the construction cost estimates. The majority of the reduction in the midpoint cost is from the results of AoAs conducted for the Trusted Microsystems Capability and the Lithium Production Capability, due to the selection of less costly options than the original planning options. The significant increase in the high-range cost is a new estimate for a domestic uranium enrichment capability.

Table 8–12. Total cost of construction for fiscal years 2023–2042

Then-Year Dollars in Millions	*Low*	*High*	*Midpoint*
Total Construction Resource Planning List cost	8,639	39,329 [a]	13,960

[a] The high estimate for construction includes provisional funding for a $15 billion domestic uranium enrichment capability.

Chapter 9 Conclusion

This DOE/NNSA FY 2018 SSMP, together with the classified Annex, is a key planning document for the nuclear security enterprise. The SSMP represents the 25-year strategic program of record that captures the plans developed across numerous NNSA programs and organizations to maintain and modernize the scientific tools, capabilities, and infrastructure to ensure mission success. The NNSA Federal workforce prepares each SSMP in collaboration with its eight M&O partners. The plan in the FY 2018 SSMP is also coordinated with DOD through the Nuclear Weapons Council and is fully consistent with the Nuclear Weapons Council's Strategic Plan for 2017–2042. As with previous SSMPs, a new version is published each year as NNSA updates its strategic plans in response to new demands and challenges related to stewardship and management of the stockpile. The FY 2018 SSMP builds on previous SSMPs and updates the costs and resources required for execution of the program. Changes to the program based on mission needs, the strategic environment, or new guidance will require adjustments.

NNSA maintained the existing nuclear weapons stockpile, continued progress on an unprecedented number of LEPs, and advanced the science and engineering capabilities that underpin the Nation's Stockpile Stewardship Program.

For example, NNSA began addressing long-term infrastructure challenges and broke ground on construction projects that will provide high-quality workspace for its workforce and will serve the nuclear security enterprise for decades to come. In addition, the Trinity high-performance computing system was installed at LANL. Trinity is one of the most advanced computers in the world, with initially at least seven times better performance than LANL's former supercomputer (Cielo). When fully built out, it will have a speed of 41 petaFLOPS, enabling robust modeling and simulation capabilities.

Although many of the warheads in America's nuclear stockpile have exceeded the original design life, the Stockpile Stewardship Program continues to maintain the safety, security, and effectiveness of the nuclear weapons stockpile. This effort harnesses leading-edge science, engineering, high-performance computing, and advanced manufacturing to enable the Secretary of Energy and Secretary of Defense to annually certify 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. The unique, state-of-the-art capabilities for RDT&E and production enabled this critical effort. The scope, budgets, and schedules of the LEPs, infrastructure modernization, and the DOD's nuclear delivery systems have been fully integrated through coordinated and tightly coupled efforts.

To facilitate future scientific and engineering excellence at its national security laboratories and nuclear weapons production facilities, NNSA has expanded university collaborations and science, technology, engineering, and mathematics educational outreach in applied and technical research supporting technology development. In addition, NNSA has expanded site-directed R&D, as well as direct mission-specific activities by its Federal, laboratory, and contractor partners.

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

- Advance the innovative experimental platforms, diagnostic equipment, and computational capabilities necessary 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.
- Deliver the first production unit of the W88 Alt 370 (with refresh of the CHE) by FY 2020.
- Achieve a first production unit of the W80-4 by FY 2025.
- Produce not less than 10 War Reserve pits in 2024, not less than 20 War Reserve pits in 2025, and not less than 30 War Reserve pits in 2026.
- Create a modern, responsive nuclear infrastructure that includes the capability and capacity to produce, at a minimum, 50 to 80 pits per year by 2030.
- Cease enriched uranium programmatic operations in Building 9212 at Y-12 and deliver the Uranium Processing Facility for no more than $6.5 billion by 2025.
- Implement the 3+2 Strategy for a smaller stockpile with upgraded safety and security and interoperable NEPs (for missile warheads).

The program of record will be adjusted as necessary to ensure that the underlying plan enables the U.S. nuclear deterrent to be modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st-century threats and address the priorities established in the upcoming *Nuclear Posture Review*. To achieve these objectives, the nuclear security enterprise will require major recapitalization. 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.

NNSA has confidence in its ability to execute the program described in the FY 2018 SSMP. The LEPs remain on schedule and, once completed, will ensure an extended service life and improve the safety and effectiveness of the stockpile. With Congress' support, the safety, security, effectiveness, and reliability of the current stockpile can be maintained while ensuring the nuclear security enterprise is postured 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 2018 Stockpile Stewardship and Management Plan* (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 2018 SSMP.

A.2 Ongoing Requirements

50 U.S. Code § 2521	*FY 2018 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
(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
(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
(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
(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

50 U.S. Code § 2521	***FY 2018 Response***
(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, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 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
(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.	*Unclassified* Chapter 3, Sections 3.2.2, 3.7.1; Appendix C
(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
(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))).	*Unclassified* Appendix C
(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
(e) SUBMISSION TO CONGRESS.—The Administrator shall submit the plan required by subsection (a) to the congressional defense committees 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*
§ 2522. Report on 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
(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*
§ 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*
(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*
(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*
(3) The summaries and reports required by this subsection shall be submitted in unclassified form, but may include a classified annex.	
(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*
(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*
(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*
(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*
(5)A summary of the status, plans, and budgets for carrying out the stockpile responsiveness program under section 2538b of this title.	*N/A*
(6) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*N/A*
(7) Such other information as the Administrator considers appropriate.	*N/A*

50 U.S. Code § 2523	*FY 2018 Response*
(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, 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*
(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, 8.7.2, 8.7.3, 8.7.4 *Classified Annex*
(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, 2.3.3, 2.3.4, 2.3.5, 2.3.6; Chapter 8, Sections 8.2.4, 8.7.4 *Classified Annex*
(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
(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
(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, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 3.5.7, 3.5.8, 3.5.9, 3.5.10 *Classified Annex*
(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
(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
(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, 2.3.2, 2.3.3, 2.3.4, 2.3.5, 2.3.6; Chapter 7; Appendix E

50 U.S. Code § 2523	*FY 2018 Response*
(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
(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, 8.3.2, 8.3.3, 8.7.4
(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
(M) the status, plans, activities, budgets, and schedules for carrying out the stockpile responsiveness program under section 2538b of this title; and	*Unclassified* Chapter 1, Section 1.7.3; Chapter 3, Sections 3.1, 3.2.3; Chapter 8, Section 8.1
(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.	*Unclassified* Chapter 8, Section 8.1
(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
(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
(C) the criteria developed under section 2522(a) of this title (including any updates to such criteria).	
(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, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 3.5.7, 3.5.8, 3.5.9, 3.5.10 *Classified Annex*
(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, 3.2.2, 3.2.3, 3.2.4, 3.7, 3.7.1, 3.8
(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, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 3.5.7, 3.5.8, 3.5.9, 3.5.10 *Classified Annex*
(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

50 U.S. Code § 2523	*FY 2018 Response*
(i) the number of scientists, engineers, and technicians, by discipline, required to maintain such competencies; and	*Unclassified* Chapter 7, Section 7.2; Appendix E
(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
(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
(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; and	*Unclassified* Chapter 4, Sections 4.2.4, 4.3.4
(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.	*Unclassified* Chapter 8, Sections 8.5, 8.5.1, 8.7.1, 8.7.2, 8.7.4
(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
(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
(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
(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
(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
(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*
(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*
(C) An assessment of manufacturing and handling technology for plutonium and plutonium components.	*Unclassified* Chapter 2, Section 2.4.1
(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*

50 U.S. Code § 2523	*FY 2018 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*
(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, 8.3.2, 8.3.3, 8.3.4
(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, 8.3.2, 8.3.3, 8.3.4
(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
(7) Identification of any modifications or updates to the plan since the previous summary or detailed report was submitted under subsection (b).	*Unclassified* Chapter 8
(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*

50 U.S. Code § 2523	*FY 2018 Response*
(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*
§ 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
(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
(3) To achieve reductions in the future size of the nuclear weapons stockpile.	*Unclassified* Chapter 2, Sections 2.2, 2.3, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.3.5, 2.3.6
(4) To reduce the risk of an accidental detonation of an element of the stockpile.	*Unclassified* Chapter 2, Sections 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.4.6; Chapter 3, Sections 3.7.1, 3.7.2
(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
(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*
§2538a. Plutonium pit production capacity (a) Requirement (b) 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
(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*
(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*

50 U.S. Code § 2538b	*FY 2018 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
(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, 3.4.1, 3.4.4, 3.2.3; Chapter 8, Section 8.3.2
(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.	*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
(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. (Pub. L. 107–314, div. D, title XLII, § 4220, as added Pub. L. 114–92, div. C, title XXXI, § 3112(b)(1), Nov. 25, 2015, 129 Stat. 1189.)	

A.3 Other Requirements

National Defense Authorization Act for Fiscal Year 2016, H.R. 1735, Section 3112	FY 2018 Response
Sec. 3112. STOCKPILE RESPONSIVENESS PROGRAM (a) SENSE OF CONGRESS.—It is the sense of Congress that—	
(1) a modern and responsive nuclear weapons infrastructure is only one component of a nuclear posture that is agile, flexible, and responsive to change; and (2) to ensure the nuclear deterrent of the United States remains safe, secure, reliable, credible, and responsive, the United States must continually exercise all capabilities required to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons.	
(b) ESTABLISHMENT OF PROGRAM.—	
(1) IN GENERAL.—Subtitle A of title XLII of the Atomic Energy Defense Act (50 U.S.C. 2521 et seq.) is amended by adding at the end the following new section:	
Sec. 4220. 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.	
(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 4201 and the stockpile management program under section 4204, 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
(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.	*Unclassified* Chapter 3
(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.	*Unclassified* Chapter 7, Sections 7.5.4, 7.6.3
(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.	*Unclassified* Chapter 2, Section 2.2.2; Chapter 3
(4) Shorten design, certification, and manufacturing cycles and timelines to minimize the amount of time and costs leading to an engineering prototype and production.	*Unclassified* Chapter 2, Section 2.5.3
(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.	*Unclassified* Chapter 1, Sections 1.1, 1.5, 1.7.3; Chapter 3, Sections 3.1, 3.2.3, 3.4.1, 3.4.4
(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.''	

Appendix B
Weapons Activities Capabilities

This table is a representation of capabilities that delineate critical functions of Weapons Activities in the nuclear security enterprise and provides definitions to support Figure 1–3 in Chapter 1. The list is intended to represent the breadth of capabilities used to carry out all phases of the nuclear weapons life cycle process. These capabilities should not be viewed in isolation as each capability is complementary and supports multiple Weapons Activities' mission elements.

Capability	***Category***	***Definition***
Nuclear Physics and Radiochemistry	Research & Development	Nuclear physics is the study of atomic nuclei and their interactions, especially fission and fusion. Knowledge of the probabilities of interactions of neutrons with fissile material and of interactions of light nuclei that can result in fusion is necessary. Radiochemistry is the chemistry of radioactive materials. This capability is important in evaluating data from legacy underground tests as well as from experiments on facilities such as the National Ignition Facility (NIF), Omega, and Z Pulsed Power Facility (Z).
Atomic and Plasma Physics	Research & Development	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.
Chemistry	Research & Development	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 reactivities change with time, must be understood to ensure quality, performance, and safety of the stockpile.
Materials Science and Engineering	Research & Development	Materials science, in the context of stockpile stewardship, is the study of how materials in a nuclear weapon behave under extreme conditions of temperature and pressure and under more moderate conditions. Materials engineering involves the evaluation and selection of materials for performance in these environments. Strength, aging, compatibility, viability, and damage mechanisms are among the material characteristics to be understood. 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).
High Explosives Science and Engineering	Research & Development	High explosives science and engineering is the study of how energetic materials operate (*i.e.*, how they detonate and how the explosive shock wave propagates though a material) and of 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.

Capability	***Category***	***Definition***
High Energy Density Physics	Research & Development	High energy density physics is the study of matter and radiation under extreme conditions such as those in an operating nuclear weapon or in experiments on facilities such as NIF, Omega, and Z that provide fundamental data for validating computational models.
Laser, Pulsed Power, and Accelerator Technology	Research & Development	Designing and deploying new technologies associated with lasers, pulsed power devices, and accelerators. These enhanced technologies provide data at pressure, temperature, and radiation conditions closer to those present in a nuclear weapon while ensuring safe, reliable, and efficient operation of the lasers, pulsed power devices, and accelerators. Laser and pulsed power devices are capable of accumulating energy over a long period of time and releasing it very quickly using light and electricity, respectively. Accelerators are machines that use electromagnetic fields to accelerate charged particles to very high speeds. These charged particles can be used to produce high-energy x-rays (which can be used to take radiographs) or to produce high-energy neutrons (which can be used in nuclear physics investigations).
Simulation Codes and Models	Research & Development	Developing and using computer programs (*i.e.*, codes) that simulate or model physical behavior. NNSA codes operate on computers ranging in capacity from desktop machines to the world's largest high performance supercomputers.
High Performance Computing	Research & Development	Developing, deploying, and operating computers (including the requisite software, hardware, and facilities) of sufficient computing power to achieve the resolution, dimensionality, and complexity required of simulation codes to model the performance of weapon systems, components, and relevant experiments.
Hydrodynamic and Subcritical Experiments	Research & Development	A hydrodynamic experiment is performed to understand the dynamics of an implosion. A subcritical experiment is an experiment that contains special nuclear material that never achieves a critical configuration and does not create nuclear yield. Both hydrodynamic experiments and subcritical experiments provide data essential to predicting the performance of nuclear weapons and validating the multi-physics design codes and the models embedded in these design codes.
Advanced Experimental Diagnostics and Sensors	Research & Development	Developing, deploying, using, and analyzing advanced diagnostics and sensors. Diagnostics are used in experiments and tests to measure what is occurring. Standard diagnostics have limitations that provide less data than what is required to fully capture the behavior of many of these tests and experiments; continued development is targeted at remediating 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 or neutrons) to view the internal structure of an object that is opaque to visible light. Static radiography (*i.e.*, taking a radiograph 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 is used to take multiple images of an object as it is imploding or expanding.

Capability	*Category*	*Definition*
Weapons Physics Design and Analysis	Design	Design and analysis of the nuclear weapon physics package (known as the nuclear explosive package, or NEP) 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.
Weapons Engineering Design, Analysis, and Integration	Design	Elements of design 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 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 DOD systems, which is collectively known as systems integration.
Environmental Effects Analysis, Testing, and Engineering Sciences	Design and Research & Development	Analyzing and testing effects of different environments on weapon systems and components using an array of engineering science test equipment, tools, and techniques. Examples of environments (normal and abnormal) include shock, vibration, radiation, acceleration, thermal, electrostatic, and pressure. Examples of engineering sciences that support this analysis include thermal and fluid sciences, structural mechanics, dynamics, and aerodynamics.
Weapons surety Design, Analysis, Integration, and Manufacturing	Design and Manufacturing	Developing, analyzing, integrating, and manufacturing of safety and use control systems to prevent accidental nuclear detonation and unauthorized use of nuclear weapons is necessary to ensure a safe and secure stockpile. This knowledge, infrastructure, and equipment require strict classification control and secure facilities and equipment.
Radiation-Hardened Microelectronics Design and Manufacturing	Design and Manufacturing	Hostile environments require the design, production, and testing of radiation-hardened microelectronics that will function. This ability requires a secure, trusted supply chain, including quality control of the materials used in the process and the products.
Weapon Component and System Prototyping	Design, Manufacturing, and Surveillance	Development, qualification, and manufacture of high-fidelity, full-scale prototype weapon components and systems reduce the cost and life-cycle time required to develop new designs and technologies prior to producing components. This capability includes the ability to design, manufacture, and employ mockups with sensors to support laboratory and flight tests that will provide evidence that components can function with DOD delivery systems in realistic environments.
Handling, Packaging, Processing, and Manufacturing of Energetic and Hazardous Material	Manufacturing	Hazardous and energetic materials require safe and secure handling, packaging, processing, manufacture, and inspection. Hazardous materials (*e.g.*, lithium, beryllium, or 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.

Capability	***Category***	***Definition***
Handling, Packaging, Processing, and Manufacturing of Special Nuclear Material	Manufacturing	Special conduct of operations, physical security protection, facilities, and equipment are required to handle, package, process, manufacture, and inspect components that contain special nuclear material (*e.g.*, plutonium or enriched uranium).
Tritium Production, Handling, and Processing	Manufacturing	Tritium has a 12-year half-life and must be periodically replenished in gas transfer systems. The creation, handling, and processing of tritium includes the recovery, extraction, refinement, storage, filling, and inspection of gas transfer systems.
Metal and Organic Material Fabrication, Processing, and Manufacturing	Manufacturing	Although many parts are supplied by U.S. industries, specialized components and materials must be produced within the nuclear security enterprise. This production requires the enterprise to synthesize organic materials and process, manufacture, and inspect metallic and organic products, using knowledge of material behavior, compatibility, and aging.
Non-Nuclear Weapon Component Manufacturing and Assembly	Manufacturing	Many non-nuclear weapon components require special manufacturing, assembly, and inspection protocols (*e.g.*, microelectronics; gas transfer systems; arming, fuzing, and firing assemblies; environmental sensing devices; radars; neutron generators; and batteries).
Weapon Component and Material Process Development	Manufacturing	Process development involves small-lot production, precise controls, and a deep understanding of the hazards of working with special nuclear material and other exotic materials. Component process development is also required whenever process changes are made to reduce cost and production time.
Weapon System Assembly and Disassembly	Manufacturing	Weapons system assembly involves the final assembly of the nuclear and non-nuclear components. This assembly requires special conduct of operations, equipment, and facilities. Disassembly, inspection, and storage or disposal of the components of a nuclear weapon require similar special conduct of operations, quality control, equipment, and facilities.
Advanced Manufacturing	Manufacturing	Advanced manufacturing uses innovative techniques from industry, academia, or internal research and development to reduce costs and production time, improve safety, and improve waste streams. Examples include additive or digital manufacturing, microreactors, microwave casting, and electrorefining.
Testing Equipment Design and Fabrication	Design, Manufacturing and Surveillance	Design and fabrication of special test equipment to simulate environmental and functional conditions is necessary to ensure that products meet specifications. Data from test equipment provide evidence for qualification, certification, reliability, surety, and surveillance.
Weapon Component and System Surveillance and Assessment	Surveillance	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.
Secure Transportation	Security	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.

Appendix C
Advanced Simulation and Computing

The predictive capabilities of the Advanced Simulation and Computing (ASC) Program's integrated design codes (IDCs) are the products of scientific and engineering advances, and increases in computing capabilities. Current high performance computing (HPC) capabilities, while sufficient to support the NNSA national security mission today, must be improved to support future demands. Predictive capabilities (as opposed to confirmative capabilities) provide agility, assurance, credibility, and responsiveness, all of which must be developed and improved to maintain and increase confidence in enduring stockpile weapon performance.

The aging of weapon components, the development of advanced and additive manufacturing techniques, and the continuing of life extension programs and major alterations are moving the Nation's nuclear weapons further from original design configurations and legacy underground nuclear explosive test data. The capability of IDCs to predict weapon performance is currently limited by approximations in the physics models, the inability to resolve critical geometric and physics features at very small-length scales, and the need to quantify margins and uncertainties more accurately. To overcome these challenges, NNSA must be an integral partner to deploy more powerful supercomputers, including developing and implementing exascale computing research activities, in the next decade.

Computer hardware and computer architectures are evolving rapidly in response to market factors created by mobile computing devices and other consumer electronics. Industry is not focused on HPC needed for the NNSA mission. (Industries, particularly the financial industry, require more raw networking and input/output speed, while NNSA demands more raw serial processor speed.) The computer industry has responded to the need for performance by incorporating more processing cores on a single chip, resulting in multi-core chips, with many cores running in parallel to complete a single computation. Historically, slower advances in memory devices, relative to the speedup in computing, have led to off-the-shelf memory subsystems and have become the primary factor in cost and power consumption.

High Performance Computing

Trinity is the first Advanced Technology System (ATS) delivered by Cray and sited at LANL. Phase 1 uses Intel Haswell processors, and Phase 2 uses Intel Knights Landing processors. The two partitions together will provide 41 petaFLOPS of performance. Trinity ushers in several new technologies such as DataWarp burst buffer and advanced power management functionality.

The second ATS will be sited at LLNL in early FY 2018. NNSA continues to participate actively in the CORAL (Collaboration of Oak Ridge, Argonne, and Livermore) effort, which will be a significant step on the path to exascale computing. Via CORAL, Intel and Cray will deliver a system to Argonne National Laboratory, and the IBM-NVIDIA-Mellanox partnership will deliver a separate system to both Oak Ridge National Laboratory and LLNL.

The Advanced Simulation and Computing's third and fourth ATSs are planned for early 2020s delivery to LANL and LLNL, respectively. The ATS 3 Request for Proposal was released in the first quarter of FY 2017 with contract award scheduled for late 2017.

The challenges of next-generation computing were articulated in Presidential Executive Order 13702, which established the National Strategic Computing Initiative (NSCI). DOE, DOD, and the National Science Foundation are the three NSCI lead agencies participating in this initiative.[1] Per the Executive Order that created the NSCI, "the DOE Office of Science and DOE/NNSA will execute a joint program focused on advanced simulation through a capable exascale computing program emphasizing sustained performance on relevant applications and analytic computing to support their missions." The mandated DOE joint exascale computing program was officially kicked off as the Exascale Computing Initiative (ECI) in 2016, involving the DOE/NNSA and Office of Science's HPC and applied programs. As a subset of ECI, the Exascale Computing Project (ECP) was established between NNSA and the Office of Science's Advanced Scientific Computing Research (ASCR) to collaborate more closely accelerating the development of an exascale computing ecosystem.

C.1 Mission Need: Critical Stockpile Stewardship Applications

Deployment of exascale-class HPC systems will improve specific simulations applicable to stockpile stewardship. Key needs in stockpile stewardship for exascale-class computing include assessment of and performance in hostile and abnormal environments, aging effects and significant finding investigations, and confidence in nuclear deterrence.

Hostile and Abnormal Environments. Nuclear weapons system requirements are rapidly changing to address emerging threat environments. Analyzing these threats can require modeling high-frequency coupling effects in weapon-sized (and aircraft-sized) systems. For a problem of this type, a simulation ensemble with a data size of roughly 100 petabytes is required with a runtime of approximately 14,000 hours on a petascale system. An exascale system has the potential to reduce the runtime for such a simulation to approximately 1 day.

Understanding and mitigating the effects of abnormal environments (that is, accidents and security threat scenarios) related to nuclear weapon systems is one of the major mission challenges for the three national security laboratories. This complex problem involves multiple physics and disparate time and length scales and requires exascale-class computing.

Aging Effects and Significant Finding Investigations. Exascale-class systems capability will allow NNSA to be more responsive in resolving significant findings. LEPs are often designed using a combination of reused, remanufactured, and replacement materials. Designers and engineers must ensure that the weapon performance will remain robust and that performance margins and uncertainties can be well characterized. Moreover, the design and qualification of non-nuclear components must also keep pace with developments in modern materials, electronics, and energetic sources. Accordingly, improved predictive capabilities using exascale-class computing systems would support qualification of non-nuclear components and systems in stockpile-to-target sequences and abnormal environments.

C.2 Ongoing Investments in Exascale Computing Within NNSA

For more than six decades, NNSA invested in research and development (R&D) to develop and use supercomputers for large-scale simulation capabilities in support of nuclear weapons stockpile work. The modeling and simulation goals of the nuclear security enterprise have made use of the maximum computing power and capacity of the largest supercomputers since the inception of the HPC industry.

[1] The focus of DOD is on data analytics, and the focus of the National Science Foundation is on scientific discovery and development of the workforce.

Current HPC systems at DOE's national laboratories can perform in the tens of petaFLOPS range and are expected to be capable of hundreds of petaFLOPS before 2020.[2] The ASC Program is continuing to build on the foundation of previous and existing HPC efforts, with a focus on exascale through tri-laboratory co-design activities, formal vendor partnerships, and targeted application research.

NNSA, through the ASC effort, is investing in products and approaches directly related to anticipated, disruptive changes in the HPC ecosystem. Activities include initiating partnerships with multiple HPC vendors *via* the EPC PathForward project, creating proxy applications, procuring advanced architecture test beds, developing abstraction layers, and improving performance analysis capabilities. These activities have provided a wealth of experience and lessons learned and have delivered a wide variety of software development tools and libraries upon which many applications now rely. This work has formed a solid foundation for ASC's IDCs and, in some cases, have been adopted by other DOE national laboratories, Government agencies, universities, and industry as building blocks for other scientific software packages. The close cooperation with HPC vendors has also led to significant advances in HPC software and hardware technology.

C.3 Challenges

Specifically, providing advanced computing technology for the nuclear security mission and exascale computing capabilities within the next decade while maintaining and modifying the IDCs requires:

- developing computing systems that provide at least a 25-fold increase in sustained application code performance over the currently largest ASC supercomputer, Trinity, which is a 41-petaFLOPS system;
- limiting system power consumption to no more than 30 megawatts; and
- addressing code performance of next-generation hardware, which is anticipated to incorporate multi-core, heterogeneous computing architectures.

To partially address these challenges, ASC established the Advanced Technology Development and Mitigation (ATDM) subprogram in mid 2014 to address programmability and usability challenges posed by the anticipated advanced computer architectures. ATDM is focusing on rewriting key application packages to efficiently run on next-generation exascale systems and on interacting early on with hardware vendors to improve performance of applications of critical importance to stockpile stewardship. NNSA's exascale or ECI efforts are funded through the ATDM subprogram (see Section C.4) and in selected line item construction projects.

NNSA will continue to acquire progressively more capable HPC systems on a strategic schedule to meet the needs of the nuclear weapons stockpile mission. Developing and adapting IDCs to this set of new architectures is also part of ASC's core undertaking.

C.4 Advanced Technology Development and Mitigation

Existing hardware and software codes will need substantial modification to be able to address increasingly complex problems and to use exascale computing systems efficiently. New models, techniques, and

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

algorithms are necessary to increase the fidelity of the scientific predictions and to take advantage of the advanced computing technologies.

The goals of ATDM subprogram are to address the need to adapt current IDCs and to build new IDCs that are aligned on emerging technologies, interact in co-design ventures with academia and industry to evolve operating systems and other support software, and work with HPC vendors to develop and use technologies that are useful for stockpile stewardship. There are three components:

- **Next-Generation Code Development and Applications.** The funding of new code development efforts at each of the three national security laboratories. These efforts are focusing on building integrated, balanced, and scalable simulation and modeling capabilities to address the predictive physics and engineering thresholds on future computer architectures.
- **Next-Generation Architecture and Software Development.** The inclusion of projects to develop and produce software development tools, supply code performance and portability support, enhance workflow R&D, and investigate advanced architecture software component and software framework development.
- **Interagency Co-design.** Support for the NSCI in increasing the capacity and capability of an enduring national HPC ecosystem *via* interagency collaborations with other U.S. Federal agencies. These projects will use the HPC systems, software, and applications to address the sponsor agencies' mission needs.

NNSA's ATDM Office, working in close collaboration with DOE's Office of Science, are using two approaches to address barriers to exascale and evolving architectures:

- **Co-design Efforts.** Co-design refers to a system-level design process in which scientific problem requirements influence architecture design and technology and architectural characteristics inform the design of algorithms and software. Co-design methodology uses the combined expertise of vendors, hardware architects, software stack developers, domain scientists, computer scientists, applied mathematicians, and systems staff working together to make informed decisions about the design of hardware, software, and underlying algorithms. The transformative co-design process is rich with trade-offs, and give and take will be needed from both the hardware and software developers. Understanding and influencing these trade-offs is a principal co-design requirement.[3]
- **Collaborative Application Exploration.** Interactions with vendors provide invaluable opportunities for the code teams to prepare for and adjust to more complex hardware environments. These activities bring vendor subject matter experts together with application developers to identify where to focus future application development and see the effects of real-time code changes with feedback and collaboration with tools and performance experts. The vendor subject matter experts bring domain knowledge of hardware, compilers, and performance analysis tools. The code developers bring domain knowledge about the physics in the source code, as well as the architecture, design, constraints, and portability goals of the application. The computer scientists at the national security laboratories are exploring traditional and emerging parallel programming models using proxy applications in order to determine the strengths and weaknesses of the different models.

[3] For more information see the ASC Co-Design Strategy document (February 2016) at https://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/ASC_Co-design.pdf

C.5 Joint Exascale Computing Project

The DOE Office of Science's ASCR and NNSA's Office of Defense Programs' ASC Programs have developed an integrated and coordinated portfolio of activities with the goal of delivering at least 1 quintillion calculations per second in computational capability to key DOE national security and basic science application areas by the beginning of the next decade. This effort, known as the ECP, supports the NSCI. ECP is a jointly administered project that will follow DOE's Office of Science project management processes and procedures to implement a tailored process to meet DOE Order 413.3B, "Program and Project Management for the Acquisition of Capital Assets." The ECP project will fund teams comprised of personnel from the DOE national laboratories, large and small HPC vendors, and universities selected through peer review processes to conduct research, development, and engineering activities for the ECP.

This partnership is focused on achieving common objectives, eliminating duplication, interacting with the vendor community, and improving solutions using the broad, combined experience and strengths of both ASC and ASCR. A Memorandum of Understanding documents the agreement between the Under Secretary for Science and Energy and the Under Secretary for Nuclear Security regarding the Federal coordination of ECP execution and associated activities between the two organizations. Each program (ASC and ASCR) will continue to have its own unique challenges that must be addressed for full use of exascale resources. Budget authority for the exascale computing activities will continue to reside within the respective ASC and ASCR programs.

C.6 Exascale Computing Project Approach and Strategy

Historically, industry has delivered successive new generations of leading-edge HPC systems every 4 to 5 years. An exascale capable system will be more challenging to achieve than previous systems because of the complex trade-off between hardware (processors, memory, energy efficiency, reliability, and interconnectivity) and software (programming models, scalability, data management, productivity, *etc.*). In February 2014, the DOE Advanced Scientific Computing Advisory Committee issued a report on the top 10 technical challenges for exascale.[4] These challenges are (1) energy efficiency; (2) interconnecting technology; (3) memory technology; (4) scalable system software; (5) programming systems; (6) data management; (7) exascale algorithms; (8) algorithms for discovery, design, and decision; (9) resilience and correctness; and (10) scientific productivity.

Through ASC and ASCR investments, several co-design centers have begun to perform exploratory research to co-design the hardware and architecture, software stacks, and numerical methods and algorithms for mission applications, as well as to determine trade-offs in the design of exascale hardware, system software, and application codes.

The strategy to address these challenges is in the following ECP focus areas:

- **Application Development.** Development of next-generation codes to address extreme parallelism, reliability and resiliency, memory hierarchies, and other performance issues caused by next-generation computing hardware.
- **Software Technology.** Development of an expanded, vertically integrated software stack to support applications on next-generation hardware. ECP plans to extend current technologies to exascale where possible, perform research to address unique problems where current

[4] http://science.energy.gov/~/media/ascr/ascac/pdf/meetings/20140210/Top10reportFEB14.pdf

approaches will not suffice, and deploy high-quality, high-performing software products for exascale-class platforms in 2021 (DOE Office of Science) and 2023 (DOE/NNSA).

- **Hardware Technology.** Support for vendor R&D activities to develop and deliver next-generation systems suitable for DOE's Office of Science and NNSA applications. A central element of the hardware technology effort is the PathForward project. That project is the follow-on to the prior FastForward and DesignForward projects and will run through 2019. PathForward seeks solutions that will improve application performance and developer productivity while maximizing energy efficiency and reliability of advanced and exascale systems.

Appendix D
Federal Workforce

D.1 Overview

NNSA's Federal workforce primarily operates out of headquarters facilities in Washington, DC, Germantown, Maryland, and Albuquerque, New Mexico. In addition, Federal staff are dispersed throughout field offices largely located around each of the sites with the exception of Pantex and Y-12, which are jointly overseen by the NNSA Production Office. The Federal workforce plans, manages, and oversees the nuclear security enterprise and is accountable to the President, Congress, and the public. In addition, the field offices employ subject matter experts in a wide variety of fields to provide oversight for each site's diverse national security missions. NNSA's Federal workforce, like its management and operating (M&O) and non-M&O partners, is composed of dedicated professionals working to promote the nuclear security mission. This appendix contains the Federal workforce data.

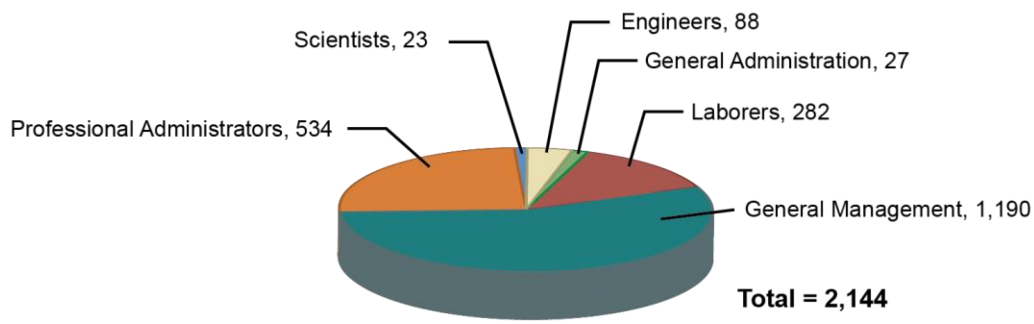
D.2 National Nuclear Security Administration

D.2.1 Federal Workforce

Out of a total of 2,144, at the end of FY 2016 the Federal workforce in the nuclear security enterprise had 1,622 employees under NNSA Federal Salaries and Expenses (FSE) and 522 in the Secure Transportation Asset.[1] The number of full-time equivalents (FTEs) is 1,622, which is below the *National Defense Authorization Act* mandated cap of 1,690 FTEs for FSE-funded FTEs. Since the end of FY 2014, the Federal workforce had 369 hires and 341 separations, for a net gain of 28. Attrition is around 9 percent, with retirements accounting for more than half of separations. In the past few years, the number of early- and mid-career employees has decreased slightly while the number of advanced-career employees has remained relatively constant. Though currently unmet, the authorization cap in the future may limit NNSA's ability to address a pending retirement bow wave and to manage the increased work scope in major mission areas, particularly for life extension programs and major construction projects. In FY 2017, NNSA partnered with the Office of Personnel Management's Strategy and Evaluation Branch to conduct an objective review of NNSA's staffing level. It is a phased approach, examining NNSA's Federal program and field offices.[2]

[1] This number excludes the Naval Reactors workforce, and includes employees in Defense Nuclear Nonproliferation activities and the Office of Secure Transportation.

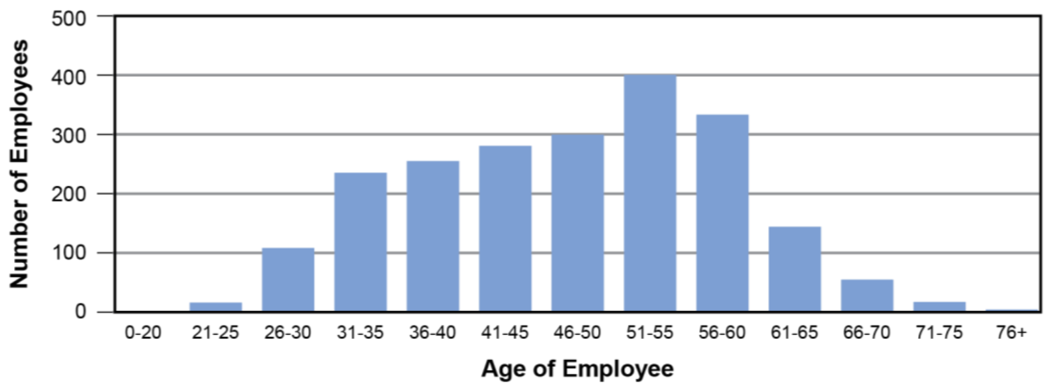
[2] Phase I is completed, having focused on Defense Programs, Defense Nuclear Nonproliferation, Acquisition and Project Management, Management and Budget, and the Los Alamos Field Office. Phase II started in June 2017 and is examining the rest of the program and field offices.



Notes:

The *National Defense Authorization Act*-mandated cap constrains the Federal workforce yet still affords some opportunity to reshape the workforce for NNSA's oversight and program management roles.

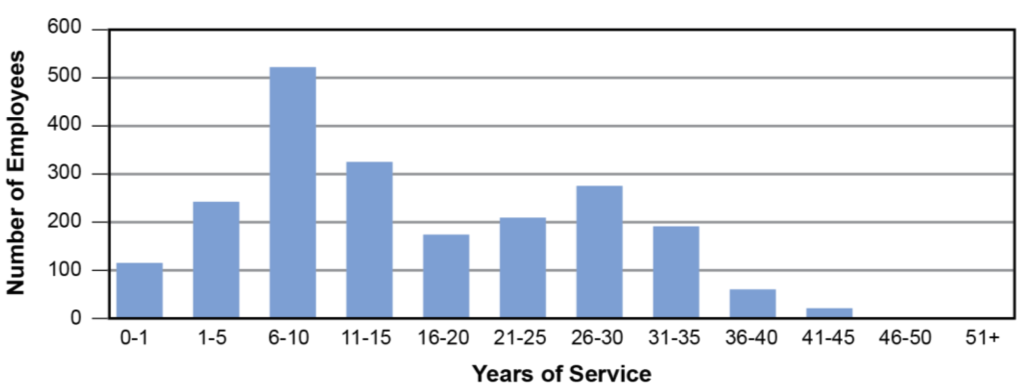
Figure D–1. Total Federal workforce for the nuclear security enterprise by Common Occupational Classification System



Notes:

The Federal workforce has an average age of 48, with about 17 percent retirement eligible.

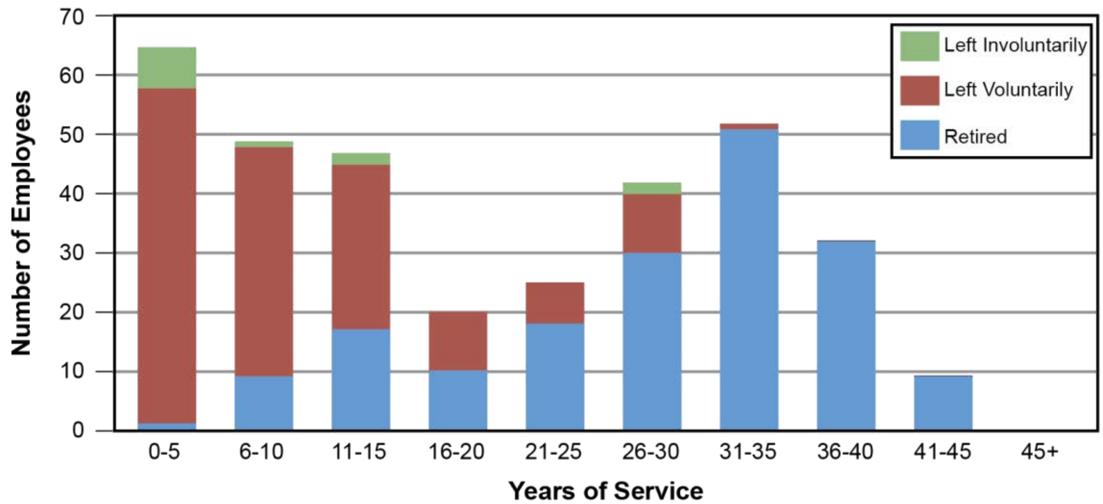
Figure D–2. Federal employees by age



Notes:

The NNSA Federal workforce by years of service has a bimodal distribution, with the average number of years served being 16. On the left side of the bimodal distribution, 849 experienced employees have 6 to 15 years of service.

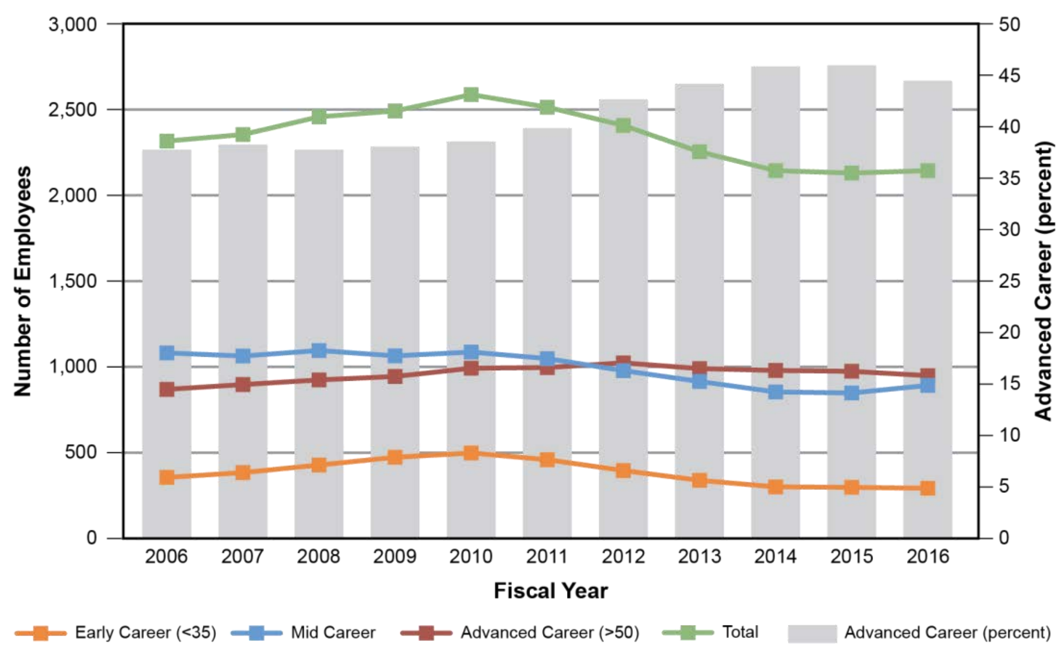
Figure D–3. Federal employees by years of service



Notes:

Attrition continues to be fairly consistent and predictable at 7.5 to 9 percent with retirements representing more than half of separations.

Figure D–4. Years of service of Federal employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

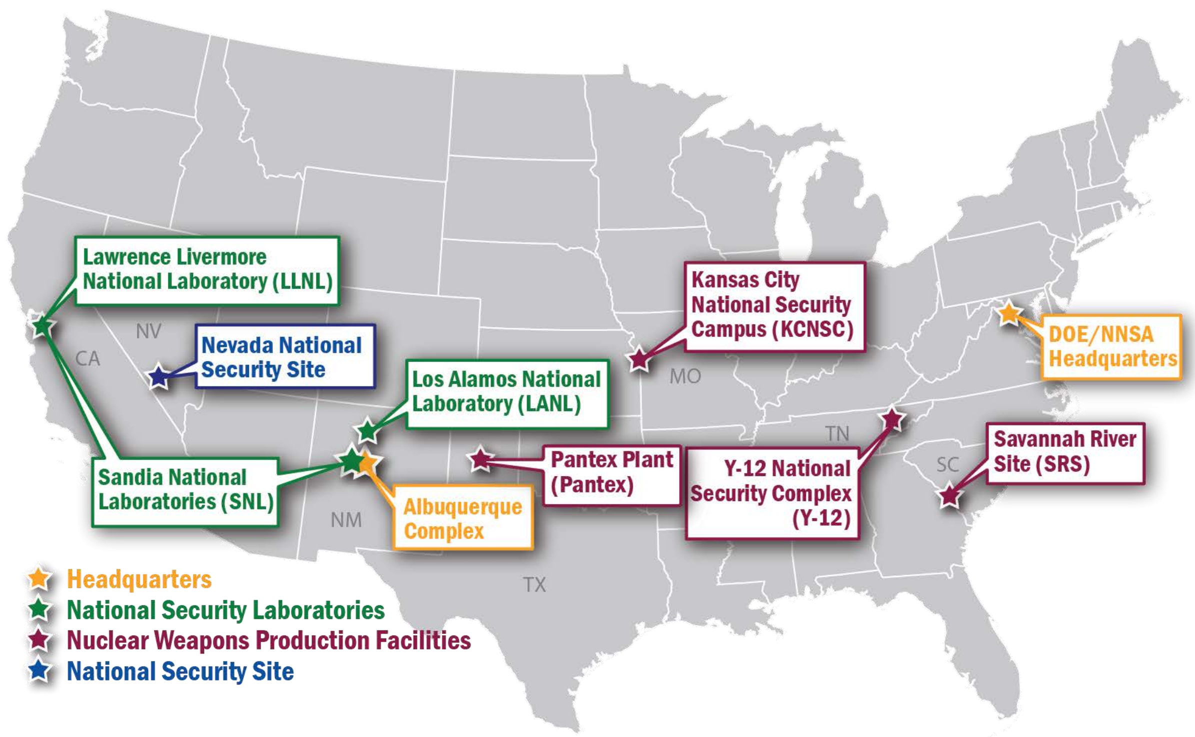
NNSA has used the excepted service hiring authority to recruit and retain highly qualified scientific, engineering, and technical personnel to support its missions.

Figure D–5. Federal employee trends by career stage

Appendix E
Workforce and Site-Specific Information

E.1 Overview

NNSA has eight nuclear security enterprise sites, spread across the Nation, which possess the expert workforce and advanced capabilities to maintain the Nation's nuclear deterrent. These eight sites include three national security laboratories (LLNL, LANL, and SNL), four nuclear weapons production facilities (KCNSC, Pantex, SRS, and Y-12), and the test site (Nevada National Security Site). Specific information is included in this appendix to familiarize stakeholders and the public with each site's mission, mission capabilities, FY 2018 budget request, recent accomplishments, and workforce data.



E.1.1 Critical Importance of Investing in Advanced Science, Technology, Engineering, and Manufacturing Capabilities

Planning and investing in advanced capabilities, infrastructure, and, most importantly, the workforce are at the heart of achieving U.S. nuclear security objectives.

- The advanced capabilities and accomplishments by NNSA's eight management and operating (M&O) partner sites demonstrate a continuing commitment to nuclear deterrence and to assurance of security guarantees to the Nation's allies.

- Advanced capabilities help to ensure evolving deterrence needs can be met.
- The nuclear deterrent must provide decision makers with capabilities that are modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st-century threats. NNSA's capabilities for weapons activities enable these characteristics.

E.1.2 Contributions of the Nuclear Security Enterprise to National and Global Welfare

DOE is the lead Federal agency supporting fundamental scientific research for energy, the Nation's largest supporter of basic research in the physical sciences, and the employer of tens of thousands of individuals within the science, engineering, and defense communities.

- The science, technology, engineering, and manufacturing capabilities, infrastructure, and human capital within the nuclear security enterprise make NNSA a significant and enduring contributor to scientific understanding and engineering innovation that benefit the Nation and the world.
- The creation and discovery of new science and technologies influence America's economic and national security objectives on a global level.
- Given its mission and asset profile, DOE/NNSA directly influences the shape of the Nation's balance of power on the global level.
- Strategic use of these assets by the workforce, in particular, will determine how profound the contributions to global stability, technological progress, and economic growth are around the world.
- Recent examples of innovations by the nuclear security enterprise are listed in **Table E–1**.

Table E–1. Recent innovations by the nuclear security enterprise

Innovation	*Description*	*Significance*
Genomics	A broad computational study of cancer genome sequences identified telltale mutational signatures associated with smoking tobacco. The study demonstrates that smoking increases cancer risk by causing somatic mutations in tissues directly and indirectly exposed to tobacco smoke. This study was based on data generated by the international cancer consortia and leveraged the high-performance computing resources and machine-learning capabilities at LANL.	This study has the potential to impact an enormous public health issue in first-, second-, and third-world nations. Examining the DNA of cancers has the potential to provide insight into how to prevent those cancers.
Printing "living" blood vessels	LLNL used bio-ink to print cells and other biomaterials that formed tubes able to deliver nutrients to tissue.	The printing process allows efficient reproduction of cell physiology for *ex vivo* human health research.
"Second skin" to protect soldiers	LLNL's nano-manufactured material is lightweight, breathable, and protective.	The goal is to provide military-grade clothing to protect U.S. soldiers against use of chemical and biological agents.

Innovation	***Description***	***Significance***
Isotope research	The isotope program is actively researching the production of isotopes for therapeutic applications, including promising alpha-emitting radionuclides for targeted radiotherapy such as actinium-225. Medical isotopes have long been a product of the isotope production capability, which creates strontium-82, germanium-68, and other short-lived isotopes for medical scans. Facilities such as the linear particle accelerator at the Los Alamos Neutron Science Center and hot cells in technical areas are leveraged to satisfy this mission.	Research continues on methods to increase isotope supply in order to meet the needs of the medical community. Actinium-225 is used around the world for radiotherapy of prostate cancer, malignant neuroendocrine tumors, and other malignant tumors.
Improving the reliability of domestic medical isotope supply for molybdenum-99 (Mo-99)	In response to the *American Medical Isotopes Production Act of 2012*, which accelerates the elimination of worldwide use of HEU for medical isotope production, a Cooperative Research and Development Agreement between the Nevada National Security Site and Global Medical Isotope Systems, LLC, has been established to develop a novel approach to produce the medical isotope Mo-99 (NNSA now has four cooperative agreements in place with three commercial entities). Currently, 95 percent of the global supply of Mo-99 for medical use is produced in seven research reactors and supplied from five target processing facilities located in Australia, Canada, Europe, and South Africa. The United States currently consumes about half the global supply of Mo-99/ technetium-99m for medical use. There has been no U.S. production of this isotope since the late 1980s.	Eliminating worldwide use of HEU in reactor targets and medical isotope production facilities reduces the likelihood of global nuclear proliferation and provides the United States with an adequate supply of Mo-99 for medical diagnostic imaging and therapy.
Protein-based biological identification	LLNL partnered with Protein-Based Identification Technologies, LLC, to develop a biological identification method that exploits information encoded in proteins of human hair.	Human identification from biological materials often relies on DNA, which can degrade over time based on environmental factors. Protein is chemically more robust than DNA and provides an additional forensics tool for law enforcement and archaeology.
First quantum computer bridge	SNL and Harvard partnered to demonstrate the next key step in building the first quantum computer by embedding two silicon atoms in a diamond matrix at the Ion Beam Laboratory.	Quantum computers will vastly increase the computing speed over current high-performance computing technology.
Efficient conversion of methane to methanol	LLNL used three-dimensional printing to create the first chemical reactor that can continuously produce methanol from methane at room temperature.	The high-efficiency chemical reactor can cut methane emissions from energy and other industries to mitigate global warming.
ChemCam	Laser-induced breakdown spectroscopy, developed to locate materials in glove boxes in LANL's plutonium facilities at TA-55, is the basis for the ChemCam laser unit on the Curiosity rover. ChemCam resulted in discovery of manganese oxides and boron on Mars.	ChemCam provides insight into the history of Mars. SuperCam was selected for the Mars 2020 mission, which will pave the way for human visitation.
Paleomagnetic techniques for seismic monitoring	Experimental results from seismic research and development suggest new methods can be deployed to detect, locate, and characterize underground nuclear explosions.	Paleomagnetism may offer a significant new direction to monitor treaty violation and verification and preclude nuclear weapon proliferation activities.

Innovation	*Description*	*Significance*
Optimization Planning Tool for Urban Search (OPTUS)	LLNL led a multi-institutional effort to develop a prototype OPTUS as a more efficient urban search for hidden radiological or nuclear devices.	OPTUS enables more thorough searches before special events or if there are credible reasons to conduct such a search.
Multi-Path Communication Device (MPCD)	MPCD is a fully integrated “central” command system that allows multiple pathway communications to interconnect from radios, Wi-Fi, cellular, satellite, and other carrier frequencies.	This device overcomes serious limitations in communications and data dissemination with disparate systems during nuclear or other public emergency and disaster response.
Novel fluorescent technetium compounds	Incorporated novel silicates with technetium-99 into a robust fluorescent material for realistic operational radiation detection training.	Allows first responders to be trained to deal with radioactive compounds in a more environmentally benign manner over longer periods than traditional methods.
Urchin	Urchin is a tiny, quarter-sized, ultra-low power computer and smart sensing hardware platform to integrate energy harvesting and low-energy communications with chemical and other sensors.	These devices, when deployed together, form semantic networks to allow hundreds to thousands of sensors to talk to each other and assist firefighters or other responders in dealing with hazardous conditions.
“Memzyme” membrane technology	SNL and the University of New Mexico created this powerful technology, which captures CO_2 from coal- and gas-fired electrical plants. The bubble-like membrane harnesses nature to reduce CO_2 emissions.	The new membrane is 100 times faster in passing flue gas than any membrane on the market today and is 10 to 100 times more selective for CO_2 emissions over nitrogen (the main flue gas component).
Hydrogen Station Equipment Performance (HyStEP)	SNL and the National Renewable Energy Laboratory developed HyStEP to reduce the time to commission hydrogen fuel stations from months to one week.	The availability and affordability of the fuel stations will keep pace with advances in fuel cell technology.
Starlite-Synthetic Aperture Radar – Coherent charge Detection (CCD) software	The CCD software package allows imagery to detect improvised explosive devices.	The software enhances the ability to protect troops and civilians on the battlefield and regions with hostile activity.

CO_2 = carbon dioxide
DNA = deoxyribonucleic acid
HEU = highly enriched uranium
TA = technical area

E.1.3 Site-Specific Introduction

Given the integral role that the sites play in managing the country’s nuclear deterrent and contributing to national security, Appendix E provides a detailed look at each. Specific information is included in this appendix to familiarize stakeholders and the public with each site’s mission, mission capabilities, FY 2018 budget request, recent accomplishments, and workforce data. New to the FY 2018 version of this appendix are increased attention to site overview information, an in-depth look at each site’s weapons activities capabilities and their strategies to maintain them, and an informational overview of each site’s workforce data to summarize the corresponding charts.

E.2 National Security Laboratories

E.2.1 Lawrence Livermore National Laboratory

E.2.1.1 Mission Overview

DOE sponsors Lawrence Livermore National Laboratory (LLNL) as a Federally Funded Research and Development Center (FFRDC) to provide research, development, test, and evaluation (RDT&E) capabilities for the stockpile, as well as a broad range of national security needs integral to the mission and operation of DOE and other Federal agencies. LLNL is managed by Lawrence Livermore National Security, LLC.

- Locations: Main site, Livermore, California (Site 200); Experimental Test Site, Tracy, California (Site 300)
- Total Employees: 5,783
- Type: Multi-program national security laboratory
- Website: www.llnl.gov
- Contract Operator: Lawrence Livermore National Security, LLC, a corporate subsidiary of Bechtel National, University of California, BWXT, Washington Division of URS Corporation, and Battelle.
- Responsible Field Office: Livermore Field Office

LLNL Accomplishments

Stockpile Management
- *The Nuclear Weapons Council approved the W80-4 Life Extension Program (LEP) Phase 6.1 Concept Study and directed the LEP to enter Phase 6.2, Feasibility Study.*
- *Completed annual stockpile assessment for Cycle 21.*

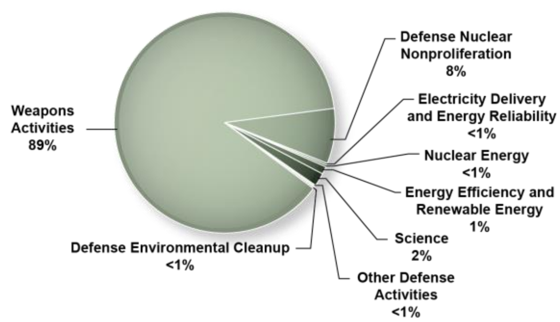
Stockpile Stewardship Science
- *Surpassed the challenging goal of 400 target shots at the National Ignition Facility in FY 2016.*
- *Demonstrated the first double-pulse, dynamic radiographic test capability at Flash X-Ray and Contained Firing Facility.*
- *Demonstrated first-known capability to additively manufacture three-dimensional high-explosive structures.*
- *Conducted first-ever ministerial-level nuclear terrorism exercise with 37 nations to identify national and international actions to address a nuclear crisis.*

Physical Infrastructure
- *Constructed High Performance Computing facility within budget and on schedule.*
- *Achieved Secretarial mandate to reduce infrastructure deferred maintenance from $587 million to $541 million, a reduction of $46 million.*

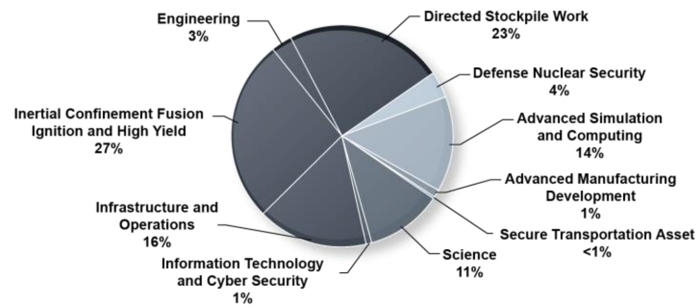
Sustaining the Workforce
- *Received three R&D 100 awards and seven LLNL scientists were selected as American Physical Society fellows.*

E.2.1.2 Funding

FY 2018 Request – Site Funding by Source
(Total LLNL FY 2018 Request = $1,390.4 Million)



FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($1,230.4 Million)*



E.2.1.3 Site Capabilities

LLNL is an NNSA Center of Excellence for Nuclear Design and Engineering, with core competencies in high explosives (HE) RDT&E, high energy density (HED) physics, high performance computing (HPC), nuclear physics, and materials science and engineering. LLNL is the lead design physics laboratory for the W80-4 (the Air Force's cruise missile warhead) and IW1 Life Extension Program (LEP). LLNL has primary certification responsibility for the W80, W87, and B83.

LLNL operates several NNSA flagship facilities such as the National Ignition Facility (NIF), Livermore Computing Center, High Explosives Applications Facility, Contained Firing Facility, Flash X-Ray, and Plutonium Superblock, as well as physical infrastructure and capabilities supporting research, development, science, and technology missions in weapons engineering and physics, advanced materials, HPC, and HED physics.

LLNL capabilities that relate to design and development of stockpile systems include the following.

Weapons Physics Design and Analysis

- **Capability.** LLNL is integral to the design and performance assessment of the nuclear explosive package (NEP) and supports the capability to certify the stockpile without nuclear testing. LLNL characterizes primary and secondary performance, HE, and material performance *via* physics design and analysis and maintains critical capabilities, such as advanced diagnostics and sensors; laser, pulsed power, and accelerator technology; hydrodynamic and subcritical experiments; and weapons surety design, analysis, integration, and manufacturing.
- **Challenges.** Improvements in key capabilities are required for LEPs, including operational risk reduction activities for dynamic radiography, increased experimental workloads, and investment in advanced diagnostics for NEP performance testing.
- **Strategies and Path Forward.** NNSA is investing in infrastructure support and recapitalization to modernize Site 300 capabilities, including firing sites at the Flash X-Ray and Contained Firing Facility, and in plutonium infrastructure and advanced diagnostics development to support weapons certification.

Weapons Engineering Design, Analysis, and Integration

- **Capability.** LLNL is responsible for weaponizing the physics package to ensure performance through the warhead stockpile-to-target sequence at sub-scale and device scale and to support production engineering. Engineering design and analysis provide the fundamental capability to certify the stockpile without nuclear testing by destructive and nondestructive surveillance evaluations and reliability and condition assessments. This capability is also used to fabricate complex special nuclear material (SNM) target assemblies to support design physics.
- **Challenges.** LLNL will need continuous modernization of warhead test and evaluation capabilities and needs investment in and evaluation of disruptive manufacturing technologies such as advanced manufacturing.
- **Strategies and Path Forward.** NNSA is making multi-year sustainment investments in weapons engineering capabilities, including fabrication and inspection, nondestructive evaluation, environmental testing, plutonium science, and radioactive material processing. LLNL is continuing to invest in advanced manufacturing laboratory space and equipment development.

High Explosives Science and Engineering

- **Capability.** LLNL's HE RDT&E capabilities support stockpile stewardship, nuclear nonproliferation, and nuclear counterterrorism efforts *via* a multidisciplinary approach to synthesis, formulation, characterization, processing, and testing of energetic materials, components, and warhead subassemblies. LLNL characterizes HE performance and safety at device and laboratory scales. Modernization activities support LEP and warhead assessments in facilities and equipment for HE large charge pressing and plot-scale synthesis and formulation systems.

  LLNL has demonstrated the first-known capability to additively manufacture three-dimensional HE structures and demonstrated their ability to detonate. LLNL holds three Records of Invention in HE-additive manufacturing technology.
- **Challenges.** LLNL is responsible for qualifying insensitive high explosives (IHE) for assigned U.S. stockpile systems. HE processing capabilities require modernization for LLNL to meet programmatic demands for additional prototyping of warhead HE systems as well as support RDT&E capacities and throughputs. Infrastructure supporting HE pressing and machining capabilities needs continued condition assessment and recapitalization.
- **Strategies and Path Forward.** NNSA is investing in the High Explosives Applications Facility and Site 300 infrastructure through a 5-year program that addresses short- and long-term facility recapitalization for mission objectives. LLNL is currently implementing Capability Based Investments and minor construction projects that make investments in scaled HE synthesis and large charge pressing capabilities.

High Performance Computing

- **Capability.** LLNL is a key contributor to the Nation's ability to field premier computing platforms. Multi-laboratory collaborations have been developed to achieve exascale-class computing. LLNL HPC support includes operating systems, architecture, and code development.
- **Challenges.** LLNL must anticipate, develop, and deploy new computing architectures to support weapons design codes and weapons design and certification needs.
- **Strategies and Path Forward.** Planning for the exascale paradigm includes architecture, code-developing environments, operating systems, and physical infrastructure. NNSA plans to

focus investment on the utility backbone of the laboratory, including electrical and water systems. Investment in computing facilities will support deployment of the first U.S. exascale-class computing platform.

High Energy Density Physics

- **Capability.** LLNL conducts physical process experiments to ensure that, if called on, the NEP can produce militarily effective yield. NIF conducts major experimental campaigns on high-Z material properties, burn physics, radiation transport, radiation hydrodynamics, mix, and code validation.
- **Challenges**. The priorities for infrastructure are currently too low to support an aggressive stockpile stewardship experimental program. LLNL must develop an enduring infrastructure capability base in target fabrication and be prepared to manage increased facility usage in the future.
- **Strategies and Path Forward.** LLNL has developed a 3-year investment plan to consolidate target fabrication equipment for efficiency while supporting more than 400 shots per year. Infrastructure recapitalization and modernization are essential to realizing this plan.

Nuclear Physics and Radiochemistry

- **Capability.** LLNL radiochemistry infers device performance from past nuclear test data to support certification, assessment, and design of the U.S. stockpile.
- **Challenges.** Historical nuclear test data are currently stored on a wide range of media that are difficult to access and at risk of becoming irretrievable. LLNL must also increase priorities to recapitalize laboratory space with a focus on glove box equipment.
- **Strategies and Path Forward.** NNSA is supporting a 4-year modernization of LLNL's radiochemistry laboratories, as well as a vault expansion for archiving U.S. radiochemistry test data.

Materials Science and Engineering

- **Capability.** LLNL maintains the physical database to characterize materials in the NEP from microscale to mesoscale. LLNL performs research and development (R&D) in plutonium science, metals, organics (polymers), and energetic materials. This capability is key to supporting design and certification, as well as testing and evaluation of materials under stockpile-to-target sequence conditions and for modeling and code development.
- **Challenges.** Critical capabilities are housed in a building that is more than 60 years old, with process contamination and the highest seismic risk hazard at the laboratory.
- **Strategies and Path Forward.** LLNL is continuing a 5-year facility consolidation and replacement effort to provide enduring infrastructure for this critical capability. NNSA and LLNL are developing plans to sustain and consolidate the materials science and engineering capabilities from a 140,000-square foot to a 50,000-square foot footprint. NNSA and LLNL will maintain these capabilities critical to the program while undertaking this effort.

Lawrence Livermore National Laboratory Centers of Excellence

National Ignition Facility (NIF)

- NIF is a core experimental facility for the Stockpile Stewardship Program, which has driven capabilities of high energy density physics, diagnostics, targets, and lasers.
- The facility provides regimes of pressure, density, and temperature relevant to the operation of a nuclear weapon.

Livermore Computing Center

- Advanced computing is required to run predictive models and provides support to every mission area.
- Sequoia, a 20 petaFLOPS system, is a Stockpile Stewardship Program national user facility.
- Sierra, a 150 petaFLOPS machine, will be installed in 2017; an exascale class system is the goal for FY 2023.

High Explosives Application Facility (HEAF)

- HEAF addresses performance and aging of high explosives.
- Recapitalization at Site 300 is underway to ensure production of insensitive high explosives and W80-4 Life Extension Program qualification. The Contained Firing Facility at Site 300 handles explosive experiments.

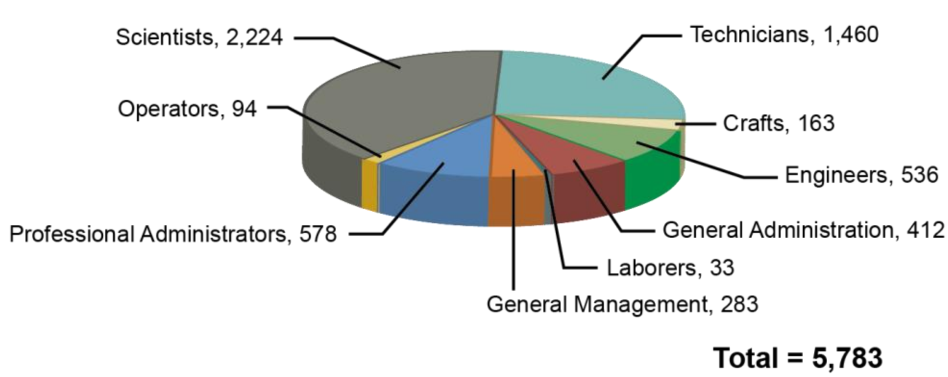
E.2.1.4 Accomplishments

- Scientific staff received three R&D 100 awards for their development in the GLO Transparent Ceramic Scintillator, Polyelectrolyte Enabled Liftoff technology, and the Carbon Capture Simulation Initiative toolkit.
- The American Physical Society selected seven LLNL scientists as American Physical Society Fellows. More than 100 LLNL employees have been elected American Physical Society Fellows in the past 30 years.
- LLNL received a Gold 2016 Optimas Award for Recruiting from *Workforce Magazine* to recognize excellence in its military internship programs, including the Military Academic Research Associates program, the Reserve Officers' Training Corps Internship Program, and the Newly Commissioned Officer program.
- LLNL partnered with NNSA to develop new tools and methodologies for real property management. LLNL supported the refinement and update of DOE Order 430.1C, NNSA implementation of BUILDER (an asset management tool) and asset management programs, and the Deep Dive infrastructure planning process. LLNL achieved a Secretarial mandate to reduce its infrastructure deferred maintenance in FY 2016 from $587 million to $541 million, a reduction of $46 million.
- LLNL hosted Apex Gold, the first-ever gathering of ministers and other senior delegates from 37 nations to discuss effective responses to national and international actions in the event of a nuclear crisis. Ministers and delegates toured LLNL facilities to better understand some of the technical tools available to detect and analyze nuclear materials in a crisis.
- LLNL completed all deliverables for Cycle 21 of the Annual Assessment Review, including comprehensive peer review to support the Independent Nuclear Weapon Assessment Process. Laboratory scientists continue to add rigor to the science and engineering capabilities. In FY 2016, LLNL demonstrated the first double-pulse, dynamic radiographic test capability at the Flash X-Ray and Contained Firing Facility to support the hydrodynamic test program.

- LLNL made progress on Phase 6.2 activities for the W80-4 LEP, such as implementing effective project management and control tools, developing design options, making infrastructure upgrades, and maturing component technologies. LLNL recently completed comprehensive facility modernization to support warhead assessment and the LEP.
- The CORAL [Collaboration of Oak Ridge, Argonne, and Livermore] effort, including LLNL's Sierra machine, is on schedule, and Sierra early delivery systems arrived in September 2016. LLNL also managed procurement of the next-generation capacity computing Commodity Technology System 1 for NNSA, with the first scalable unit arriving in FY 2016. NNSA is recapitalizing electrical and cooling infrastructure to support deployment of the Advanced Technology System (ATS) 4 exascale-class machine at LLNL, in line with the current program of record.
- LLNL performed 417 experiments at NIF in FY 2016, including SNM experiments and the first high-Z strength shot. Newly installed capabilities at NIF include the Advanced Radiographic Capability, which continues to undergo qualification and has been used as a backlighter, and the Target and Diagnostic Manipulator, which will improve efficiencies in experiments.
- As part of the Nuclear Test Heritage program, LLNL generated and demonstrated an information pipeline and is prepared to begin scanning large volumes of material on different media.
- LLNL researchers have produced parts to support hydrodynamic testing. The laboratory has demonstrated refined control of microstructure and physical properties of parts produced by additive manufacturing processes. LLNL has completed design of the Advanced Manufacturing Laboratory facility.

E.2.1.5 Lawrence Livermore National Laboratory Workforce

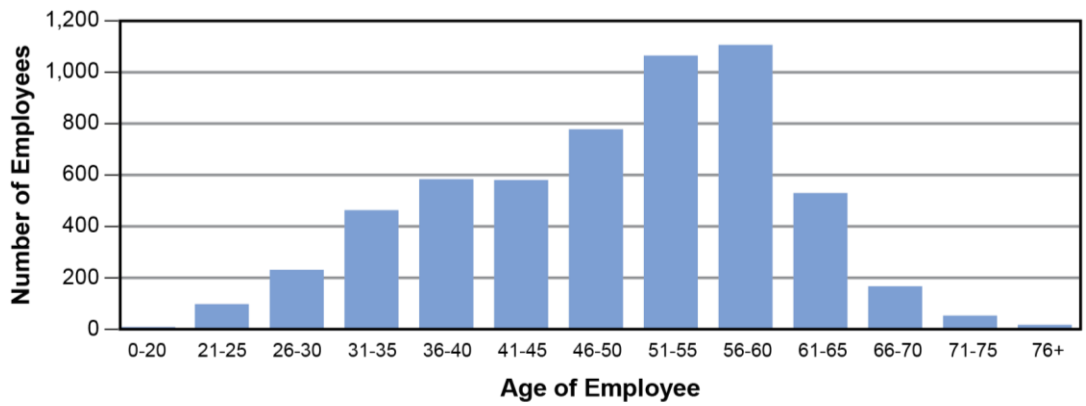
LLNL has 5,783 employees, with an average age of 50 years and an average of 16 years of service. Approximately 30 percent of LLNL's employees are eligible to retire. Since the end of FY 2014, LLNL hired 993 employees and experienced 629 separations, resulting in a net gain of 364. Retirement separations dispersed throughout many different "years of service" groups. Voluntary separations were most pronounced among employees with 15 years of service or less. LLNL's population was reduced after a contract transition in FY 2008, although hiring has increased in the last 2 years. Recent hires have increased in the early- and mid-career workforce, while the advanced-career workforce has remained relatively stable. LLNL anticipates growth over the Future Years Nuclear Security Program (FYNSP) period, especially as the work scope increases for W80-4 LEP activities.



Notes:

A large number of scientists and engineers at LLNL are engaged in research, development, test, and evaluation.

Figure E–1. LLNL total workforce by Common Occupational Classification System



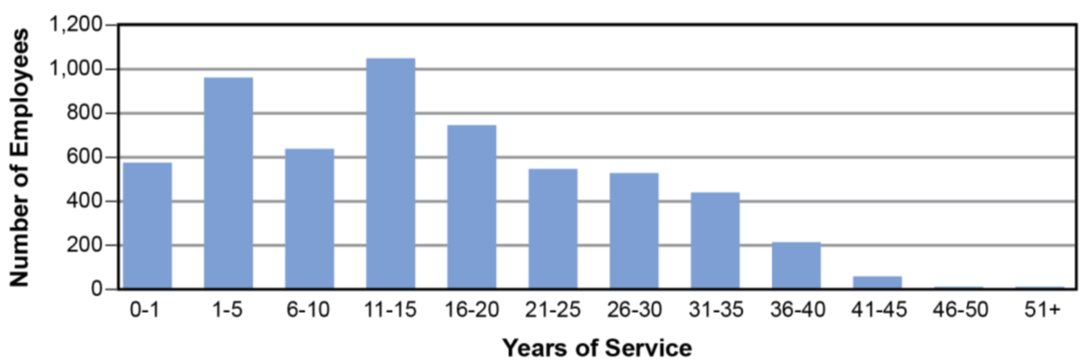
Notes:

The average age of the LLNL workforce is 49.7 years old with a median age of 52 years.

About 52 percent of the population is over 50 years old.

Given the aging demographics at LLNL, succession planning is critical for knowledge preservation.

Figure E–2. LLNL employees by age

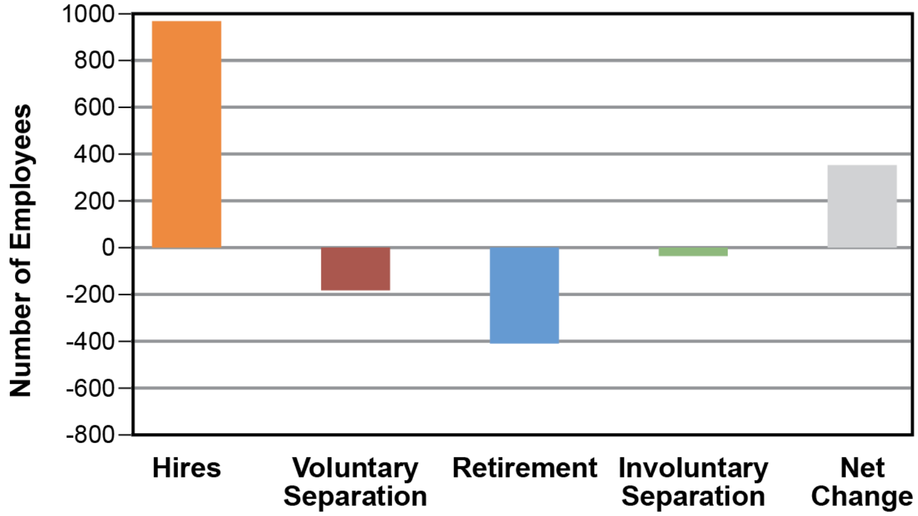


Notes:

The laboratory average for years of service is 15.7.

About 31 percent of the workforce has over 21 years of service.

Figure E–3. LLNL employees by years of service



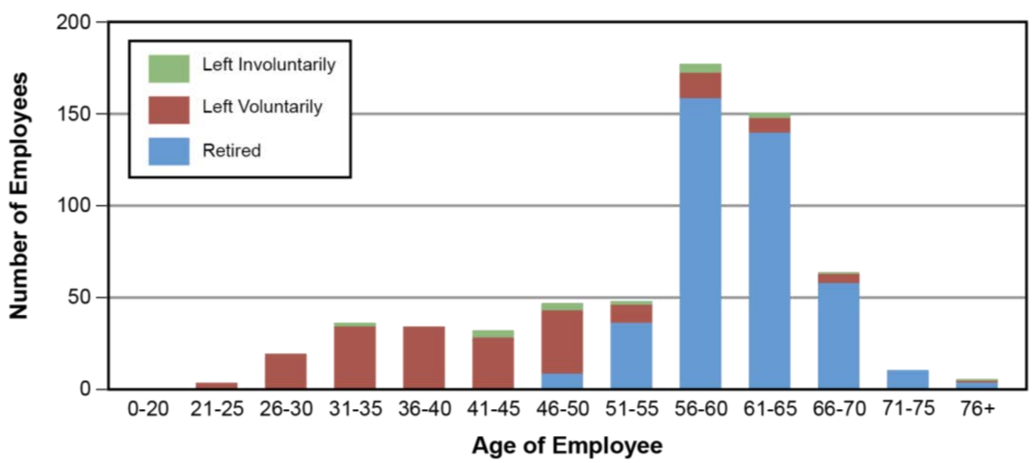
Notes:

Two-thirds of the net workforce reduction resulted from retirements.

The remaining workforce reduction was caused by other factors, including a Security Organization restructuring and a self-select voluntary separation plan.

Hires included 122 conversions from noncareer (students/post-doctorates) to career appointment types.

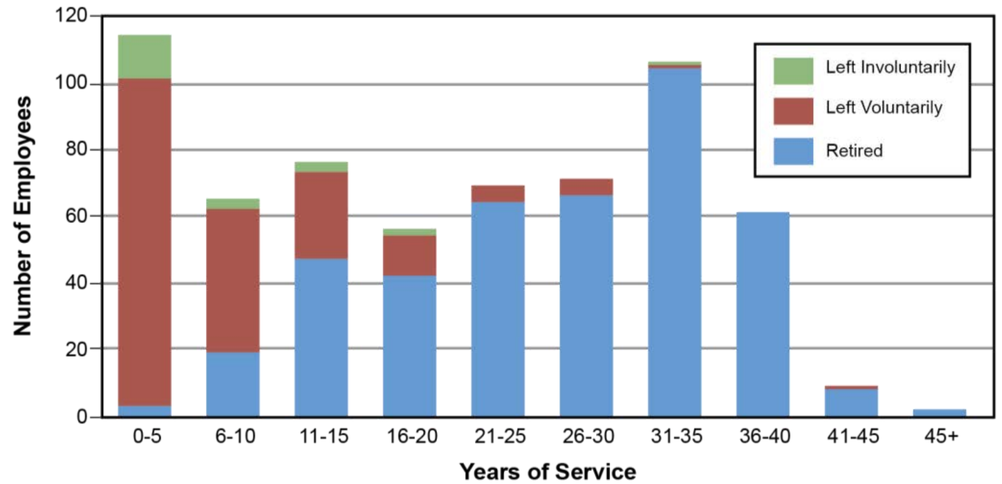
Figure E–4. Change in last two fiscal years at LLNL (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The average age for retirement separations is 62 years old. The average age for nonretirement separations is 46 years old.

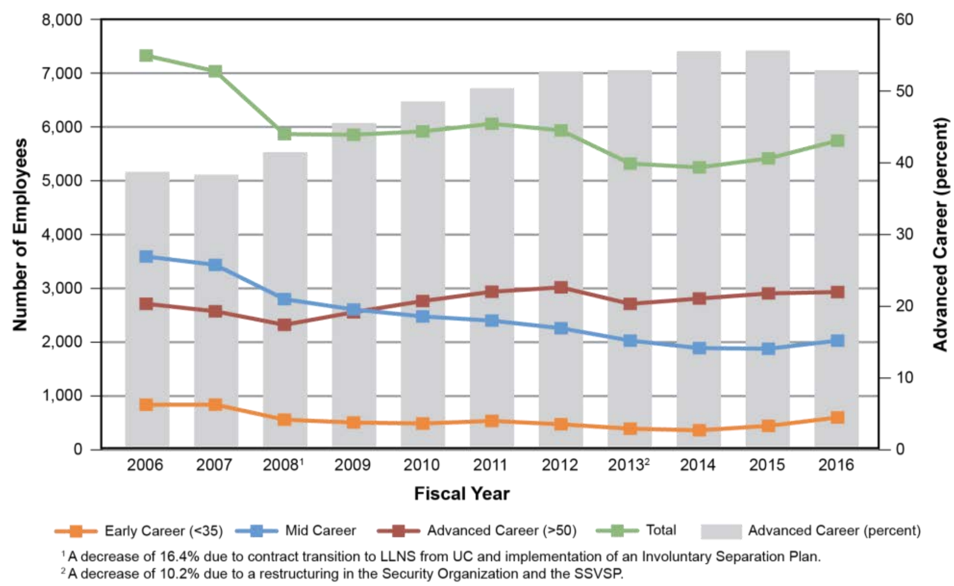
Figure E–5. Age of LLNL employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The average for years of service for retirement separations is 27.7. The average for years of service for nonretirement separations is 9.4 years.

Figure E–6. Years of service of LLNL employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

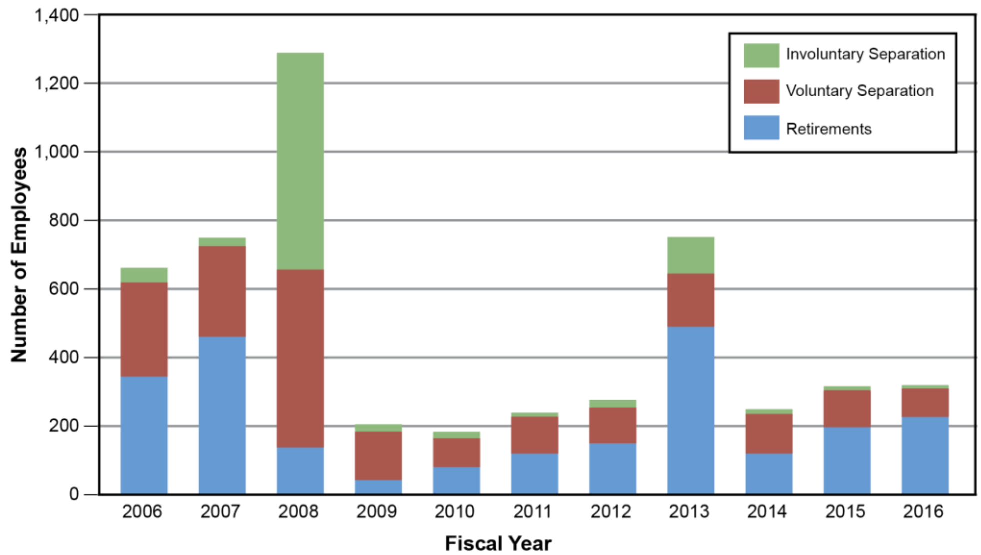
The biggest change in the population was during FY 2008, when LLNL went through a contract transition to Lawrence Livermore National Security, LLC, from the University of California, resulting in a 16.4 percent reduction in the workforce.

In FY 2013, LLNL experienced another significant decrease of 10.2 percent caused by a restructuring in the Security Organization and the self-select voluntary separation plan.

The LLNL aging population is also a concern; 52 percent are over 50 years old.

The LLNL strategy for knowledge preservation and succession planning is critical.

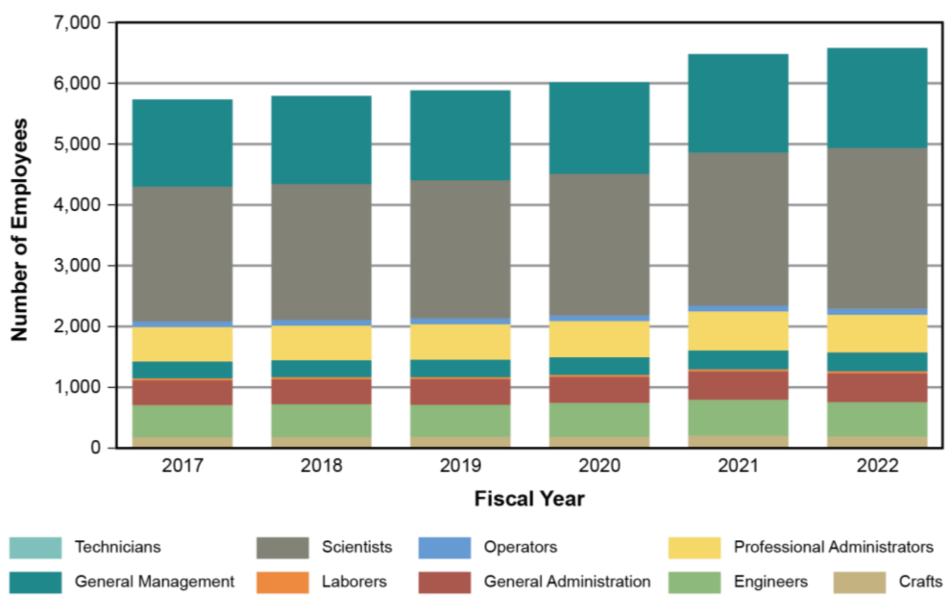
Figure E–7. LLNL trends by career stage



Notes:

The separations in FY 2008 were caused by the contract transition from the University of California to Lawrence Livermore National Security, LLC, and the associated involuntary separation program. The increase in FY 2013 was caused by restructuring in the Security Organization and the self-select voluntary separation plan.

Figure E–8. LLNL employment separation trends



Notes:

The LLNL workforce is projected to grow over the Future Years Nuclear Security Program period, particularly in FY 2021, in order to meet the laboratory missions and anticipated scope increase associated with the W80-4 Life Extension Program nuclear design and certification activities.

Figure E–9. Total projected LLNL workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

E.2.2 Los Alamos National Laboratory

E.2.2.1 Mission Overview

DOE sponsors Los Alamos National Laboratory (LANL) in Los Alamos, New Mexico, as an FFRDC. LANL champions four "science pillars": information science and technology, materials for the future, nuclear and particle futures, and the science of signatures. These pillars capture the laboratory's diverse array of scientific capabilities and expertise to address global challenges in national and economic security (including nuclear nonproliferation and counterterrorism), medicine and health sciences, and advanced computational capabilities as an FFRDC and participant in DOE's Strategic Partnership Projects.

Los Alamos National Laboratory

Los Alamos, NM

- Nuclear design/physics lab
- Pit, radioisotope thermoelectric generators, and detonator production
- Plutonium Center of Excellence
- Design agency for the B61, W76, W78, and W88

Los Alamos NATIONAL LABORATORY

- Location: Los Alamos, New Mexico
- Total Employees: 7,120
- Type: Multi-program national security laboratory
- Website: www.lanl.gov
- Contract Operator: Los Alamos National Security, LLC, a corporate subsidiary of Bechtel National, BWXT, University of California, and URS Corporation, an AECOM Company
- Responsible Field Office: Los Alamos Field Office

LANL Accomplishments

Life Extension Program (LEP) and Alteration (Alt) Design Agency

- *Maintained Phase 6.6 (Full-Scale Production) for the W76-1 LEP.*
- *Entered Phase 6.4 (Production Engineering) for the B61-12 LEP.*
- *Maintained schedule of Phase 6.3 and completed the Preliminary Design Review and Acceptance Group for the W88 Alt 370.*

Capital Acquisition Projects

- *Achieved beneficial occupancy at the Transuranic Waste Facility.*
- *Achieved Critical Decision-2/3 for the Chemistry and Metallurgy Research Replacement.*
- *Achieved Critical Decision-0 for the Enhanced Capability for Subcritical Experiments.*

Nuclear Facilities Operations

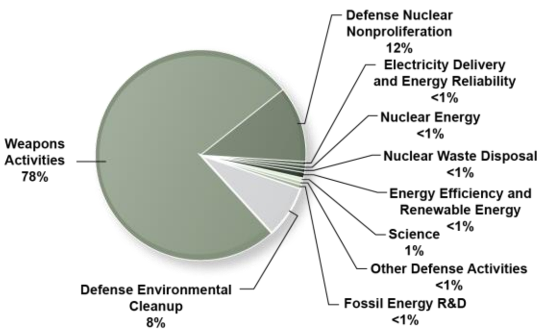
- *Conducted plutonium operations at the Plutonium Facility.*
- *Performed tritium operations at the Weapons Engineering Tritium Facility.*

Nuclear Weapon Component Production

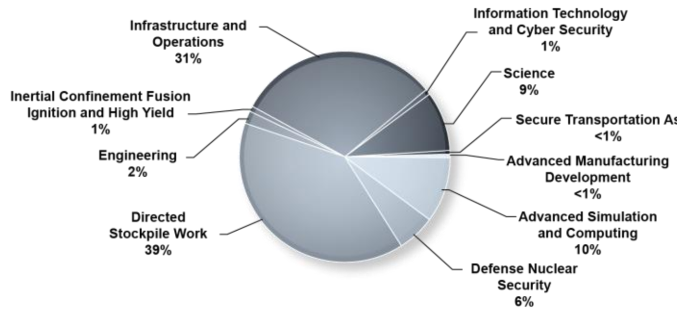
- *Greatly improved capacity and yield rate for War Reserve detonators.*
- *Reestablished the Nation's ability to manufacture radioisotope thermoelectric generators.*
- *Fabricated a production development pit.*

E.2.2.2 Funding

FY 2018 Request – Site Funding by Source
(Total LANL FY 2018 Request = $2,226.2 Million)



FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($1,728.3 Million)*



E.2.2.3 Site Capabilities

LANL is one of two nuclear design and physics laboratories in the nuclear security enterprise and the NNSA Center of Excellence for Plutonium. Core competencies at LANL include weapons physics design and analysis; weapons engineering, design, analysis, and integration; HED physics; materials science and engineering; and HPC. LANL is the lead design physics laboratory for the B61, W76, W78, and W88.

LANL operates several NNSA flagship facilities such as the Plutonium Facility Complex (Technical Area 55 [TA-55]), Nicholas Metropolis Center for Modeling and Simulation, Dual Axis Radiographic Hydrodynamic Test Facility (DARHT), Los Alamos Neutron Science Center (LANSCE), Uranium R&D Facility (Sigma), Center for Integrated Nanotechnologies, National High Magnetic Field Laboratory, and Waste Handling Facilities.

LANL unique capabilities in design, development, certification, and assessment of stockpile systems include the following.

<u>**Weapons Physics Design and Analysis**</u>

- **Capabilities.** LANL performs integrated, non-nuclear experiments on DARHT to measure the complex and dynamic aspects of implosion systems, shock physics, and high-velocity impacts. HE science facilities synthesize, formulate, and machine small-scale HE components. The HE firing sites are used for R&D and to obtain stockpile data. The HE detonator facilities provide the capability to design, develop, manufacture, and test detonator systems. HE radiography supports characterization of HE components for detonator fabrication, hydrodynamics testing at DARHT, and subcritical testing at the Nevada National Security Site.
- **Challenges.** Over the next 10 years, several investments are required at the design and certification facilities. DARHT requires investments to ensure continued reliability and enhance capabilities. HE science facilities are aging, and a number of investments, including infrastructure replacements and improvements, are needed to ensure operability. Investments are also needed in office and laboratory space.
- **Strategies and Path Forward.** Discussions with NNSA concerning the aging HE facilities have begun and will continue in the future. These discussions include considerations for replacing the majority of HE science facilities and equipment to support the Stockpile Responsiveness Program and to reduce operating footprint and infrastructure costs. Investments will be made to maintain

operations and reliability and improve the workplace at old facilities while LANL matures these plans.

Experiments

- **Capabilities.** LANSCE provides answers to fundamental questions in weapons research and supports a range of national security, energy security, and fundamental science missions by maintaining core technical competencies, including advanced materials science, particle-beam technology, and nuclear science. LANSCE is a multi-purpose, accelerator-based, national user facility. Scientists from around the Nation and the world use LANSCE for a broad range of defense and civilian research.
- **Challenges.** LANSCE's reliability has been under increasing stress over the past few years. Major components have become obsolete, demonstrated failure, and are operating years beyond their expected service lives.
- **Strategies and Path Forward.** The Linear Accelerator Risk Mitigation projects are an independent compilation of beamline and infrastructure maintenance projects to renovate and modernize the existing linear accelerator and its related systems. The projects will sustain reliable facility operations past 2020 for defense research and applications with a priority on dependable beam delivery. Work was initiated in FY 2011 for a portion of the projects. Additional reinvestments planned for the LANSCE area include correction of legacy fire protection and life safety issues, roof replacements on several facilities, replacement of infrastructure systems, and installation of additional shielding for the Ultracold Neutron facility.

  LANL is also planning a future signature experimental facility concept, MaRIE (Matter-Radiation Interactions in Extremes). This would provide an integrated approach to transforming the nuclear weapons enterprise by defining process-aware materials performance through predictive multi-scale understanding of materials with an emphasis on radiation-matter interactions. This strategy is currently in concept development. If adopted, these capabilities will further the ability to understand the condition of the stockpile and to extend the life of nuclear materials by observing and ultimately controlling how mesoscale material properties affect weapon performance.

Plutonium

- **Capabilities.** The plutonium core capability consists of plutonium production and process R&D, manufacturing, and radioactive waste disposition. LANL provides the only fully functioning plutonium facility for R&D and the only pit manufacturing capability within the nuclear security enterprise. LANL is a consolidated Center of Excellence for plutonium research, development, and manufacturing activities. The next War Reserve pit is scheduled for FY 2023.
- **Challenges.** Plutonium operations require increased capacity and modernized infrastructure.
- **Strategies and Path Forward.** LANL's plutonium strategy has been adopted by NNSA and endorsed by the Nuclear Weapons Council. The Chemistry and Metallurgy Research facility is continuing a small set of operations, with the goal of ceasing all programmatic work in anticipation of transferring these capabilities to the Radiological Laboratory Utility Office Building and the Plutonium Facility.

High Performance Computing

- **Capabilities.** This core capability provides computer modeling and prediction of weapons performance and material properties in regimes not accessible through experimentation. The Nicholas C. Metropolis Center for Modeling and Simulation houses Trinity, the first ATS for the

Advanced Simulation and Computing (ASC) Program. Trinity has 3 times more memory and 40 times more computing power than its predecessor, Cielo, which enables scientists to routinely use multi-dimensional simulations to increase understanding of complex physics as well as to improve confidence in the predictive capability for stockpile stewardship. Trinity runs the largest and most demanding workloads for modeling and simulation, including support for LEPs and significant finding investigations.

As an ATS, Trinity introduces key elements of technologies necessary as the stepping-stone toward exascale computing. Exascale computing, which is a DOE and a national priority, will provide a hundred times increase in computing capabilities over current computer platforms such as Trinity. Installation of Trinity began in 2015, and the complete system was providing computational capabilities in 2017.

- **Challenges.** Electrical capacity for mechanical cooling equipment and the amount and scale of computing required for future Directed Stockpile Work (DSW) needs are currently being upgraded in priority. A number of upgrade projects are under consideration at the Metropolis Center and in the electrical distribution utilities to provide adequate electrical capacity for future computing missions.

- **Strategies and Path Forward.** The addition of vulnerability assessments to the required simulation capabilities, as well as the increased importance of details of material properties are increasing the scale and amount of computing requested by DSW in the coming decades. Planning is ongoing for the 25-year timeframe to determine what facility reinvestments or new construction will be required to meet ASC mission needs.

  The 2020 Crossroads ATS requires more cooling than exists in the Metropolis Center. The Exascale Class Computer Cooling Equipment project is being pursued to provide the cooling necessary for the Crossroads ATS. The 2025 system, ATS-5, is not yet defined, but it is likely to be an exascale system that uses more electricity and cooling than will exist in the Metropolis Center in 2020. Initial planning for the required infrastructure has begun.

Los Alamos National Laboratory Centers of Excellence

Plutonium Facility (PF-4)

- PF-4 and the supporting plutonium infrastructure are the cornerstone capabilities for the National Nuclear Security Administration nuclear weapons programs.
- PF-4 provides pit manufacturing, pit surveillance, and supporting scientific analytical and material characterization functions.

Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility

- DARHT is the Nation's premier facility to test a full-scale implosion nuclear device (hydrodynamic test) using surrogate nuclear components.
- DARHT accelerators produce powerful x-ray pulses from two different axes to probe the implosion: five high-resolution images show the dynamic events that trigger the nuclear detonation.

Los Alamos Neutron Science Center (LANSCE)

- LANSCE is the Los Alamos National Laboratory flagship experimental facility for basic and applied nuclear science.
- LANSCE Complex, a national user facility, provides neutron sources to measure nuclear cross-sections, examines dynamic material responses under relevant weapons conditions, produces radioisotopes, and studies unique physics and fission experiments.

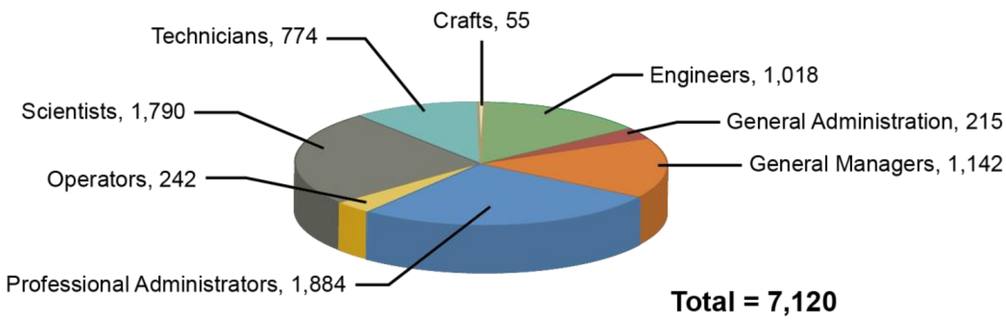
E.2.2.4 Accomplishments

In addition to the accomplishments summarized in Section E.2.2.1, other notable achievements include:

- producing two lots of war reserve detonators for the W76 and W88;
- collaborating and supporting production agencies to address qualification and acceptance of war reserve components (compression pads with KCNSC and canned assembly assets with Pantex);
- fabricating plutonium-238 fuel claddings for the National Aeronautics and Space Administration's Mars 2020 mission;
- recovering the radioactive material from 2,500 sealed sources from around the world;
- supporting Defense Nuclear Nonproliferation in its Nuclear Smuggling Detection and Deterrence Program with technical matters and data analysis;
- reconstituting centrifuge and blast tube facilities and recapitalizing a range of advanced diagnostics and testers for weapons materials and assembly evaluation and testing;
- collaborating with Atomic Weapons Establishment, LLNL, and SNL to transition the Joint Test Demonstrator from the planning to the execution phase;
- advancing the U.S. verification mission for detecting and understanding nuclear explosions through the Source Physics Experiment series at the Nevada National Security Site;
- executing experiments and field tests to support development of technical capabilities to detect, identify, and characterize foreign nuclear weapons; and
- providing leadership and technical authority on a range of major investment reviews, studies, and initiatives at the national and international levels—that is, for major acquisitions (mixed oxide, Uranium Processing Facility), weapons program future (Predictive Capability Framework, subcritical), and for experiments at other sites (Neutron Diagnosed Subcritical Experiment, NIF, Z [Z pulsed power facility]).

E.2.2.5 Los Alamos National Laboratory Workforce

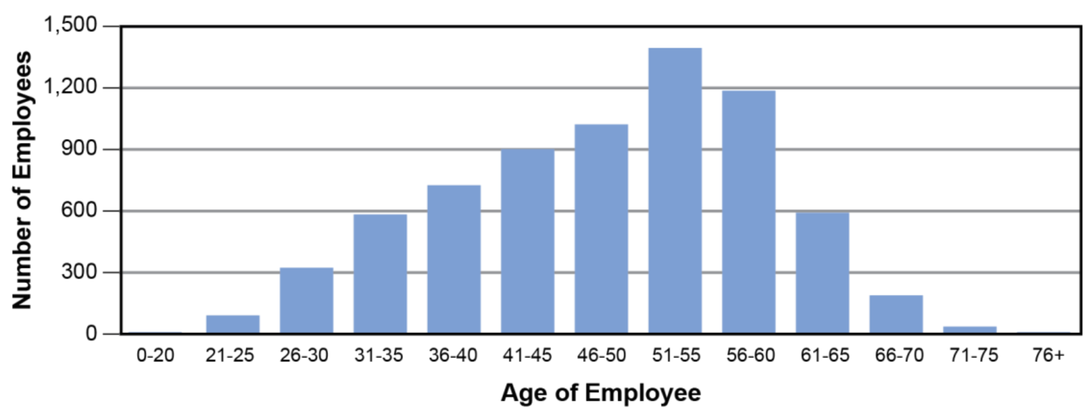
LANL has 7,120 employees, with an average age of 49 years and an average of 15 years of service. Approximately 50 percent of LANL's employees are eligible to retire. Since the end of FY 2014, LANL has hired 1,270 employees and experienced 879 separations, resulting in a net gain of 391. More than half of LANL's employee separations came through retirements, while most voluntary separations occurred among those with 15 years of service or less. Voluntary separations have remained constant while retirements have slowly increased since FY 2013. The number of early-career employees has remained relatively stable in the past few years, while mid-career employees have experienced a recent uptick after years of decline. LANL expects to maintain a stable workforce during the FYNSP period.



Notes:

LANL's shift in workforce skills toward engineers and scientists is intentional, increasing approximately 25 percent in engineers and almost 10 percent in scientists, while remaining nearly constant in professional administration and general management levels. These engineers and scientists are critical to meeting the production missions for the B61-12 Life Extension Program, the W88 Alteration 370, and components (*i.e.*, pits, radioisotope thermoelectric generators, and detonators).

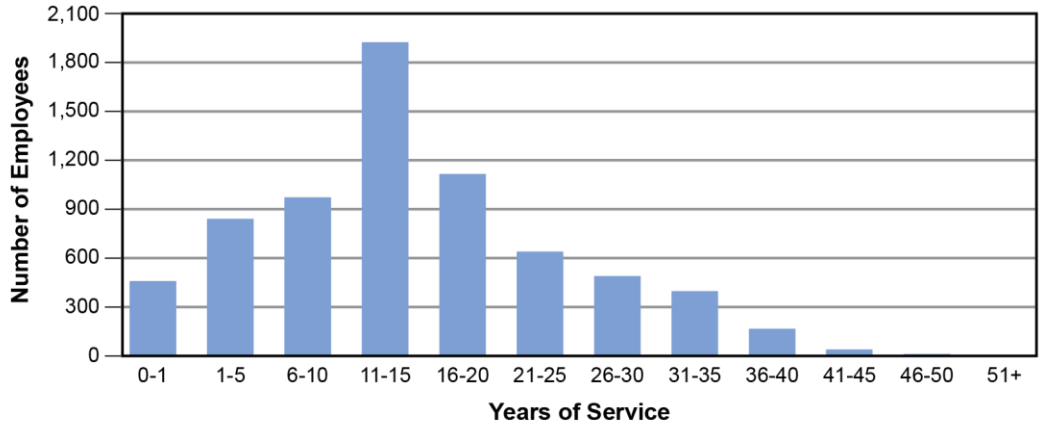
Figure E–10. LANL total workforce by Common Occupational Classification System



Notes:

The number of retirement-eligible employees is continuing to increase because of the aging workforce; over 50 percent of employees are now eligible for retirement. LANL continues to experience the impact of restricted hiring in the last several years. However, because of recent significant hiring of early-career employees coupled with the increasing number of retirements, the average age of the workforce has fallen by nearly 1 year.

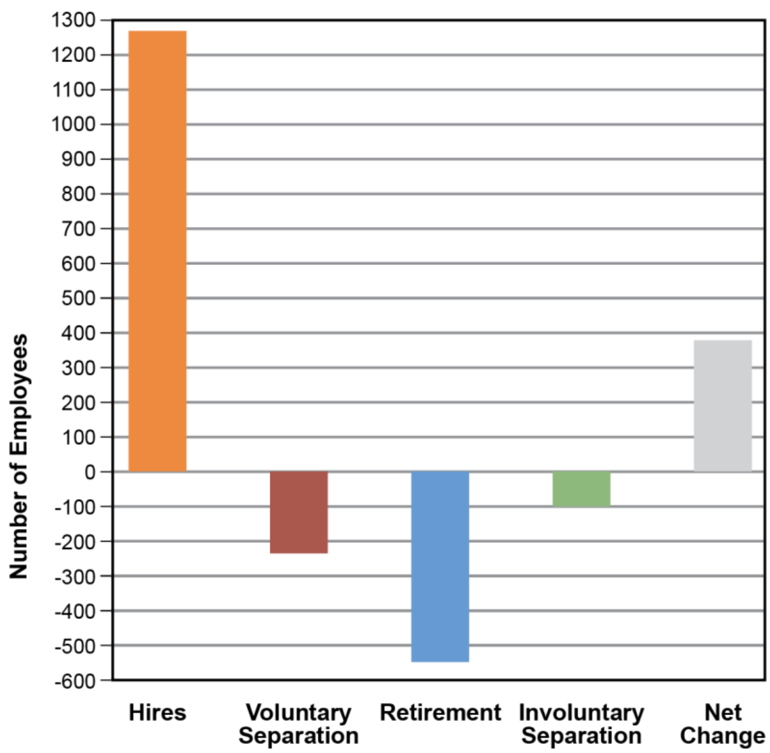
Figure E–11. LANL employees by age



Notes:

LANL's effort to hire a larger number of employees in FY 2016 is reflected in a substantial increase of employees with 0 to 5 years in service. LANL grants service credit to some employees in non-career status (*e.g.*, post-doctorate or limited-term employees); hence, if they are granted career status, it comes with pre-existing service time.

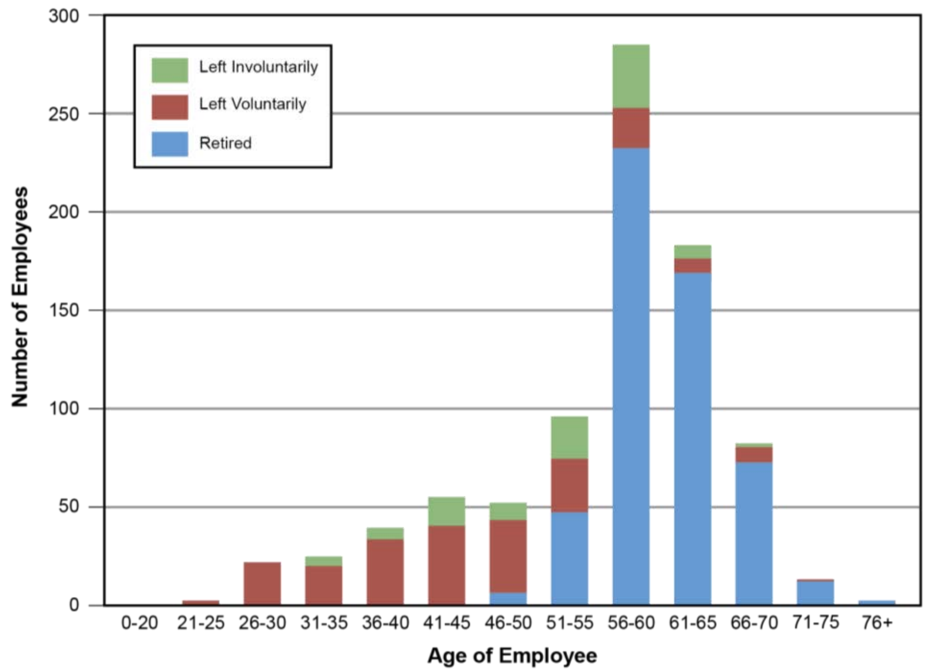
Figure E–12. LANL employees by years of service



Notes:

In the last few years, LANL's annual budget has stabilized and is steadily increasing. This has allowed LANL to shift from a shrinking workforce to an expanding workforce that not only replaces retirees but also grows the workforce in critical skills. In particular, LANL has hired a substantial number of early-career engineers and scientists.

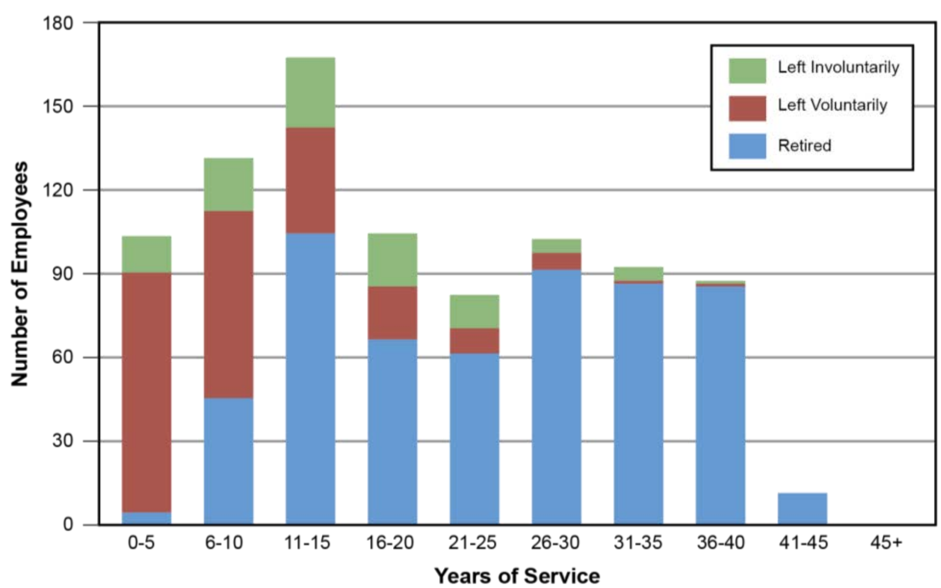
Figure E–13. Change in last two fiscal years at LANL (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

LANL retirements are increasing but are predictable and manageable with increased hiring. Retention of early- and mid-career employees is consistent with prior years and is at acceptable and manageable levels.

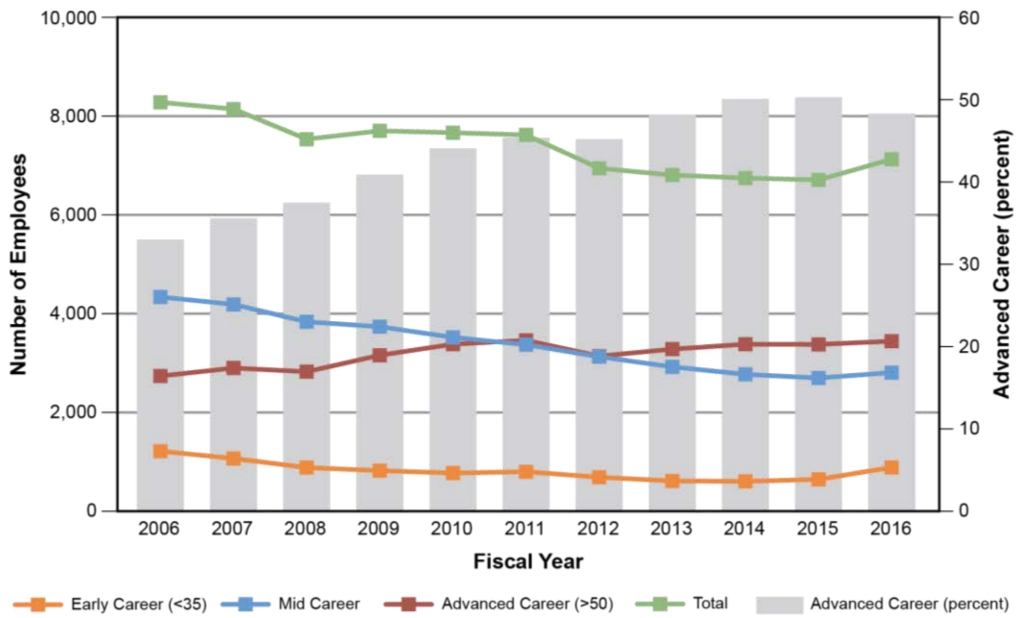
Figure E–14. Age of LANL employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The number of employees who leave LANL is fairly constant across the years of service. As expected, those with more service tend to retire while those with less service primarily leave voluntarily.

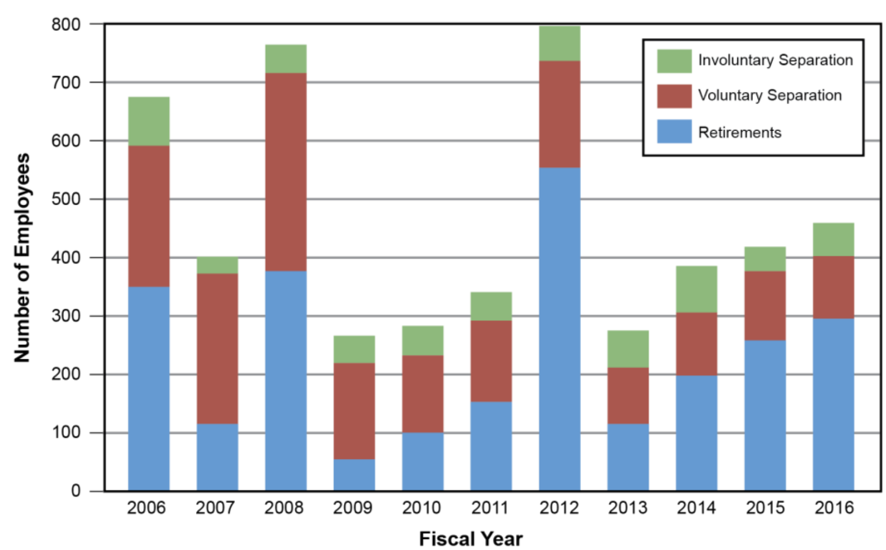
Figure E–15. Years of service of LANL employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The effect of the combination of increasing retirements and substantial hiring of early- and mid-career employees at LANL is clearly shown in the recent uptick in the percentage of staff in early- and mid-career status. Many of the new employees are engineers and scientists with the critical skills to meet the laboratory's diverse technical missions.

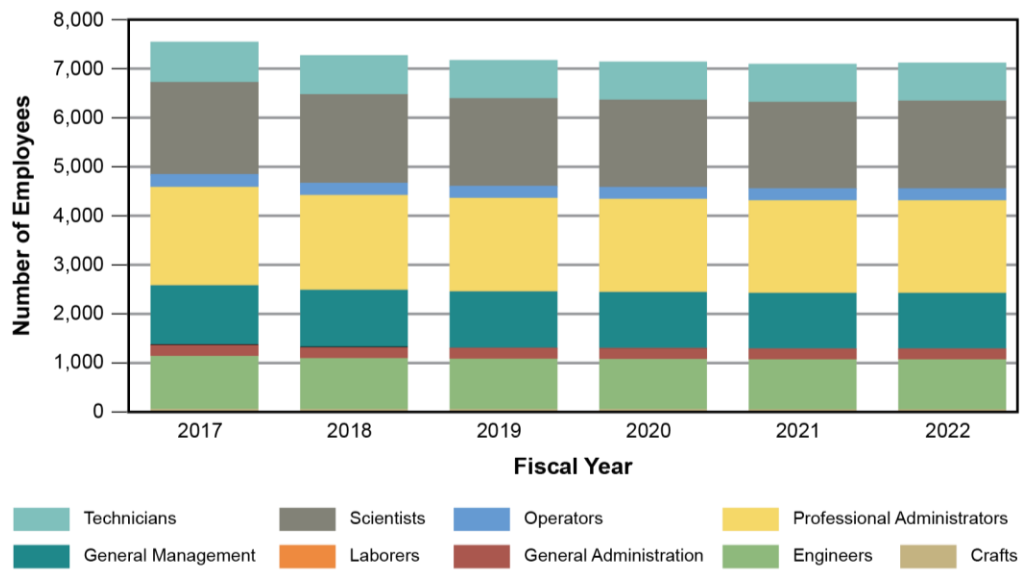
Figure E–16. LANL trends by career stage



Notes:

In FY 2014 through FY 2016, LANL experienced a slow but steady increase in the number of retirements per year. This is expected and reflects the aging workforce. The voluntary separations have remained fairly constant during the same period. The fairly predictable and consistent rate of separations has allowed LANL to establish hiring goals to not only offset the expected separations but to also grow the critical skills to meet the laboratory's missions.

Figure E–17. LANL employment separation trends



Notes:

LANL will continue to expand the workforce in FY 2017 as work on the B61-12 Life Extension Program and the W88 Alteration 370 peaks in the final years before weapon production starts. A slight decline in the workforce is expected from FY 2017 to FY 2018 associated with the award of the DOE Office of Environmental Management contract to manage legacy waste facilities. The workforce should remain fairly consistent after that adjustment.

Figure E–18. Total projected LANL workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

E.2.3 Sandia National Laboratories

E.2.3.1 Mission Overview

DOE sponsors Sandia National Laboratories (SNL) as an FFRDC to provide traditional, long-term nuclear weapons mission support. This includes research, design, development, qualification, testing, certification, and systems integration of all components to safely and securely arm, fuze, and fire a weapon to military specifications.

- Locations: Albuquerque, New Mexico; Livermore, California; Tonopah Test Range, Nevada; Kauai, Hawaii
- Total Employees: 10,656
- Type: Multi-program national security laboratory
- Website: www.sandia.gov
- Contract Operator:[1] National Technology & Engineering Solutions of Sandia (NTESS)
- Responsible Field Office: Sandia Field Office

Sandia National Laboratories Accomplishments

Stockpile Stewardship

- *Used modeling and simulation to understand and predict thermal battery performance, reliability, and safety to support assessments and reduce design time and costs.*
- *Partnered with KCNSC to produce prototype hardware with metal-based additive manufacturing to improve performance and provide an option for weapon-qualified parts.*

Life Extension Programs (LEPs)

- *Executed flight tests for the B61-12 LEP.*
- *Participated in Air Force Preliminary Design Review and Acceptance Group Reviews for the B61-12 LEP and the W88 Alteration 370.*

Experiments

- *Provided Z data comparing high-pressure behavior of new and aged plutonium for the B61-12.*
- *Conducted Thor intermediate-scale pulsed power material science experiments to develop a capability to evaluate the behavior of additively manufactured materials.*

Interagency Activities

- *Developed and supplied software for bomb technicians in law enforcement and the military to interpret the threat level of a suspect improvised explosive device.*
- *With LANL and Boeing, launched three payloads into orbit to monitor global nuclear detonations.*

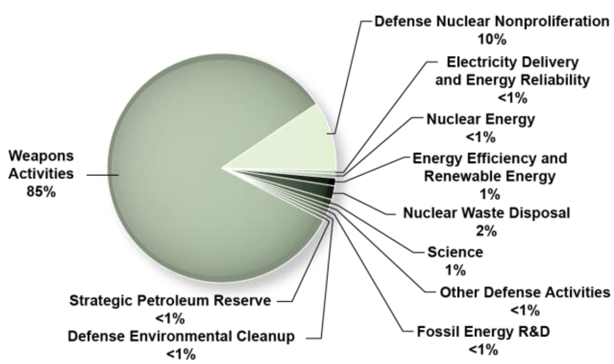
Professional Awards

- *Earned 10 R&D 100 Awards in 2016.*
- *SNL staff received nine prestigious national and international technical awards and more than a dozen staff were elevated to fellows of professional societies.*

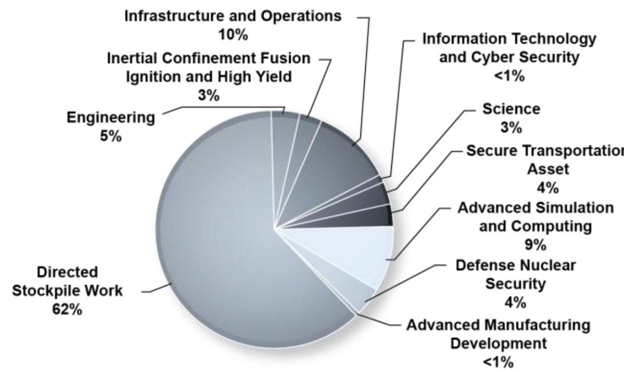
[1] Until April 30, 2017, Lockheed Martin operated the contract. NTESS, a wholly owned subsidiary of Honeywell International, is a consortium of Honeywell, Northrop Grumman Technical Services, Inc., University Research Association, and other partners.

E.2.3.2 Funding

FY 2018 Request – Site Funding by Source
(Total SNL FY 2018 Request = $2,085.8 Million)



FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($1,775.5 Million)*



E.2.3.3 Site Capabilities

SNL is involved in all LEPs and alterations (Alts) that are underway (W76-1 LEP, B61-12 LEP, W88 Alt 370, W80-4 LEP) and is responsible for the design to extend the life of the Safeguards Transporter and the design of its replacement (the Mobile Guardian Transporter) for secure transport of nuclear weapon materials and components to NNSA partner sites and Department of Defense (DOD) customer sites. SNL has production responsibilities for some weapon components (*e.g.*, neutron generators, trusted radiation-hardened microelectronics).

SNL's activities for other Federal agencies and for non-Federal entities leverage, sustain, and strengthen the unique capabilities, facilities, and essential skills that support both the Defense Programs mission and broader national security needs. The subset of SNL core and cross-cutting capabilities listed below reflect the most pressing challenges and associated strategies and are mapped to the NNSA Weapons Activities capabilities.

Warhead Systems Engineering and Integration of Non-Nuclear Components

- **Capability.** Systems engineering and integration are the core capabilities of Sandia's nuclear weapons program.
- **Challenge.** The capabilities, programs, people, and equipment are scattered around the SNL New Mexico site in aging Cold War-era facilities. Housing these people and programs needs increased priority to continue meeting mission needs.
- **Strategies and Path Forward.** Proactively engage with NNSA to ensure an integrated approach that collocates the capability assets for warhead system engineering and integration to improve efficiency and effectiveness.

Design, Development, and Qualification of Non-Nuclear Components for Alterations, Modifications, and Life Extension Programs

- **Capability.** Sandia designs, develops, and qualifies arming, fuzing, and firing (AF&F) systems, neutron generators, gas transfer systems (GTS), power sources, energetic components, and nuclear safety and security systems for Alts, modifications (Mods), and LEPs.

- **Challenge 1.** Threats by adversaries are evolving rapidly and unpredictably. Traditional weapon design development cycles are too long, impeding the ability to respond in a timely manner to emerging threats.
- **Strategies and Path Forward.** Seek ways to accelerate the development cycle and respond more quickly to emerging threats; participate in the Stockpile Responsiveness Program.
- **Challenge 2.** Manage the workforce as multiple LEPs and Alts transition from development to production.
- **Strategies and Path Forward.** SNL has developed and implemented a planning tool to estimate and project staffing needs and attrition.
- **Challenge 3.** Competition is high for electrical engineers and computer scientists.
- **Strategies and Path Forward.** Leverage campus and diversity recruiting programs to develop a pipeline of future generation warhead engineers.

Technology Development

- **Capability.** Technological progression of basic R&D to develop new or change existing weapon components and processes as a result of sunset technologies and tools.
- **Challenge.** Major life extension activities have focused laboratory attention and resources on near-term deliveries, making maturation of new technologies and components difficult.
- **Strategies and Path Forward.** Seek opportunities to advance technology development in a broad range of program venues, including the Strategic Partnership Program, Laboratory Directed Research and Development, and NNSA programs such as Stockpile Responsiveness Program and R&D Certification and Safety.

Production of Non-Nuclear Components

- **Capability.** Sandia produces neutron generators, radiation-hardened microelectronics, power sources, and trusted specialty components for nuclear weapons.
- **Challenge.** Maintain power source R&D and production capabilities.
- **Strategies and Path Forward.** Proactively engage with NNSA to ensure an integrated approach to resolving facility challenges. Developed an Integrated Facilities and Infrastructure Plan to capture infrastructure needs and define priorities.

Surety Assessment, Surveillance Evaluations, and Stockpile Maintenance

- **Capability.** In its stockpile stewardship role, Sandia partakes in surety assessments, surveillance evaluations, and stockpile maintenance to assess nuclear weapon systems and detect or anticipate potential problems.
- **Challenge.** Maintaining surveillance testing capabilities.
- **Strategies and Path Forward.** Proactively engage with NNSA to ensure an integrated approach to resolving this facility challenge. Developed an Integrated Facilities and Infrastructure Plan to capture infrastructure needs and define priorities.

Radiation-Hardened Microelectronics Design and Manufacturing

- **Capability.** Trusted, strategic, radiation-hardened advanced microelectronics (*i.e.*, nanoscale and microscale system science, engineering, and technology).

- **Challenge.** Trusted microelectronics fabrication facilities are aging and past design life.
- **Strategies and Path Forward.** Complete SNL Silicon Fabrication Revitalization and sustainment initiatives to replace and modernize capabilities and equipment in the Microsystems and Engineering Sciences Applications (MESA) facility to bridge the gap until 2025; support NNSA in planning for Trusted Microsystems Capability to maintain R&D capability and ensure uninterrupted ability to produce radiation-hardened microelectronics.

Material Science and Engineering

- **Capability.** Virtually every class of non-nuclear materials, including metals, polymers, glasses, ceramics, and electronic and optical materials, as well as their interfaces and interactions with their environments, are critical to the safety, security, and effectiveness of the U.S. nuclear weapon stockpile. This capability at SNL includes (1) evaluation of materials for aging, compatibility, and model validation to resolve stockpile and production issues rapidly and (2) innovation to replace legacy materials and to evaluate new materials for insertion into the stockpile.
- **Challenge 1.** SNL must support evaluating materials' aging, compatibility, and model validation and sustain the innovation necessary to replace legacy materials and evaluate new materials for insertion into the stockpile.
- **Strategies and Path Forward.** SNL must advance material science R&D for response to evolving threats and future needs. This includes developing new capabilities to enhance our understanding of the characterization, structure, and processing of materials in order to evaluate their behavior and performance in the current and future stockpile and for future applications in additive manufacturing.
- **Challenge 2.** The material science and engineering facility at SNL California needs increased priority to continue meeting mission need and does not meet modern seismic and other building code standards.
- **Strategies and Path Forward.** Proactively engage with NNSA to ensure an integrated approach to resolving facility challenges. Developed an Integrated Facilities and Infrastructure Plan to capture infrastructure needs and define priorities.
- **Challenge 3.** The current generation of materials scientists is approaching the end of their careers. The number of students seeking advanced degrees in material disciplines who choose to enter and work within the nuclear security enterprise may not be sufficient to meet future workforce needs. Competition is high for scientists and engineers qualified in these disciplines.
- **Strategies and Path Forward.** Leverage campus and diversity recruiting programs to develop a pipeline of future-generation material scientists and engineers.

Environmental Effects Analysis, Testing, and Engineering Sciences

- **Capability.** Evaluation of the effects of operational and abnormal environments on nuclear weapon systems and components using an array of engineering science test equipment, tools, and techniques.
- **Challenge.** The workload imposed by concurrent LEPs is stressing the capacity and capability of aging facilities and equipment, thereby accelerating replacement needs. Experimental test capabilities to validate data models require more and higher-fidelity data to enable stronger coupling with integrated design codes (IDCs).

- **Strategies and Path Forward.** Select facility and equipment investments to ensure continuity of engineering sciences capability. Support enhancement of the predictive capability by tightening the coupling and integration between modelers and the data necessary for model validation.

Radiation Effects Science

- **Capability.** Radiation effects research and testing to support certification.
- **Challenge 1.** The Annular Core Research Reactor delivers high-power, short bursts of neutron and combined neutron-gamma spectra to qualify designs under extreme combined radiation environments. The facility housing the reactor is older than 50 years and predates modern nuclear safety standards.
- **Strategies and Path Forward**. Proactively engage with NNSA to ensure an integrated approach to resolving this facility challenge. Developed an Integrated Facilities and Infrastructure Plan to capture infrastructure needs and define priorities.
- **Challenge 2.** Competition is high for certain specialists in radiation effects science.
- **Strategies and Path Forward.** Develop a pipeline of scientific and engineering expertise *via* campus and diversity recruiting programs to secure highly talented graduates.

High Energy Density Physics

- **Capability.** Pulsed power science, engineering, and technologies.
- **Challenge.** Next-generation pulsed power experimental capabilities are needed to ensure models that validate safe, secure, and reliable performance of the Nation's weapons.
- **Strategies and Path Forward.** Develop experimental and theoretical basis to provide confidence that the next-generation pulsed power experimental capability will attain needed pressures and fusion yields.

High-Performance Computing and Computational Science and Engineering

- **Capability.** Modeling and simulation capabilities of physical phenomena.
- **Challenge 1.** Enhance predictive capabilities of IDCs to support design, development, qualification, and assessments of non-nuclear components and systems for normal (including hostile) and abnormal environments.
- **Strategies and Path Forward.** Participate in the DOE Exascale Computing initiative; design and conduct experiments to support validation of IDCs that increase understanding of the physical phenomena and close the gap between models and the physical world.
- **Challenge 2.** Competition for high-demand disciplines, such as computational modeling with an emphasis on engineering analysis, makes recruiting, training, and retaining technical staff increasingly challenging.
- **Strategies and Path Forward.** Leverage campus and diversity recruiting programs to develop a pipeline of future generation HPC scientists and engineers.

Sandia National Laboratories

Commodity Technology Systems (CTS-1)

- CTS-1 was procured via a National Nuclear Security Administration/ Advanced Simulation and Computing (ASC) tri-lab competitive procurement.
- Serrano and Cayenne each provide approximately 1.3 petaFLOPS of peak computing.
- These systems deliver robust, cost-effective computing to meet the needs of the Nuclear Weapons/ASC program.

Microsystems and Engineering Sciences Application (MESA) Facility

- The mission of MESA is to develop beyond-leading-edge trusted microsystems technologies to enable new and increasingly powerful macro-system capability and functionality for critical national security platforms.
- Extensive scientific and engineering expertise, in areas such as material growth and process development for silicon and compounds, device and product design, advanced packaging technologies for three-dimensional integration, reliability, and failure analysis, makes possible the custom trusted solutions that Sandia National Laboratories delivers to the Nation today.

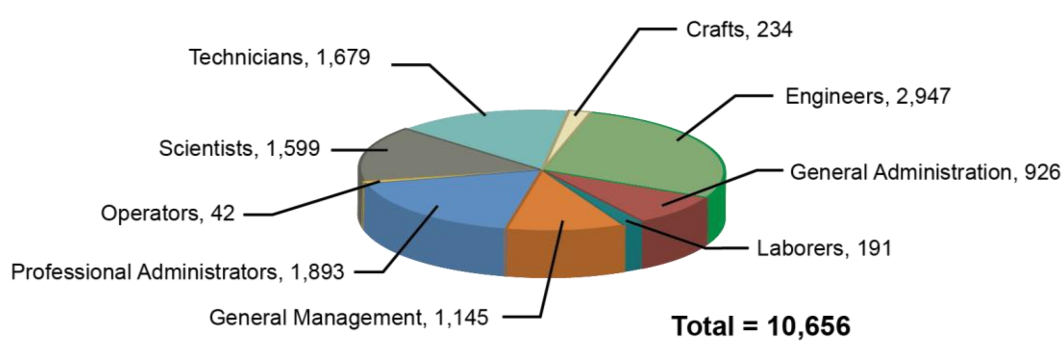
E.2.3.4 Accomplishments

- Continued executive of multiple LEPs and Alts on budget and schedule.
- Executed flight tests for the B61-12 LEP to ensure dual aircraft capability, and implemented nuclear enterprise assurance measures to enhance nuclear safety and security.
- Tested, in multiple flights, a small transmitter for the Navy that has improved power efficiency.
- Developed a chemical process to impart radiation tolerance to Mylar films and improve production rates. These films are used in modern nuclear systems as pulse discharge capacitors to ensure reliable safety performance in abnormal thermal environments.
- Developed software that allows bomb technicians in law enforcement and the military to look inside a suspect improvised explosive device and interpret the threat level.
- Developed a new technology using advanced additive manufacturing (PLAtinum Topology Optimization) that promises to change the mechanical design approach by placing material only where needed (*e.g.*, optimizing stiffness-to-weight ratios when space is at a premium).
- Achieved world's best fidelity levels for a two-qubit gate using trapped ions in devices from SNL's MESA facility. These states are exquisitely delicate; the ability to control them can eventually unlock the potential of quantum computation.
- Launched three payloads into orbit, with LANL and Boeing, to monitor nuclear detonations. The latest generation of the display system was certified for use by the U.S. Strategic Command.
- Partnered with Harvard to build the first quantum computer bridge (a key step in creating the first useful quantum computer) by embedding two silicon atoms in a diamond matrix in SNL's Ion Beam Laboratory.
- More than a dozen employees were named fellows of various technical and professional societies.

- Developed the Sandia Cooler, which reduces the energy to cool processor chips in large-scale computing environments. The cooler is 30 times more efficient than conventional air-cooled heat exchangers and is available for licensing to electronics and solid-state lighting manufacturers.
- Created a memzyme technology with the University of New Mexico to capture carbon dioxide (CO_2) from coal- and gas-fired electricity plants with a bubble-like membrane to reduce CO_2 emissions efficiently. The new membrane is 100 times faster in passing flue gas than current membranes on the market and 10 to 100 times more selective for CO_2 over nitrogen, the main component of flue gas.
- Partnered with the National Renewable Energy Laboratory to develop a device to reduce the time to commission new hydrogen fuel stations from months to 1 week.
- Developed arrays of microneedles integrated with electrochemical biosensors to monitor an individual's health in real time by analyzing interstitial fluid sampled through the skin.

E.2.3.5 Sandia National Laboratories Detailed Workforce

SNL has 10,656 employees, with an average age of approximately 46 years, and the majority have 15 years of service or less. Approximately 20 percent of SNL's employees are eligible to retire. A large proportion of the workforce is 56 years and older. Since the end of FY 2014, SNL hired 1,767 employees and experienced 1,117 separations, resulting in a net gain of 650. Of the separations, most were voluntary or retirements, with most voluntary separations among those aged 50 or younger (and the largest portion of those with 0 to 5 years of service) and most retirements among those aged 51 and older. Retirements increased in FY 2015 and FY 2016, while voluntary and involuntary separations have remained relatively constant since FY 2013. The total population has increased steadily since FY 2009, while early-, mid-, and advanced-career employees have remained largely stable with steady increases. SNL expects a consistent workforce over the FYNSP period.

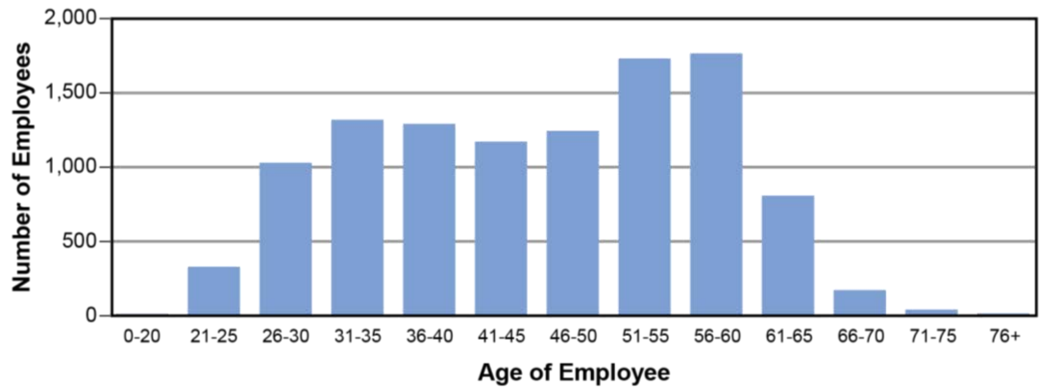


Notes:

Approximately 62 percent of SNL's workforce are aligned with technical duties and responsibilities ranging from research and development to applied engineering to operations. Fifty-five percent of the workforce have advanced degrees.

SNL uses a systems integration approach to workforce assignments. Team members are matrixed to support key mission areas, including Strategic Partnership Projects.

Figure E–19. SNL total workforce by Common Occupational Classification System



Notes:

The average age of the employee population is 46.2 years. A large proportion of the population is aged 56 and above (25.5 percent). Approximately 12.4 percent of the population are aged 30 or less. The remaining 62.1 percent are between the ages of 31 and 55.

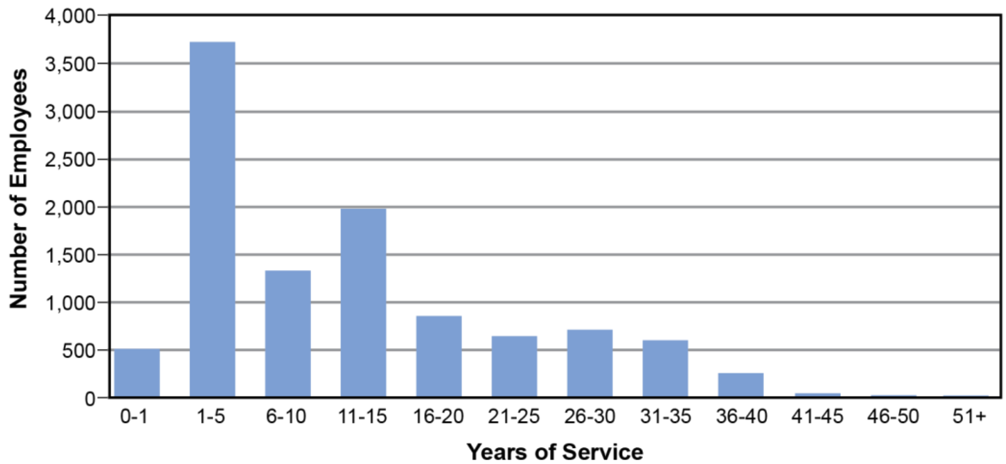
About one-fifth (19.8 percent) of SNL's employees are retirement eligible; that proportion has remained stable over the last 2 years.

The bimodal age distribution has lessened in recent years because of increased hiring of experienced professionals to meet skill gaps. While the bimodal distribution is not extreme, it is more pronounced in several categories (*i.e.*, engineers and, to a lesser extent, scientists and professional administrators). SNL is taking this into account through a Knowledge Development Program, which includes mentoring, knowledge transfer, and, especially, actively engaging in mission work such as LEPs and Alts.

The FY 2017 and FY 2018 hiring projections reflect a mix of hires between experienced and new college graduates to meet skill gaps. SNL is experiencing some challenges in attracting and hiring personnel in science, technology, engineering, and mathematics because of increased competition from the private sector.

Based on the age distribution, an increase in retirements is anticipated. These openings will place increased pressure on recruiting future talent as well as retention of SNL employees.

Figure E–20. SNL employees by age

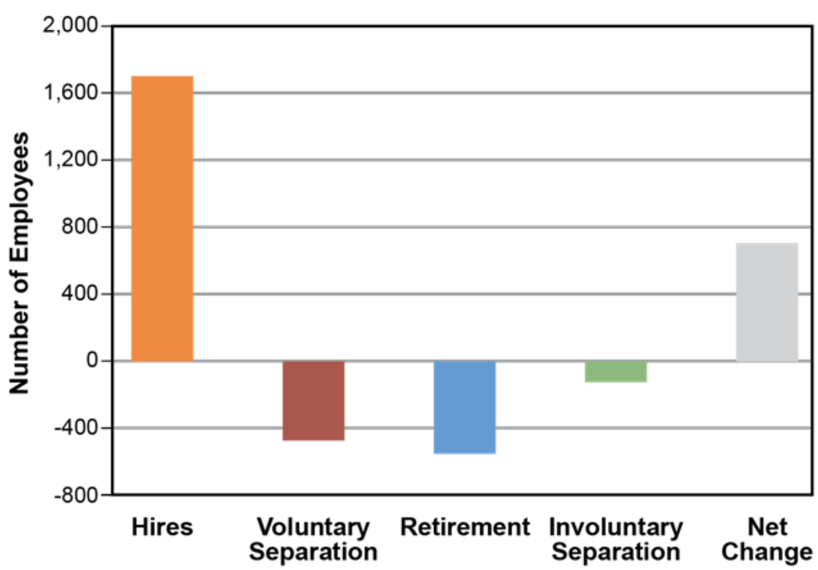


Notes:

Approximately 71 percent of personnel have 15 or less years of service. Approximately 40 percent have less than 5 years of service. These numbers reflect hiring more than 3,699 new regular employees over the last 5 years (FY 2012 through FY 2016).

The mix of experienced and new college graduates ensures that the skills and capabilities are present to support SNL's mission work. Strong hiring over the past 5 years ensures that a substantial percentage of employees are in earlier phases of their careers to replace those in later career phases.

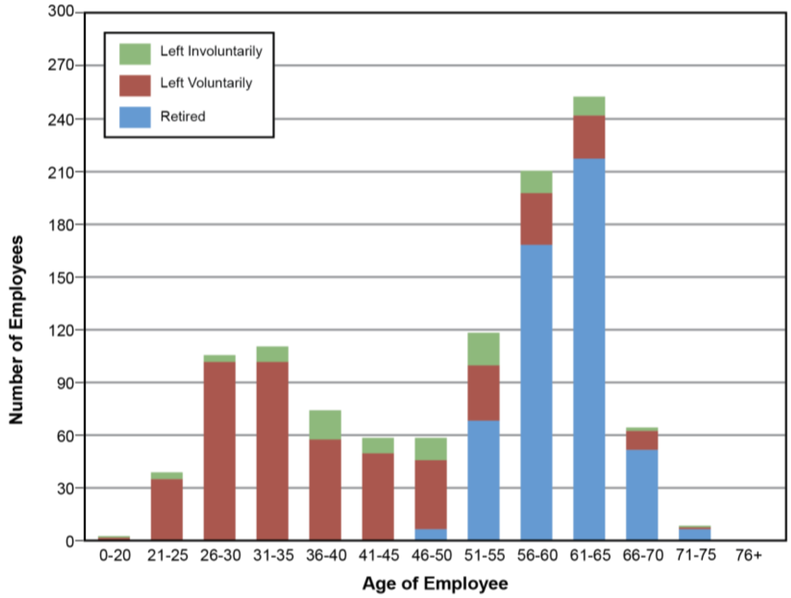
Figure E–21. SNL employees by years of service



Notes:

A net change of 650 reflects continued robust hiring efforts during FY 2015 and FY 2016 to meet mission demands. Most of this growth is attributable to growing mission scope related to stockpile modernization through life extension program activities and some growth in Strategic Partnership Projects.

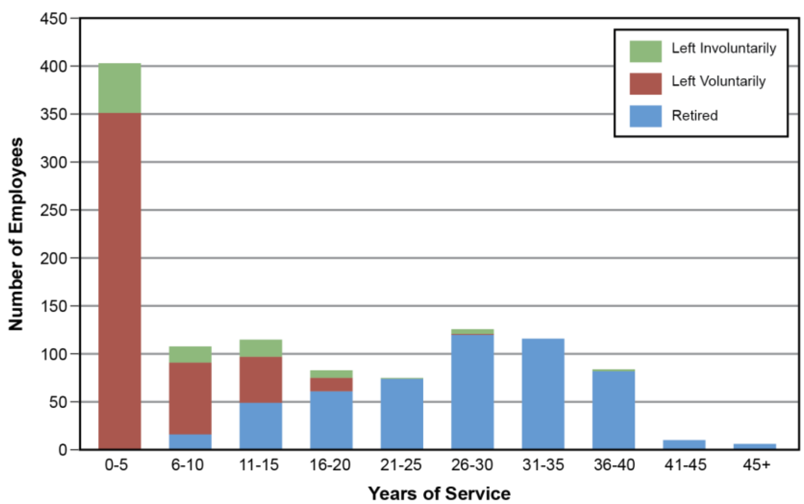
Figure E–22. Change in last two fiscal years at SNL (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

Voluntary separations are clustered in the younger age groups, with 42 percent between the ages of 26 and 35. Higher numbers of retirements are reflected in the age groups between 51 and 75 years of age, which represents 46 percent of separated employees in FY 2015 and FY 2016.

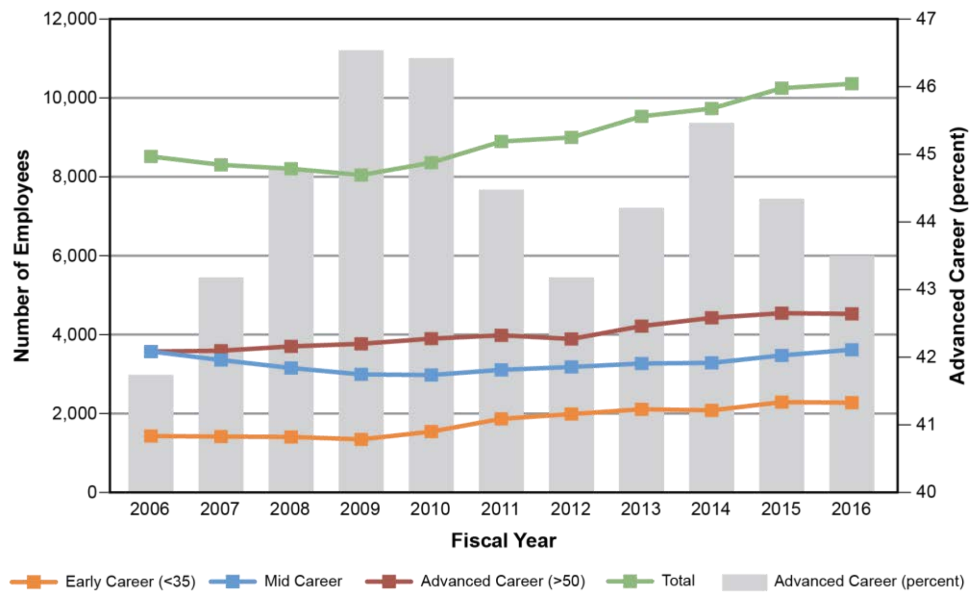
Figure E–23. Age of SNL employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

Of the voluntary employee separations, 72 percent had 5 or less years of service, 87 percent had 0 to 10 years of service, and 97 percent had 15 or less years of service. This turnover may reflect the external demand for skills and highly competitive value propositions in other companies. These losses place increased importance on a speedier clearance process, training programs, and knowledge transfer to be able to train new staff entering SNL.

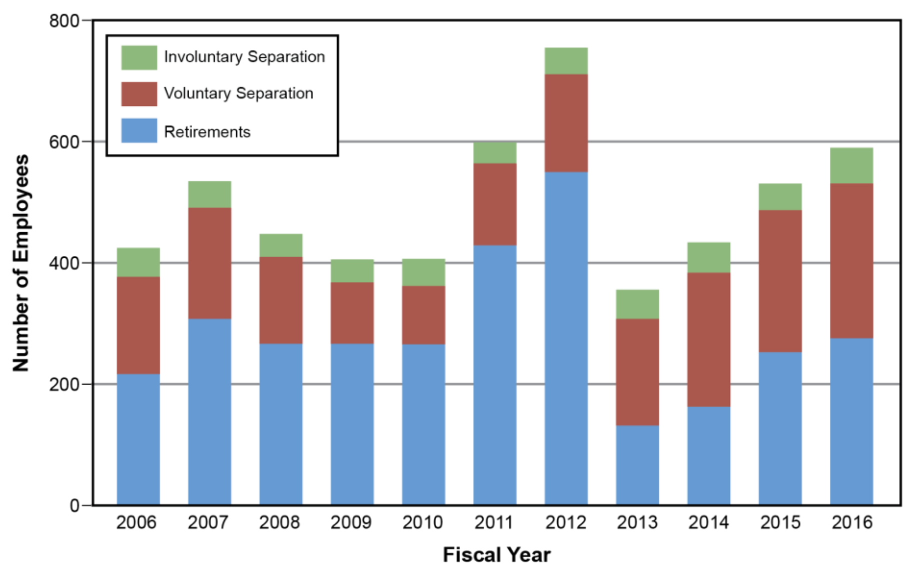
Figure E–24. Years of service of SNL employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The upward trend for all career stages reflects increased hiring to staff growing mission programs.

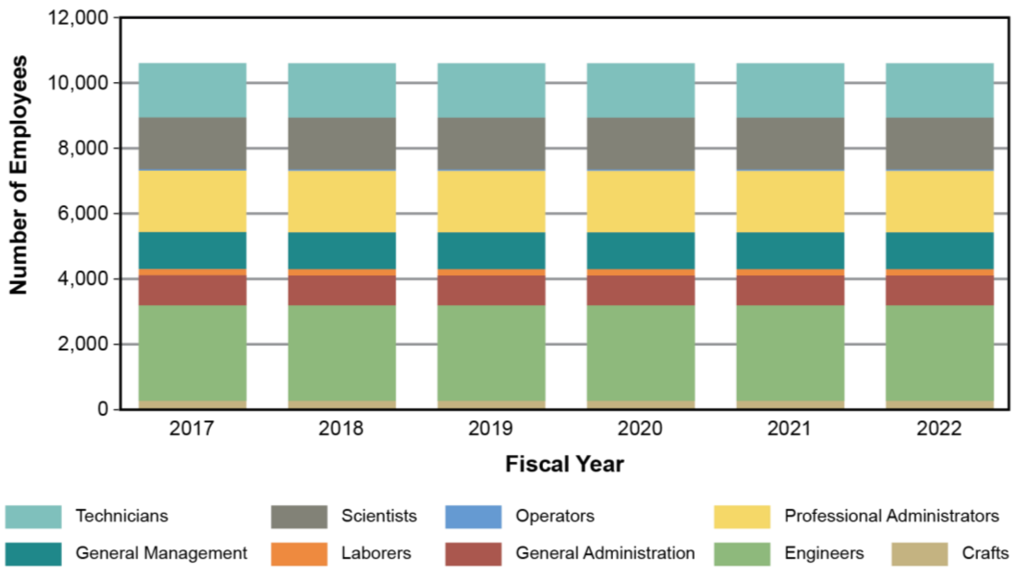
Figure E–25. SNL trends by career stage



Notes:

Retirements were higher in FY 2007, FY 2011, and FY 2012 because of announced changes in retiree benefits, which encouraged some employees to leave early. The surge in retirement in FY 2011 and FY 2012 resulted in reduced retirements in FY 2013 and FY 2014. Retirements increased in FY 2015 and FY 2016, as expected, as SNL returned to historical retirement rates. With the SNL contract changing in FY 2017, an increase in retirements may occur. This area will be closely monitored by SNL, and increased hiring may be required to address the exits.

Figure E–26. SNL employment separation trends



Notes:

The workforce is not only a function of workload but retirement, separation, and internal movement as well. SNL expects to maintain its total workforce at a nearly constant level from FY 2018 to the end of the Future Years Nuclear Security Program (FYNSP). SNL will monitor workload fluctuations and manage the stability of the workforce by leveraging the Strategic Partnership Program, temporary staffing positions, cross-training within programs, and strategic hiring. Beyond the FYNSP, SNL's best estimate of workload suggests a continued flat trend. SNL will also manage the stability of the workforce through the Strategic Partnership Projects.

Figure E–27. Total projected SNL workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

E.3 Nuclear Weapons Production Facilities

E.3.1 Kansas City National Security Campus

E.3.1.1 Mission Overview

Kansas City National Security Campus (KCNSC) is responsible for manufacturing and procuring 85 percent of non-nuclear weapon components of the nuclear stockpile, including electronic, mechanical, and engineered materials. A large portion of the new 1.5 million square foot, state-of-the-art facility is dedicated to this task. KCNSC's Global Security mission also involves the development of field-ready engineering solutions for other government agencies' national security missions.

- Locations: Kansas City, Missouri; Albuquerque, New Mexico
- Total Employees: 3,077
- Type: Multi-program nuclear weapons production facility
- Website: www.kcp.com
- Contract Operator: Honeywell Federal Manufacturing &Technologies
- Responsible Field Office: Kansas City Field Office

KCNSC Accomplishments

Nuclear Weapon Stockpile

- *Delivered over 185,500 components on time at 99. 9 percent, including gas transfer system deliverables at 100 percent.*
- *Improved escorting efficiencies, established training and qualification spaces, and created a Manufacturing Innovation Center to enable new hires to contribute to the weapons mission while awaiting their clearances.*

Cost Savings

- *Printed 25,000th development item since inception of the Digital Manufacturing initiative 3 years ago, avoiding more than $45 million in costs for life extension programs.*
- *Achieved savings of $162 million, exceeding FY 2016 target of $102 million at the Supply Chain Management Center.*

Infrastructure

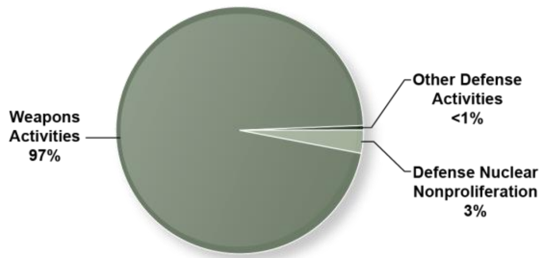
- *Completed personal property removal from Bannister for $10.4 million less than estimate, completed all requalification activities after the Kansas City Responsive Infrastructure Manufacturing and Sourcing facility relocation project.*

Nuclear Threat Reduction

- *Developed and implemented a respirator program and Radiological Worker II recertification class for responders, yielding over $100,000 in savings per fiscal year.*
- *Provided missile, enrichment, chemical/biological, and nanotechnology training to 158 personnel, supporting eight languages.*
- *Continued support of the Office of Packaging and Transportation and the Atomic Weapons Enterprise, for production of Type B fissile material shipping containers.*

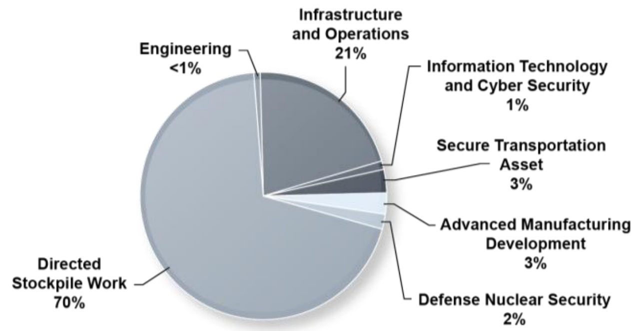
E.3.1.2 Funding

FY 2018 Request – Site Funding by Source
(Total KCNSC FY 2018 Request = $663.7 Million)



Note: KCNSC funding includes Infrastructure and Operations resources found in the Kansas City Site Office Laboratory Table.

FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($641.3 Million)*



E.3.1.3 Site Capabilities

KCNSC's capabilities support weapon systems currently in the stockpile as well as those being modernized *via* LEPs, Alts, and Mods. For legacy systems, these activities includes DSW in the management, production, processing, and delivery of hardware for limited life component exchanges and flight test systems, surveillance testing of components and materials, and maintenance and repair of weapons systems. For future stockpile systems, KCNSC's work scope includes development and maturation of manufacturing processes and technologies, production of prototypes to support design development, and manufacturing of components and systems.

The items produced and procured at KCNSC generally make up over 80 percent of the components in a nuclear weapon. KCNSC's capabilities are used to research and develop new materials for legacy and future stockpile systems. Production capabilities include over 40 manufacturing technologies and manufacturing over 1,000 unique product families, including AF&F devices, safing devices, microcircuits, machined parts, polymers, plastics, and other engineered materials. KCNSC also designs, develops, and produces associated support equipment, tooling, and fixtures.

KCNSC provides capabilities integral to the Stockpile Stewardship Program and the Stockpile Responsiveness Program. KCNSC's primary capabilities include the following.

<u>**Non-Nuclear Weapon Component Manufacturing and Assembly**</u>

- **Capability.** KCNSC is the primary site for manufacturing and procuring non-nuclear components including AF&F systems, GTS, environmental sensing devices and stronglinks, and structural components and cushions made from engineered materials. The capability to manufacture and inspect these items is highly dependent upon specialized equipment and facilities (cleanrooms, environmentally controlled areas, *etc.*) and the ability to maintain them (*i.e.*, calibration and metrology).
- **Challenges.** Balancing the growing maintenance needs of aging production equipment with the needs for emerging production technology for the LEPs.
- **Strategies and Path Forward.** Continuing to plan and budget through various funding sources including programmatic and infrastructure-related investment projects.

Weapon Component and Material Process Science

- **Capability.** KCNSC plays a key role in developing and implementing new processes and materials to support the manufacture of components because of obsolescence, cost, or flowtime improvements or to support new designs. A thorough characterization and application of adequate controls over a new process or material is necessary for accurate prediction of the process output or material performance over a wide range of environmental conditions that might be encountered during a weapon's life cycle.
- **Challenges.** The Engineering Program and the Advanced Manufacturing Development Program enable new technologies to support the Stockpile Stewardship Program. In maintaining production and LEP schedules, the challenges include the complexities of technology maturation and process development, as well as balancing priorities to ensure a continued source of adequate funding.
- **Strategies and Path Forward.** Continue to partner with the design agencies to emphasize identification and early process and material development in advance of weapon program design.

Testing Equipment Design and Fabrication

- **Capability.** A key capability is to design and produce testing equipment to support KCNSC's mission and that of the other sites within the nuclear security enterprise. Often, these testing systems are integrated with various types of environmental conditioning equipment, such as thermal chambers or centrifuges, to perform automated testing for weapon environments. These testing systems are vital to the development, qualification, and acceptance of weapon systems and components.
- **Challenges.** A key challenge is the cyclical workload, which is very heavy during the development phases and lighter during the production phases.
- **Strategies and Path Forward.** Emphasize level loading of the workload to the extent possible, combined with providing flexibility in assignments, to maintain the specialized workforce in this area. Opportunities for challenging work assignments include the Strategic Partnership Projects.

Fabrication and Support of Secure Transportation Assets

- **Capability.** KCNSC prepares secure transportation asset (STA) vehicles in its New Mexico facility, including fabrication, repair, and modification of tractors, trailers, and escort vehicles. KCNSC also supports the design, fabrication, and maintenance of multiple system capabilities and facilitates safety engineering, technical documentation, and training of the Federal agents that perform STA functions.
- **Challenges.** Challenges include manufacturability and sourcing limitations of future secure transportation programs, which could increase cost and schedule risks.
- **Strategies and Path Forward.** Continue to partner with Design Agencies to ensure that, early in the process, the design work incorporates lessons learned from past trailer production and manufacturability reviews and facilitates multiple-sourcing capabilities to reduce risks and costs.

Advanced Manufacturing Research and Development

- **Capability.** KCNSC performs R&D activities to design, develop, characterize, and deploy next-generation production processes and manufacturing tools to reduce cost and flowtime, improve safety and efficiency, and eliminate waste streams. This includes original research as well as leveraging the latest manufacturing technologies from industry and academia.

- **Challenges.** KCNSC's growing workload requires investments in process development and technology maturation.
- **Strategies and Path Forward.** Continue to partner with Design Agencies to increase the focus on identification and early process and material development in advance of weapon program designs.

Weapon Component Surveillance and Assessment

- **Capability.** KCNSC supports the surveillance and assessment of the Nation's nuclear weapons stockpile through enhanced testing of various weapon components and materials, as well as production of telemetry, joint test assemblies (JTAs), and other hardware for laboratory and flight testing. The results from those tests are used to demonstrate continued performance of stockpile systems and to predict, detect, assess, and resolve aging trends and anomalies in the stockpile. New testing and evaluation methods are also developed and implemented.

  KCNSC developed and demonstrated new processes to disassemble components from legacy firing set assemblies, allowing testing at lower levels of assembly and providing additional surveillance data. KCNSC also developed new test methods to study and better understand changes to polymer material properties during aging. These capabilities improve detection of issues and characterization of new materials for future weapons systems.
- **Challenges.** Challenges to this capability include continuing to maintain test systems well beyond the production cycle to support surveillance tests. Site-wide challenges that affect multiple capabilities include the ability to recruit and retain a skilled, diverse, and effective workforce in proportion to the increased workload that is coming along with the emerging LEP and Alt programs. This challenge lies in the difficulty of providing meaningful work during the extensive time it takes to obtain a security clearance and places a strain on limited office space at KCNSC.
- **Strategies and Path Forward.** Strategies to address these challenges include replacing select test equipment and modernizing test equipment capabilities.

Site-Wide Challenges of the Workforce Associated with Multiple Capabilities

- **Challenges.** Site-wide challenges that affect multiple capabilities include the ability to recruit and retain a skilled, diverse, and effective workforce in proportion to the increased workload with the LEPs and Alts. Providing meaningful work is difficult during the extensive time required to obtain a security clearance and also places a strain on the limited office space at KCNSC.
- **Strategies and Path Forward.** Some strategies being implemented to assist with recruiting include a strong university relations program, involvement in R&D partnerships and consortiums, and recruitment from area trade schools. Improvements in rewards and recognition programs along with an emphasis on pay for performance and employee engagement actions, such as flexible arrangements for mobile workers and flexible work hours, help to improve retention. Establishing priority and interim clearances for key workers helps to minimize the impact of long clearance times. Strategies aligned with remedying the office space challenge include acquiring leased off-site office space and innovations in the use of a mobile workforce.

Kansas City National Security Campus

- Primary mission is dedicated to delivering mission-critical mechanical, electrical, and engineered material components and services. Over 80 percent of all stockpile components are provided by the Kansas City National Security Campus (KCNSC). These capabilities are housed in the new KCNSC facility, which is privately owned and leased to the government.
- Capabilities are grouped in a number of Centers of Excellence, which include Electrical Products, Mechanical Products, Materials, Simulation & Modeling, and Test Equipment & Measuring Technology. These centers support technology development and readiness, design development, production development, production, sustainment, surveillance, and dismantlement and disposal of Directed Stockpile Work products and supporting test equipment, as well as trainers, simulators, and ancillary equipment for both the nuclear security enterprise and Department of Defense.
- Capabilities at our New Mexico facilities include manufacture, refurbishment, and maintenance/sustainment of equipment required for Secure Transportation.
- We extend our unique expertise and capabilities to benefit national security and promote nonproliferation with field-ready solutions for other government agencies.
- By catalyzing the Department of Energy and National Nuclear Security Administration Management and Operating partner community to behave like a buying consortium to use our innovative and collaborative strategic sourcing processes, we enable the sites to leverage their annual spending to save millions each year.

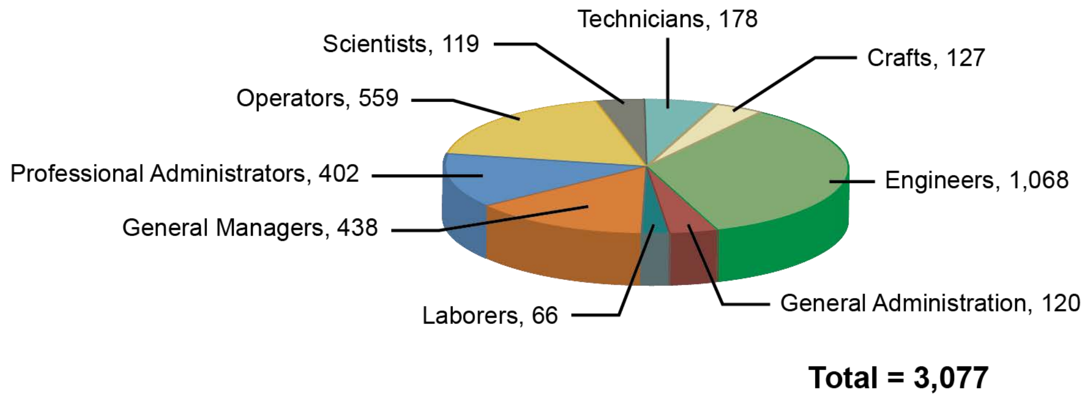
E.3.1.4 Accomplishments

- Delivered over 185,500 pieces at an on-time delivery rate of 99.9 percent, including 100 percent for GTS deliverables. Made 85 percent of deliveries early, exceeding the planned ship dates by an average of 12 days to reduce the schedule risk by allowing more time for receipt and movement at the assembly sites.
- Advanced the key components of digital manufacturing, including additive manufacturing, topology optimization, and materials research. Effective use of advanced manufacturing technologies is enabling accelerated development builds at lower cost and with fewer staff.
- Printed the 25,000th development item since the inception of the Digital Manufacturing Initiative 3 years ago, thereby avoiding more than $45 million in development costs for LEPs.
- Saved more than 40,000 engineering hours by use of the Common Tester Architecture, resulting in a combined cost avoidance of $5.5 million for the W88 Alt 370 and B61-12 LEP tester programs.
- Initiated and maintained partnerships and consortiums with universities and industry in research areas including radio frequency and radar technologies, polymeric materials, and advanced and digital manufacturing.
- Submitted 92 invention disclosures internally, filed 33 patent applications, and was issued 3 patents, 2 trademarks, and 1 copyright. Received seven Defense Programs Awards of Excellence recognizing 70 employees.
- Developed and deployed a new, interactive web-based training system for STA and implemented a new communication system ahead of schedule.

- Technical Fellows continued studies at eight universities in FY 2016. Three new fellows were selected to start in FY 2017.
- Enabled newly hired staff to contribute over 38,000 hours of direct work to the weapon mission while waiting on individual clearances in FY 2016. Used innovative security plans that improved escorting efficiencies and incorporated 63 interim clearances, established training and qualification spaces on the factory floor, and created the Manufacturing Innovation Center to facilitate the onboarding process for new employees awaiting clearances.
- Achieved over 3 million hours worked without a "days away from work" case.
- Completed personal property removal from the old Bannister Federal Complex for $10.4 million less than the original estimate.
- Completed all requalification activities following the Kansas City Responsive Infrastructure Manufacturing and Sourcing relocation project.
- Planned, constructed, and occupied the Recapitalization project to extend 15 percent humidity controlled space for major electrical fabrication work; completed project ahead of schedule and at half the original cost reserve.
- Transitioned the Roof Asset Management program to a greater scope, thereby expanding the cost savings to a broader infrastructure across the nuclear security enterprise.
- Completed independent audits by International Organization for Standardization (ISO) 9001, ISO 14001, and Occupational Health and Safety Assessment Series 18001; KCNSC had zero findings and eight noteworthy practices, highlighting continuous improvement efforts.
- The Supply Chain Management Center produced cost savings of $162 million, exceeding the FY 2016 target of $102 million.
- Developed supply chain risk management strategies under the Nuclear Enterprise Assurance initiative that are being implemented throughout the nuclear security enterprise.
- Hosted a supply chain management meeting focused on New Mexico-based small businesses, with participation from the NNSA Administrator and the office of New Mexico Senator Martin Heinrich, to enhance DOE/NNSA's reputation as a small business-friendly partner.

E.3.1.5 Kansas City National Security Campus Workforce

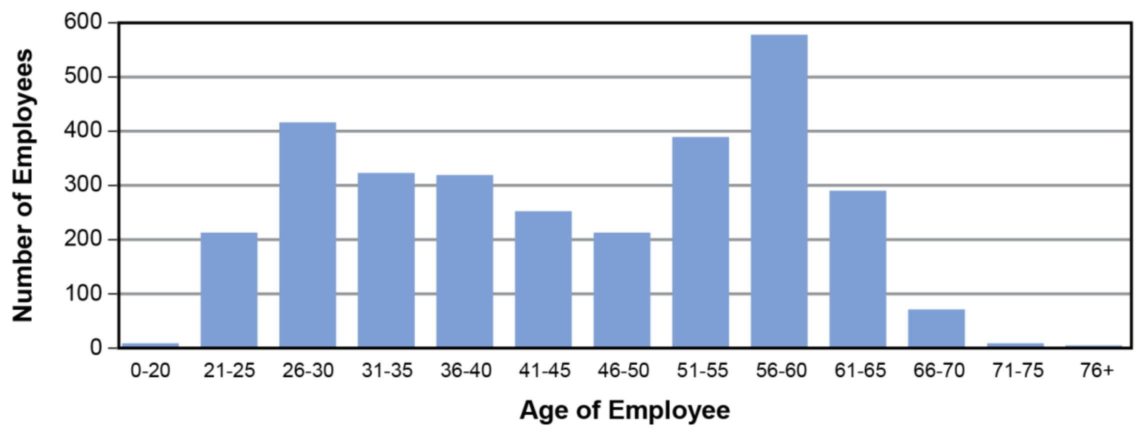
KCNSC has 3,077 employees, with an average age of 45 years and most employees having 15 or fewer years of service. Approximately 32 percent of KCNSC's employees are eligible to retire. KCNSC has a bimodal distribution for employee age; most employees have 1 to 5 years of service. Since the end of FY 2015, KCNSC hired 976 workers and experienced 486 separations, resulting in a net gain of 490. Of those separations, many were voluntary separations by early career employees while many advanced-career employees retired. Thirty-nine percent of separations were by employees with less than 5 years of service. Separations are trending upward at KCNSC, with a recent spike in FY 2014 because of a plan to increase efficiencies. Since FY 2011, the number of advanced- and mid-career employees has remained stable with slight fluctuations. Except for FY 2014, the number of early-career employees has steadily increased since FY 2011. KCNSC will continue to add staff over the FYNSP period as the workload for LEPs and Alts increases.



Notes:

KCNSC is continuing its focus on hiring employees to support emerging life extension programs, modifications, and alterations. The total workforce of 3,077 is an increase of 490 employees (18.9 percent) from FY 2014 and an increase of 388 employees (14.4 percent) in FY 2015.

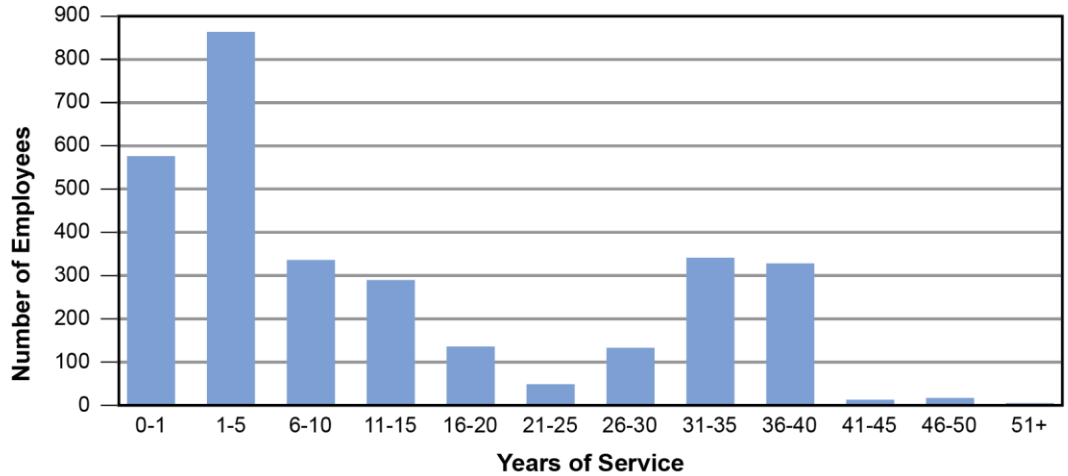
Figure E–28. KCNSC total workforce by Common Occupational Classification System



Notes:

The distribution of the staff by age continues to be bimodal, with most in their late 50s and the next highest group in their late 20s. The late-20s group now exceeds the early-50s group for the first time. This reflects the hiring effort to support emerging programs and replace ongoing attrition. Over 34 percent of engineers and scientists are over age 50 (down from 39 percent in FY 2015), and 50.6 percent of the operators and technicians are over age 50 (down from 61 percent in FY 2015). The average age of the workforce is 45.5 years, down from 47.2 in FY 2015. The workforce eligible to retire under the current benefits plan is 32.3 percent, down from 39.2 percent a year ago. Not all employees take an early retirement option. Projected retirements are less than 20 percent based on current trends.

Figure E–29. KCNSC employees by age



Notes:

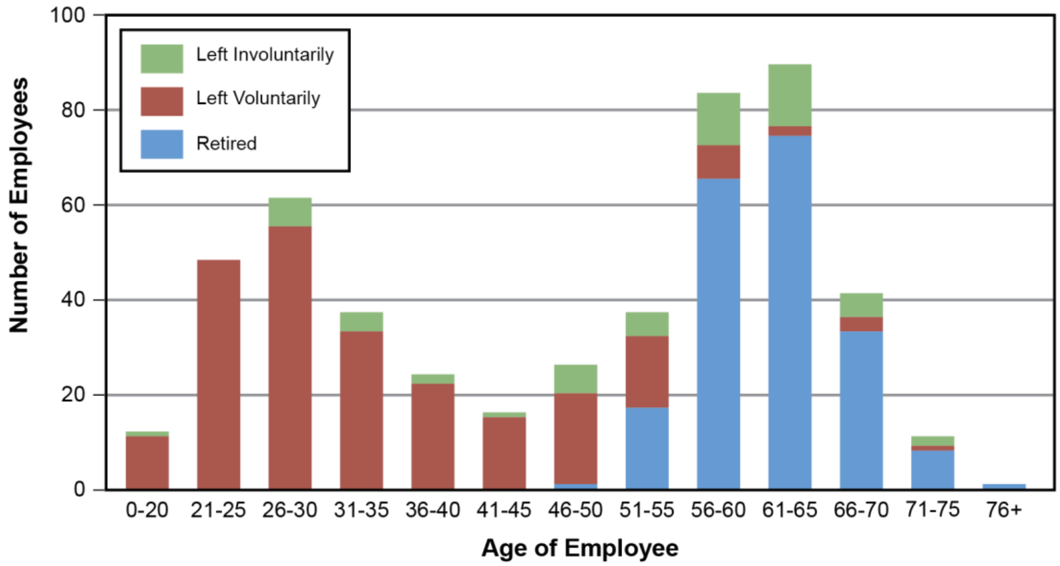
The distribution of employees by years of service continues to be bimodal and reflects recent hiring to support emerging programs as well as recent retirements. Nearly half (47 percent) of all employees have 5 years or less experience. The number of employees with less than 1 year of experience has nearly doubled in the last year, going from 291 to 578. Over 20 percent of engineers and scientists have 25 years or more of service, as do 31 percent of operators and technicians.

Figure E–30. KCNSC employees by years of service

Notes:

KCNSC had a net increase of 490 employees in the FY 2014 to FY 2016 reporting period (102 in FY 2015 and 388 in FY 2016). Forty-one percent of the decreases were from retirements.

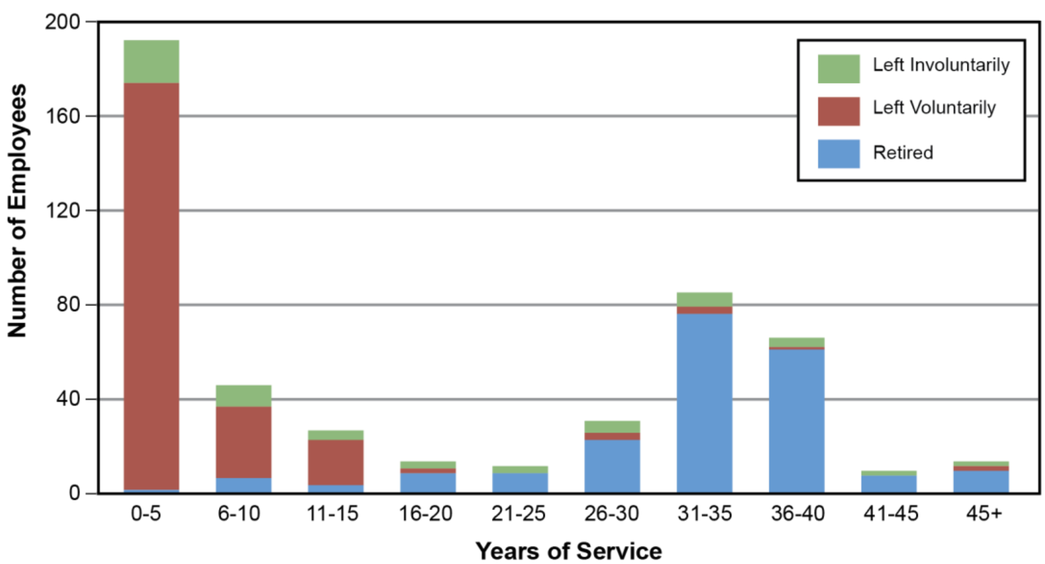
Figure E–31. Change in last two fiscal years at KCNSC (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

A total of 486 employees separated from KCNSC during the FY 2014 to FY 2016 reporting period (256 in FY 2015 and 230 in FY 2016). Most voluntary separations are by young employees, while the overall attrition has remained at less than 10 percent.

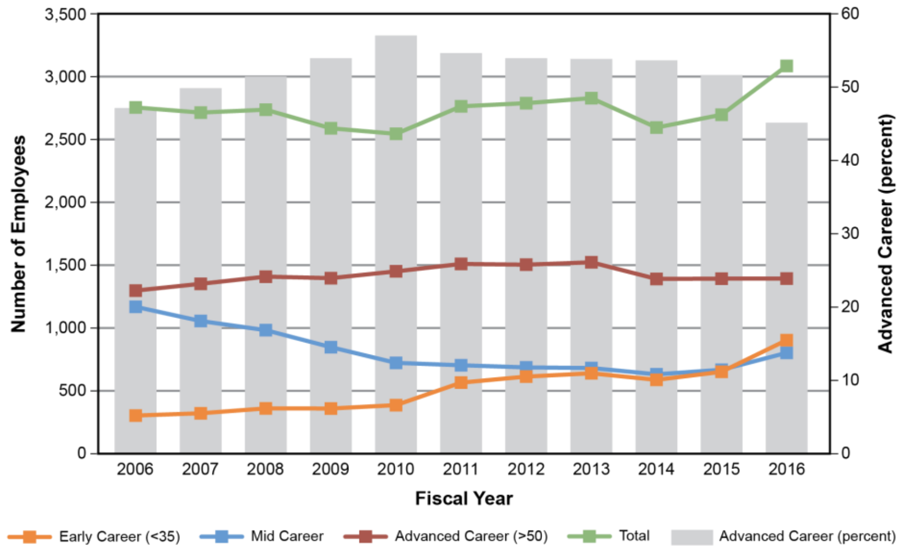
Figure E–32. Age of KCNSC employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

A total of 486 employees separated from KCNSC over the FY 2014 to FY 2016 reporting period (256 in FY 2015 and 230 in FY 2016). Thirty-nine percent of the separations were from employees with less than 5 years of service.

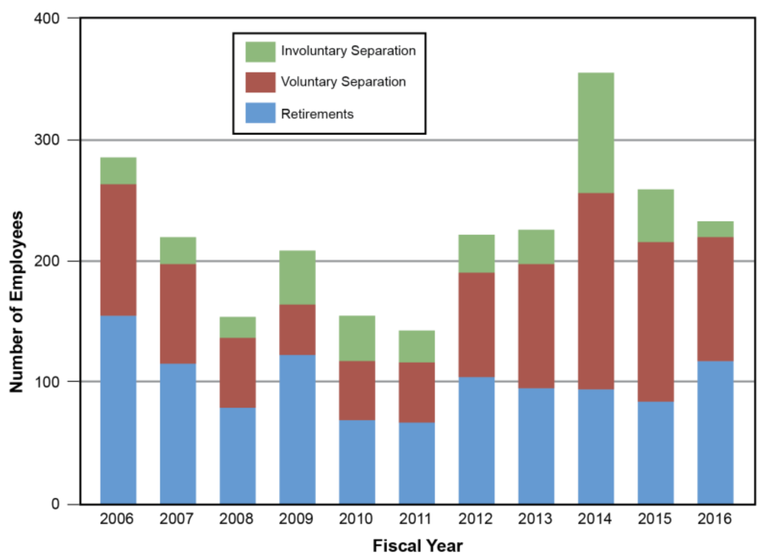
Figure E–33. Years of service of KCNSC employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The growth trend for KCNSC continues, fueled by a targeted hiring effort to staff for future work scope, including the B61-12 Life Extension Program (LEP), the W88 Alteration 370, and the W80-4 LEP. Because of the increased hiring, especially of recent college graduates, the percentage of employees in the advanced-career stage has decreased from 51.5 percent to 45 percent and the percentage of employees in the early-career stage has increased from 24 percent to 29 percent.

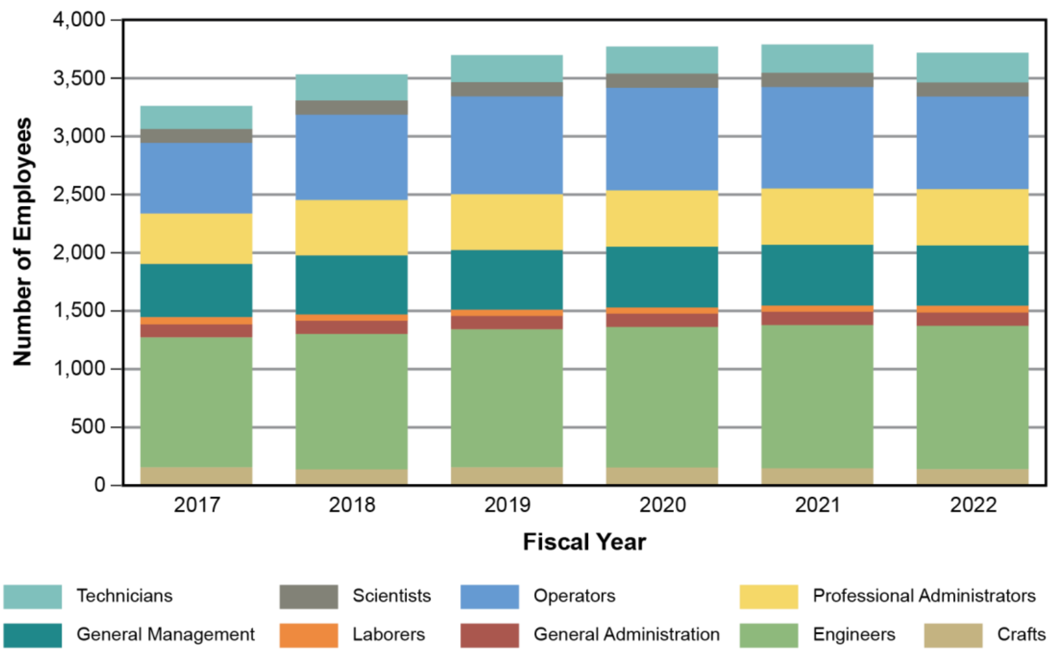
Figure E–34. KCNSC trends by career stage



Notes:

Employee separations continue to trend upward but are comparable with pre-Kansas City Responsive Infrastructure Manufacturing and Sourcing levels. The spike in FY 2014 is associated with planned separations because of the Kansas City Responsive Infrastructure Manufacturing and Sourcing facility plan for increased efficiencies and requiring fewer workers for facility maintenance. Other spikes in separation have occurred. For instance, in FY 2006 nearly 45 percent of the retirements were from bargaining unit employees, even though only 33 percent of all employees that year were represented by the union. This was likely driven by changes in the bargaining unit contract.

Figure E–35. KCNSC employment separation trends



Notes:

KCNSC will continue to add staff in anticipation of the increased workload associated with life extension programs and alterations (Alts) (*i.e.,* B61-12, W88 Alt 370, W80-4, Mark 21 Fuze). We are continuing the strategy to "pre-hire" hourly resources approximately 1 year in advance of the expected need to account for security clearance time and training and qualification.

Figure E–36. Total projected KCNSC workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

E.3.2 Pantex Plant

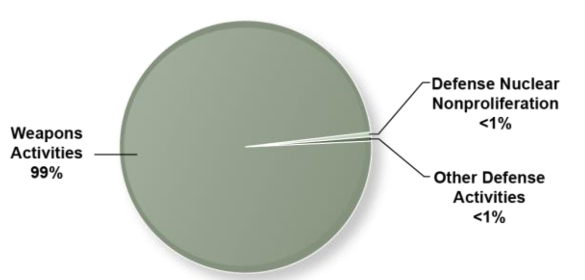
E.3.2.1 Mission Overview

Pantex is the only NNSA site authorized to assemble or disassemble nuclear weapons and, as NNSA's High Explosive Production Center of Excellence, has cradle-to-grave responsibilities for HE production. As a collaborative partner with the national security laboratories, Pantex provides capabilities to transition HE R&D from bench scale to production scale. In addition, Pantex collaborates and provides capabilities to DOD, the United Kingdom, universities, and commercial vendors. Pantex also supports the reduction of global nuclear threats through its nonproliferation activities.

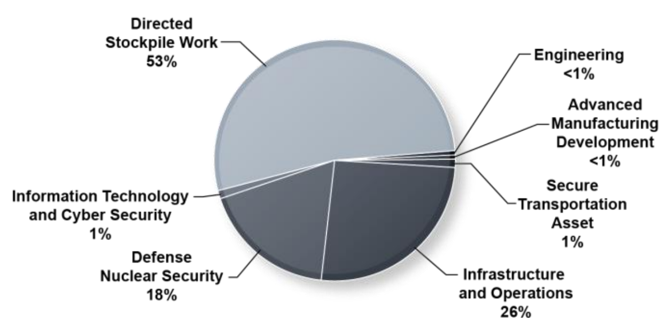
- Location: Amarillo, Texas
- Total Employees: 3,246
- Type: Single-program nuclear weapons production facility
- Website: www.pantex.com
- Contract Operator: Consolidated Nuclear Security, LLC, a corporate subsidiary of Bechtel National, Lockheed Martin Services, ATK Launch Systems, and SOC, LLC
- Responsible Field Office: NNSA Production Office

E.3.2.2 Funding

FY 2018 Request – Site Funding by Source
(Total Pantex FY 2018 Request = $748.8 Million)



FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($746.2 Million)*



E.3.2.3 Site Capabilities

Pantex's mission capabilities include manufacture of specialty explosives; fabrication and testing of HE components; assembly, disassembly, refurbishment, maintenance, and surveillance of weapons and weapon components; dismantlement of retired weapons; sanitization and disposition of components from dismantled weapons; interim staging and storage of nuclear components from dismantled weapons; pit requalification; pit surveillance; and pit packaging (including container surveillances and recertification).

Highlights of Pantex's key capabilities include the following.

Weapons Assembly and Disassembly

- **Capabilities.** Assembly and disassembly of nuclear explosive warheads and bombs, assembly and post-mortem analysis of JTA, assembly and disassembly analysis of test bed units, and electrical and mechanical tests of weapons and weapon components.
- **Challenges.** Development, establishment, and implementation of the Documented Safety Analysis process for new programmatic weapon activities.
- **Strategies and Path Forward.** Streamline the Documented Safety Analysis process methodology for efficiency and effectiveness.

Surveillance

- **Capabilities.** Nondestructive evaluation of pits and weapon components from stockpile units to support the Laboratories' Annual Assessment Reports and destructive and nondestructive evaluation of HE from stockpile units.
- **Challenges.** Production downtime associated with aging pit surveillance equipment.
- **Strategies and Path Forward.** Develop and evaluate options for upgrading or acquiring replacement equipment.

High Explosives

- **Capabilities.** Pantex is responsible for HE pressing, assembly of mock HE for JTAs, assembly of conventional high explosives and IHE for LEPs and stockpile rebuilds, and disassembly and disposition of HE from surveillance and dismantlement units.
- **Challenges.** Programmatic infrastructure (*i.e.,* equipment) is aging, and some of the general purpose infrastructure (*i.e.*, buildings) is of 1940s vintage.
- **Strategies and Path Forward.** The High Explosives Pressing Facility (HEPF) received Critical Decision (CD)-4, Approve Start of Operations, in FY 2017. HEPF consolidates HE operations from numerous buildings to reduce the movement of HE within the plant, benefiting worker safety and minimizing impact to other plant operations. High Explosive Science and Engineering and HE formulation facilities are planning recapitalization of end-of-life equipment needs and establishing major modernization plans.

Special Nuclear Material Accountability, Storage, Protection, Handling, and Disposition

- **Capabilities.** These are requalification capabilities for pits for LEP and storage of pits and weapons.
- **Challenges.** Pit storage capacity to support future DSW and production downtime associated with aging pit requalification equipment.
- **Strategies and Path Forward.** Execute pit storage projects to reconfigure facilities to increase the site storage capacity to address near-term storage constraints; proceed with the CD process for the Material Staging Facility. Deploy new requalification equipment for upcoming LEPs. Upgrade existing requalification equipment.

E.3.2.4 Accomplishments

Nuclear Weapons Stockpile

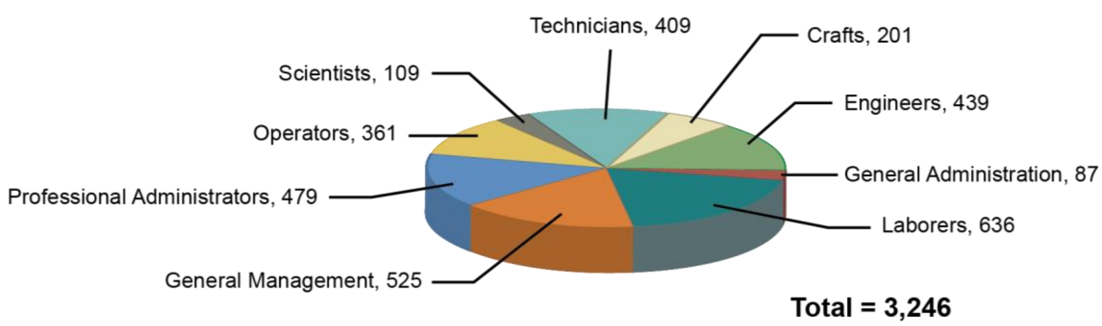
- Exceeded NNSA baseline plans for the W76-1 LEP, W87 limited life component exchange, dismantlement, and surveillance.
- Overcame obstacles to obtain authorization for W84 operations. W84 operations were authorized, and operations began on September 23, 2016, allowing completion of the FY 2016 deliverable. The W84 authorization enables the site to support the FY 2022 dismantlement goal to dismantle all units retired prior to FY 2009 by FY 2022.
- Demonstrated readiness and received approval to move from Phase 6.3 (Development Engineering) into Phase 6.4 (Production Engineering) for the B61-12 LEP.

Reduce Nuclear Security Threats

- Shared Global Security Analysis and Training knowledge and obtained a 46 percent increase in courses conducted for Alarm Response Training and Personal Radiation Detection Training over FY 2015. These courses dramatically increased the preparedness of the attendees on material protection and control. Along with those local training efforts, a significant number of site security assessments were performed at home and abroad to raise the level of security awareness, reduce vulnerabilities, and limit the potential loss of nuclear material.
  - Deployed Nuclear Counterterrorism Emergency Response and Radiological Assistance Program team personnel to training venues, drills, exercises, and real-world events without any issues. Deployed the Radiological Assistance Program team personnel and provided specialized, national-level, first-responder technical and operational capabilities and supported operations of the 2016 Nuclear Security Summit, Super Bowl 50, and the papal visit.

E.3.2.5 Pantex Plant Workforce

Pantex has 3,246 employees. The average age of the Pantex population is approximately 47, and approximately 31 percent of employees are eligible to retire. The age of employees is widely dispersed among several groups. The average years of service is about 14, with most employees having 25 or fewer years of service. Since FY 2014, Pantex hired 536 employees and experienced 401 separations, resulting in a net gain of 135. Similar to other sites, older, advanced-career employees account for retirements while younger, early-career employees account for voluntary separations. Retirements increased from FY 2012 to FY 2015 and declined in FY 2016. Voluntary separations during that time have fluctuated. The total workforce has fluctuated since FY 2006 in response to the workload funding shifts from year to year. The number of mid-career employees has declined since FY 2006, except for a recent minor uptick. Early- and advanced-career employees have remained relatively stable with minor changes. Pantex anticipates an increased need for critical skills over the FYNSP period.



Notes:

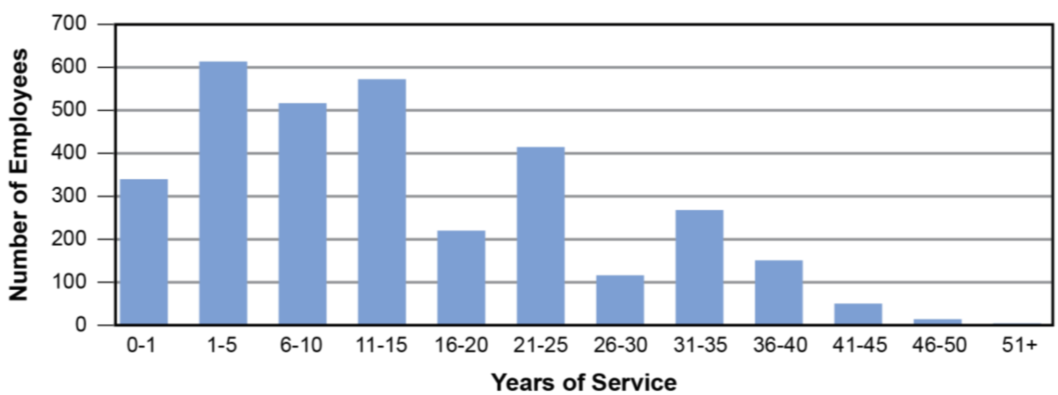
Total workforce increased from 3,054 to 3,246 from the last report. Significant recruiting and hiring efforts replaced vacancies from attrition and built the technical skill base in preparation for the increased workload scheduled in FY 2018 and beyond. The attrition rate for Pantex dropped from 7.3 percent in FY 2015 to 5.4 percent in FY 2016. This improvement was due largely to the decline in the oil, gas, and alternative energy boom, which resulted in drawing personnel with technical skills away from Pantex in FY 2015. Improved compensation and benefits were important factors in retention.

Figure E–37. Pantex total workforce by Common Occupational Classification System

Notes:

The average age of the Pantex workforce is 47.06. The percentage eligible to retire increased very slightly from 31.5 percent to 31.83 percent since the last report due to the large population over age 55 with 10+ years of service. Crafts, operators, technicians, and clerical staff are hired locally and tend to remain for many years. Pantex hires many retired veterans, which also contributes to the higher average age of the workforce. In addition, many older workers are electing to work well past normal retirement age. The average age of the workforce has remained over 45 during the past 30 years of monitoring.

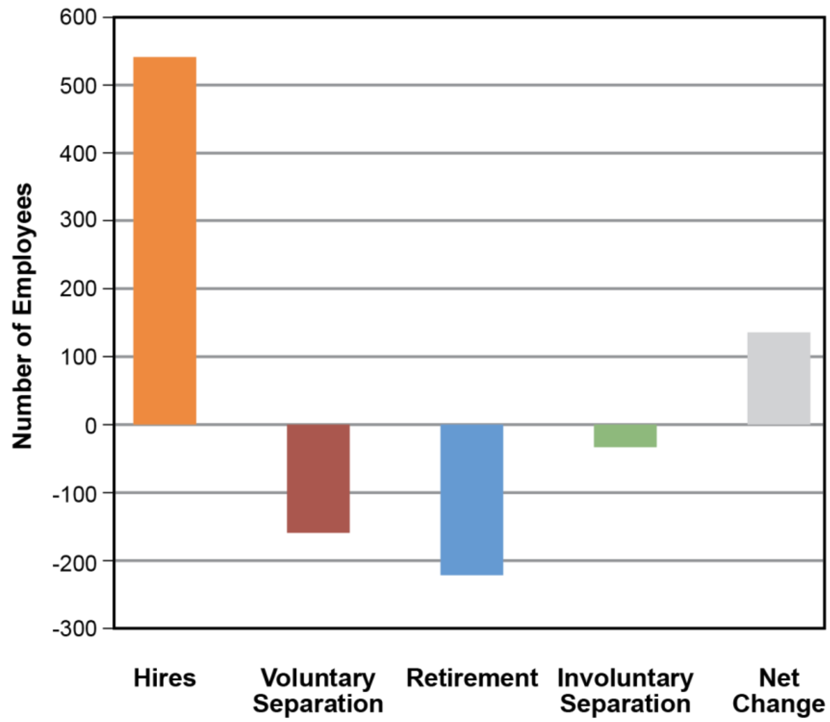
Figure E–38. Pantex employees by age



Notes:

Weapons workload funding shifts from year to year, creating peaks and valleys of hiring. During peaks, large classes of security police officers, production technicians, *etc.,* are onboarded in classes of 25-40 at a time for group training. These positions are hired locally and stay for many years, creating groupings of employees with the same years of service caused by the hiring peaks and valleys. The average years of service moved from 15.5 in FY 2015 to 14.56 in FY 2016 due to increased hiring.

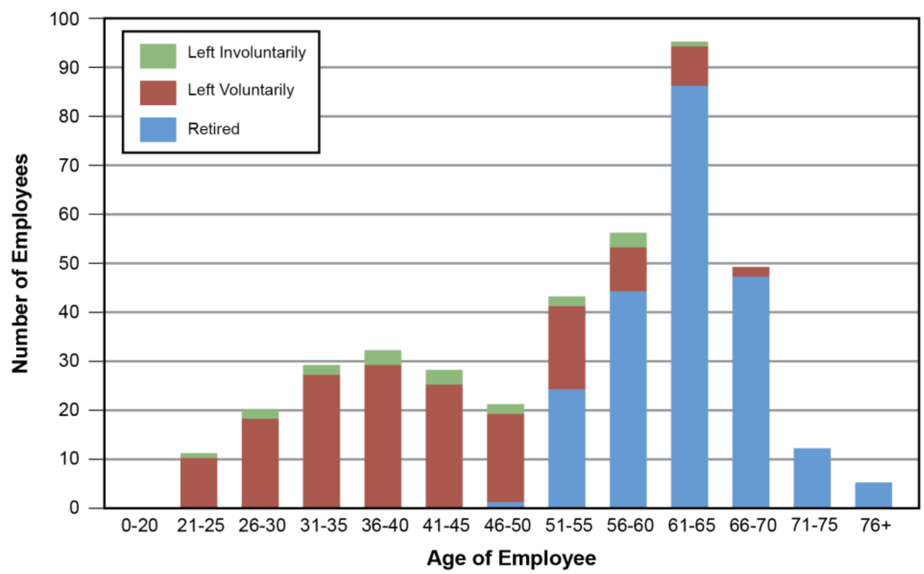
Figure E–39. Pantex employees by years of service



Notes:

Workforce increased from 3,111 in FY 2014 to 3,246 in FY 2016 due to increased hiring for attrition replacement and scheduled weapons workload. Fewer employees left voluntarily for other employment. Attrition decreased in FY 2016 due to retention efforts, increased pay to market, and curtailment of the oil and gas boom, which had been tapping Pantex technical talent. Over 54 percent of separations were retirees. Improvements in compensation and benefits in FY 2016 boosted retention.

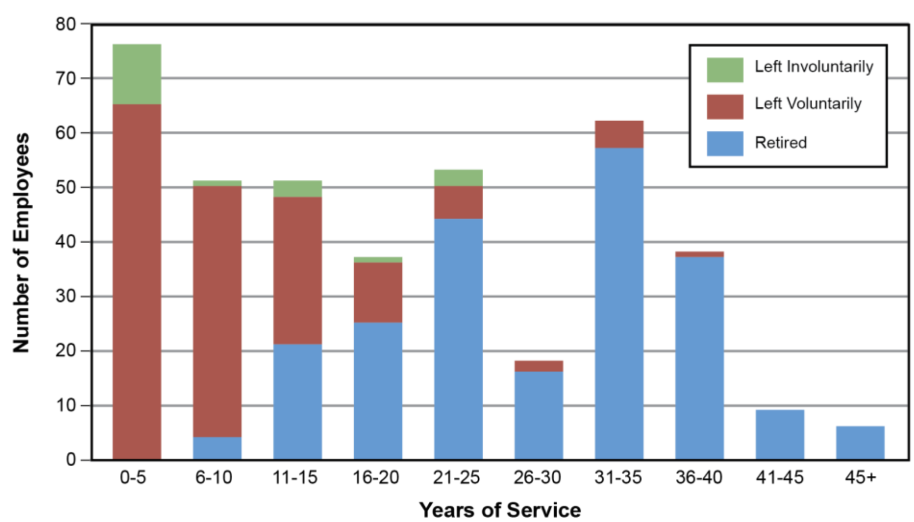
Figure E–40. Change in last two fiscal years at Pantex (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The chart indicates typical attrition and reasons based on age. Employees may retire at age 55 with 10 years of service. The majority retire closer to age 65, and many are choosing to work past 65, as indicated by the chart.

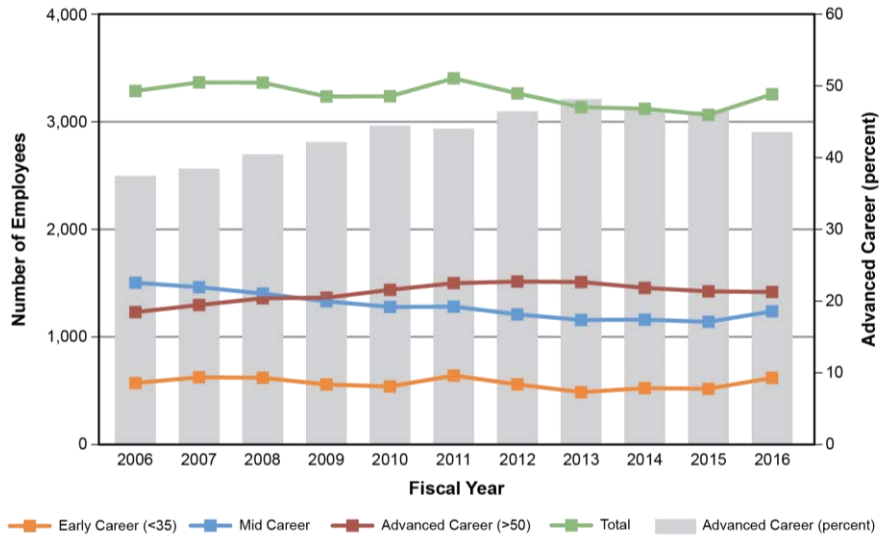
Figure E–41. Age of Pantex employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

Voluntary separations are usually earlier in the careers of mobile, young, new graduate professionals at Pantex for a variety of reasons. This includes location, industrial competition, and security requirements. The balance of employees who are hired locally tend to stay until retirement.

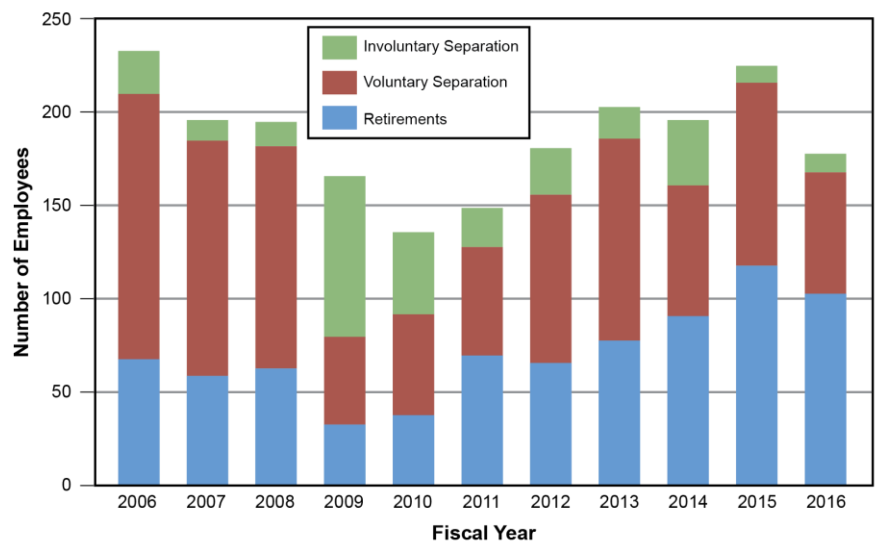
Figure E–42. Years of service of Pantex employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

This metric indicates Pantex is mirroring national demographics with an aging workforce. Early careers grew in 2016 due to increased hiring for attrition replacement and planned weapons workload. Employees are working longer, some into their 80s as health allows. More grandparents are raising their grandchildren and continue working for the additional income and social interaction. Uncertainty about healthcare is also a factor. Plant population has stayed between 3,000 and 3,400, depending on workload and prioritization.

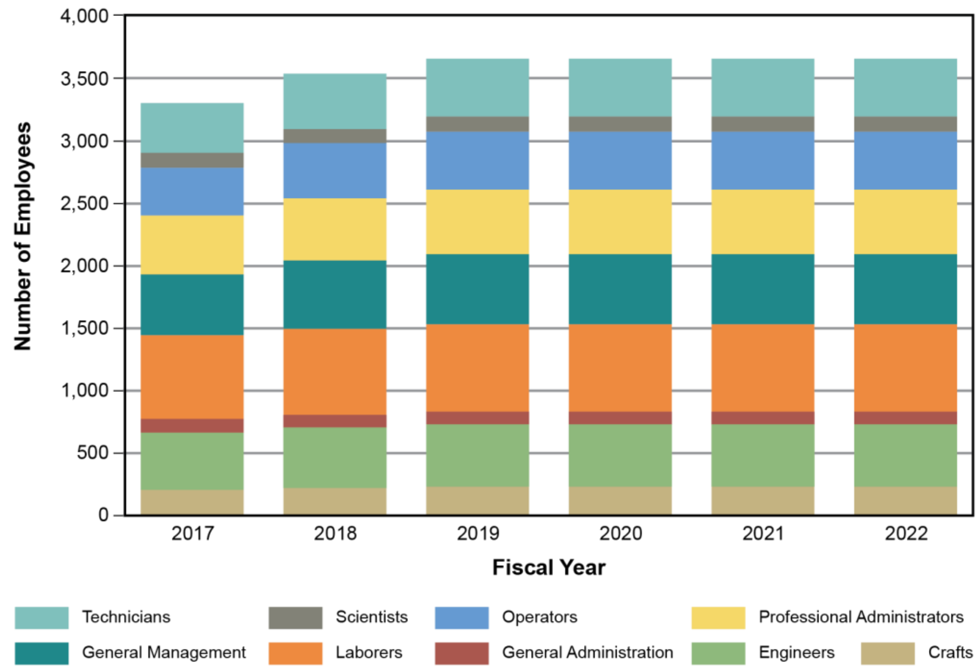
Figure E–43. Pantex trends by career stage



Notes:

There were small Voluntary Separation Programs in 2009, 2010, and 2014 as shown in the higher numbers for involuntary separation in those years. The economy dipped at the end of FY 2008. Stocks tumbled, which caused employees to postpone retirement as seen by lower attrition in 2009 and 2010 and an increase in retirements more recently. The boom in oil, gas, and alternative energy increased attrition through FY 2015 and tapered off in FY 2016. Pantex typically experiences higher attrition for engineers, professionals, and computer scientists. The majority of these classifications are typically more mobile. Classifications such as technicians, operators, crafts, and administrative are hired locally and have lower attrition rates as they have established family roots in the area.

Figure E–44. Pantex employment separation trends



Notes:

The total estimated number of full-time personnel needed to support the work is 3,289. The current plant population at the end of FY 2016 was 3,246. Internal realignment is used in some cases to fill critical vacancies. Plant attrition is 5.4 percent overall. Engineers, information technology personnel, and authorization basis staff typically have higher attrition. This is an ongoing concern, as other industries are competing for similar skills. Based on current hiring/termination statistics, we anticipate gaps in engineering, authorization basis, information technology, risk management, tooling, tester design, explosives technology, and fire protection in the next 10 years. Pantex is working closely with area universities to provide science, technology, engineering, and math curricula to fill the pipeline of critical skills for years to come.

Figure E–45. Total projected Pantex workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

E.3.3 Savannah River Site

E.3.3.1 Mission Overview

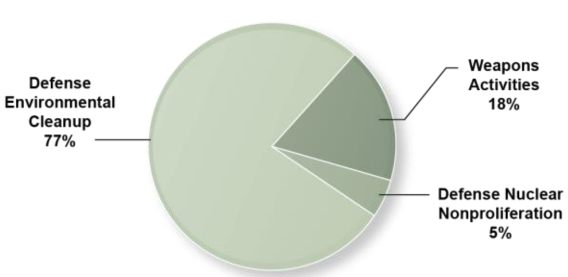
The Savannah River Site (SRS), which spans Aiken, Allendale, and Barnwell Counties in South Carolina, includes mission areas in tritium supply, stockpile maintenance, stockpile, evaluation, tritium R&D, and helium-3 recovery.

- Location: Aiken, South Carolina
- Total Employees: 534 direct tritium personnel (plus 889 full-time equivalents of support, as described in Figure E–46)
- Type: Multi-program site; DOE's Office of Environmental Management is the SRS landlord; NNSA is a tenant on-site
- Website: www.srs.gov and www.savannahrivernuclearsolutions.com
- Contract Operator: Savannah River Nuclear Solutions, LLC (Fluor, Honeywell, Huntington Ingalls Industries)
- Responsible Field Office: Savannah River Field Office

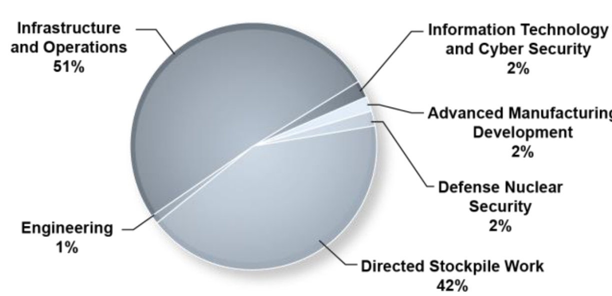
SRS tritium operations are tightly integrated with Savannah River National Laboratory, a DOE Environmental Management Laboratory that also supports NNSA's Defense Nuclear Nonproliferation, Emergency Operations, and Office of Counterterrorism and Counterproliferation; the DOE Office of Intelligence and Counterintelligence; DOD's Defense Threat Reduction Agency; the Department of Homeland Security; and the International Atomic Energy Agency.

E.3.3.2 Funding

FY 2018 Request – Site Funding by Source
(Total SRS FY 2018 Request = $1,688.1 Million)



FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($301.7 Million)*



E.3.3.3 Site Capabilities

SRS has unique capabilities that relate to nuclear weapon limited life components and the broader national security mission of reducing global nuclear security threats for the United States and its allies. Tritium is a critical component of the Nation's defense systems and must be continually replenished in order to meet the needs of the U.S. nuclear deterrent. SRS conducts large-scale tritium operations, and the SRS Savannah River Tritium Enterprise[2] (SRTE) is the NNSA Center of Excellence Involving Large Quantities of Tritium. To sustain the tritium inventory, tritium is recovered from two sources at SRS. One source is end-of-life GTS reservoirs that are returned to SRS. Another source is irradiated tritium-producing burnable absorber rods (TPBARs) received from the Tennessee Valley Authority.

Tritium Recycling (Material Recycle & Recovery Program)

- **Capability.** Systems for recovering and recycling tritium from returned GTS reservoirs.
- **Challenges.** Tritium inventory systems contain limited life components, many of which are nearing life expectancy. Recovering the contents of the limited life components requires careful planning and coordinating to avoid mission interruption.
- **Strategies and Path Forward.** SRTE has short-term and long-term strategies for addressing the challenge of system replacements:
  - *In the short-term,* schedule replacement projects to maximize efficiency and reduce impact on operational schedules.
  - *In the long-term*, deploy new technologies to enhance system operating efficiency in a smaller footprint.

Tritium Extraction (Tritium Sustainment Program)

- **Capability.** Tritium extraction from irradiated TPBARs.
- **Challenge 1.** To meet supply requirements, SRTE requires additional workforce that has training, qualifications, and proficiencies. The extraction process involves multiple time-critical complexities.
- **Strategies and Path Forward.** SRTE continuously examines multi-year staffing needs and is developing appropriate processes to ensure a continuous pipeline of knowledge, skills, and abilities to sustain tritium capabilities.
- **Challenge 2.** Tritium extraction requires the elimination of impure waste gas. Under current conditions, disposition of this gas is managed through a system obligated to multiple functions. This overdependence on critical infrastructure creates an increasing constraint.
- **Strategies and Path Forward.** SRTE is executing a small project that will alleviate some dependency on existing resources by allowing waste gas to be managed safely at the source rather than transferred to another facility for disposition.

Replenishing Tritium in Gas Transfer System Reservoirs

- **Capability.** Replenishing tritium in GTS reservoirs.
- **Challenge 1.** Maintain facilities and equipment to support stockpile deliverables and future Alts, Mods, and LEPs.
- **Strategies and Path Forward.** SRTE has developed a strategic investment process and prioritizes its infrastructure needs to ensure mission continuity. Priorities are identified through engineering analysis and risk assessment, vetted by leadership teams, and captured on a Strategic Roadmap. This process also includes infrastructure and equipment improvements.

[2] "Savannah River Tritium Enterprise" is the collective term for the facilities, capabilities, people, and expertise at SRS related to tritium, and the SRTE "umbrella" extends beyond the tritium area to include vital mission-support functions. Unless otherwise noted, the information in this appendix will reference SRTE.

NNSA's strategy to revitalize the SRTE infrastructure is to (1) relocate and right-size the remaining operational functions from functionally obsolete facilities into existing and new space *via* the Tritium Responsive Infrastructure Modifications (TRIM) program, and (2) recapitalize and sustain enduring facilities.[3]

TRIM consists of one line-item project (Tritium Production Capability) and a suite of general plant and operating expense-funded projects. Preliminary analysis was completed in FY 2016, with final sensitivity analysis and formal Tritium Production Capability Analysis of Alternatives (AoA) performed in FY 2017. Work to achieve CD-1 (Approve Alternative Selection and Cost Range) also began in FY 2017. To address the capacity issue, SRTE will modify the process and infrastructure equipment in multiple facilities and evaluate alternative options for some production areas.

- **Challenge 2.** Addressing infrastructure needs in a high-hazard area without interrupting mission schedule while adapting for multiple, more complex operations.
- **Strategies and Path Forward.** SRTE is modifying the process and infrastructure equipment and executing a strategic investment process to ensure continuity. SRTE is also evaluating critical systems to ensure optimal product capacity while carefully planning the production outages to maximize benefit.

Gas Transfer System Surveillance

- **Capability.** SRTE function testing for GTS surveillance and tritium R&D.
- **Challenge.** Maintain original function test equipment**.**
- **Strategies and Path Forward.** SRTE is initiating R&D projects and transitioning to an extended schedule that will allow for additional enhanced operations to eliminate the potential for capacity constraints.

Tritium Research and Development

- **Capability.** R&D supporting the tritium facilities, reservoir development, and future gas processing technologies.
- **Challenge.** Provide dedicated R&D capacity for stockpile maintenance, stockpile evaluation, and operations workload in support of new technologies while maintaining and recapitalizing facilities and infrastructure.
- **Strategies and Path Forward.** SRTE will continue to develop planning options with NNSA to balance operational and R&D needs and fiscal resources.

Helium-3 Recovery

- **Capability.** Recovering, purifying, and bottling helium-3, the byproduct of tritium decay.
- **Challenges.** SRTE has no significant challenges for this capability.
- **Strategies and Path Forward.** SRTE will continue to maintain and use this capability to meet U.S. Government needs.

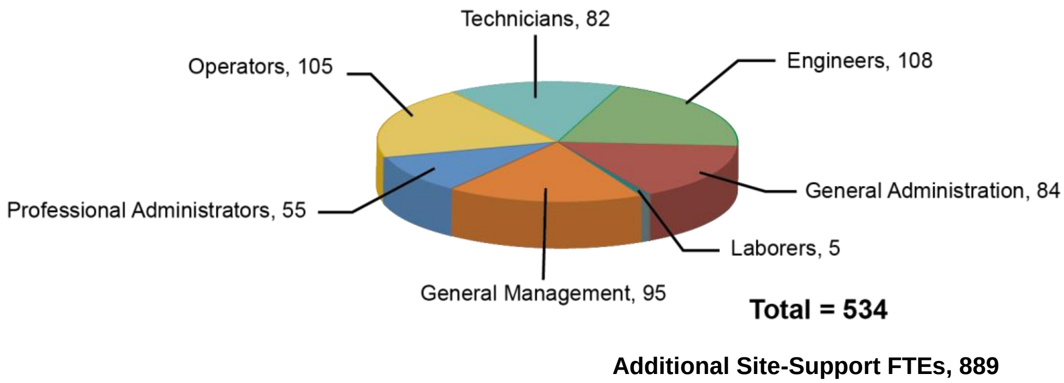
[3] The preferred alternative from NNSA's CD-1 AoA for the Tritium Production Capability project specifies two new facilities with a combined maximum footprint of 24,000 square feet.

E.3.3.4 Accomplishments

- Achieved 100 percent on-time delivery of high-quality limited life components to DOD stakeholders.
- Performed development work supporting the B61-12 LEP and W87 Alt 360 schedules.
- Completed final reclamations of GTS reservoirs as a prerequisite to retiring the legacy Reclamation Facility.
- Streamlined processing of reservoirs used in a specific GTS, thereby reducing the cycle time by 38 percent.

E.3.3.5 Savannah River Site Workforce

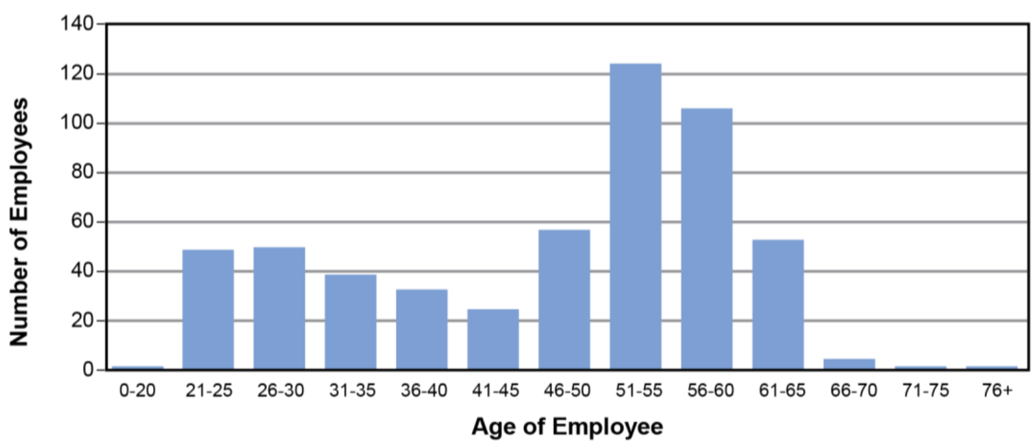
The SRTE has 534 employees, with an average age of 47 and 54 percent having between 21 to 35 years of experience. Approximately 15.5 percent of SRTE's employees are eligible to retire. Since FY 2014, SRTE hired 204 employees and experienced 90 separations, resulting in a net gain of 114. Of the separations, about 50 percent retired and 40 percent separated voluntarily. Voluntary separations were particularly high among those with 0 to 5 years of service, while retirements were highest among those with 26 to 35 years of service. Voluntary separations have increased over the past 2 years. Since FY 2008, the number of early-career employees has steadily increased, while the number in mid-career has decreased.



Notes:

The DOE Office of Environmental Management is the SRS landlord, and NNSA is a tenant. The tritium organization within the Savannah River Tritium Enterprise (SRTE) performs most of the weapons activities scope. SRTE includes approximately 10 percent (534) of the overall management and operating workforce at SRS (5,258). SRTE support organizations also perform weapons activities scope on an as-needed basis, while primarily supporting the Environmental Management and Nuclear Nonproliferation Programs. In FY 2016, SRTE was supported by 889 full-time equivalents, which included scientists from Savannah River National Laboratory, for a total of 1,423.

Figure E–46. SRTE total workforce by Common Occupational Classification System



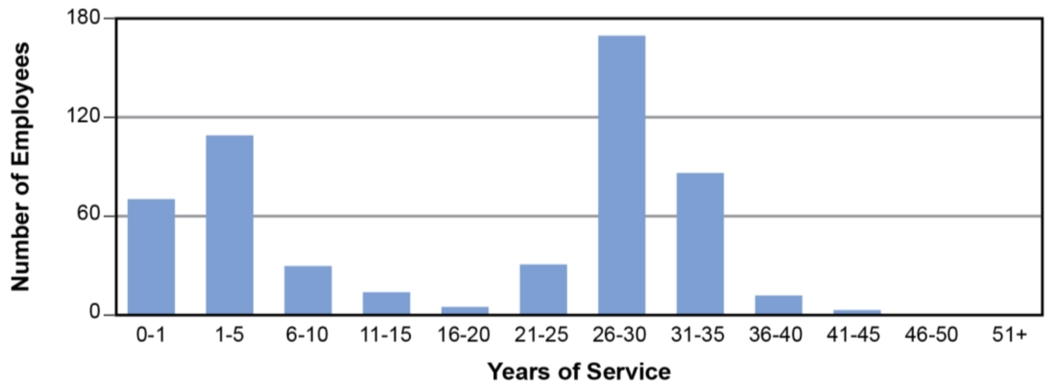
Notes:

Savannah River Tritium Enterprise (SRTE) will face an increase in retirements over the next 10 years. Tritium employees average 47 years of age, and approximately 43 percent are age 51 to 60. Over 30 percent of the tritium workforce will be retirement-eligible by 2018; this figure will increase to 45 percent by 2022.

The number of younger employees has significantly increased. The number in the 20- to 30-year-old age group doubled between 2010 and 2016, primarily as a result of pipeline funding from Program Readiness.

SRTE develops and executes annual hiring plans based on priority to address attrition, pipeline needs, and new work scope; SRTE has developed a 5-year Strategic Staffing Plan. SRTE has also enhanced local partnerships by increasing college recruiting and cultivating relationships with local universities and technical trade schools to attract local talent.

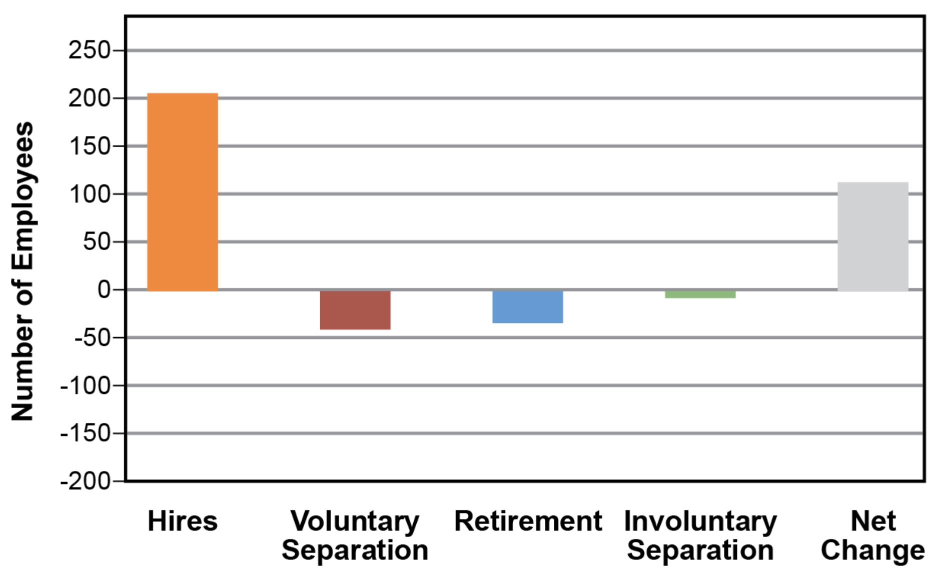
Figure E–47. SRTE employees by age



Notes:

This chart shows a wide disparity of experience in the current tritium workforce. Approximately 51 percent of the employees have over 25 years of service, and 34 percent have 5 years or less.

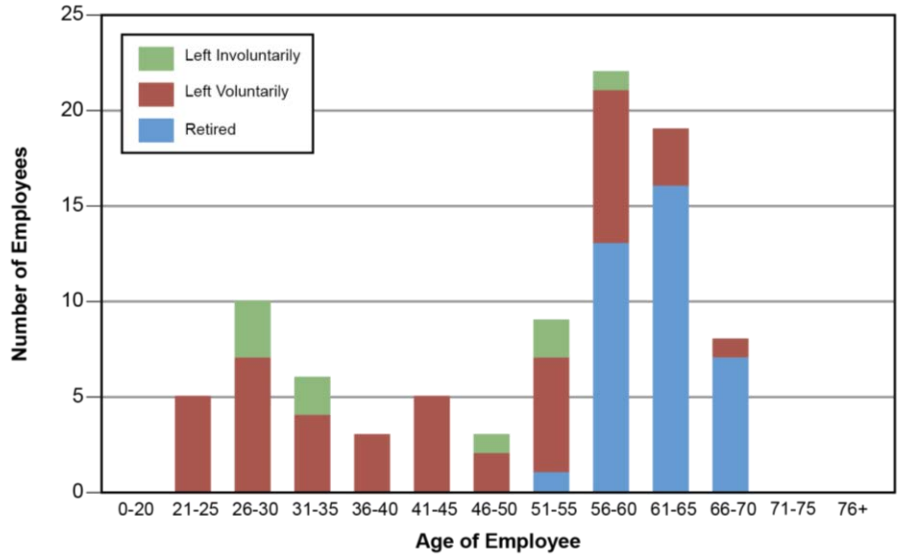
Figure E–48. SRTE employees by years of service



Notes:

The Savannah River Tritium Enterprise has continued to hire operators, mechanics, radiological control inspectors, and engineers to ensure continuity of operations. Beginning in FY 2018, an increase in pension costs will significantly erode buying power and reduce operations and maintenance of equipment and facilities, thereby increasing mission risk.

Figure E–49. Change in last two fiscal years at SRTE (end of fiscal year 2014 to end of fiscal year 2016)

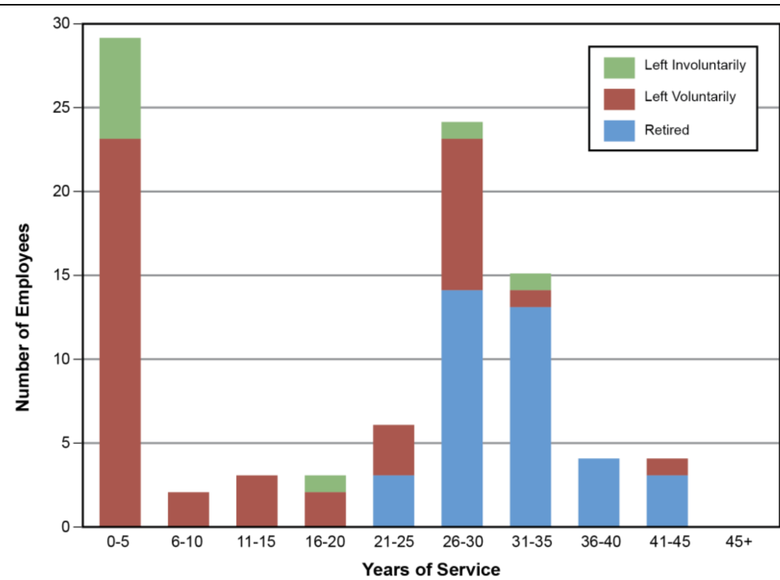


Notes:

Personnel primarily retired or pursued other opportunities.

Retirements from the Savannah River Tritium Enterprise (SRTE) are increasing, and SRTE faces competition from the commercial nuclear industry. An upcoming contract change is expected to cause additional turnover. Although SRTE made excellent progress in hiring during FY 2016, additional employees are needed to address the increased life extension program workload, facility maintenance, and transition to full operations in the Tritium Extraction Facility. SRTE is carefully managing attrition and the lengthy onboarding time (resulting from training, qualification, and clearance processes).

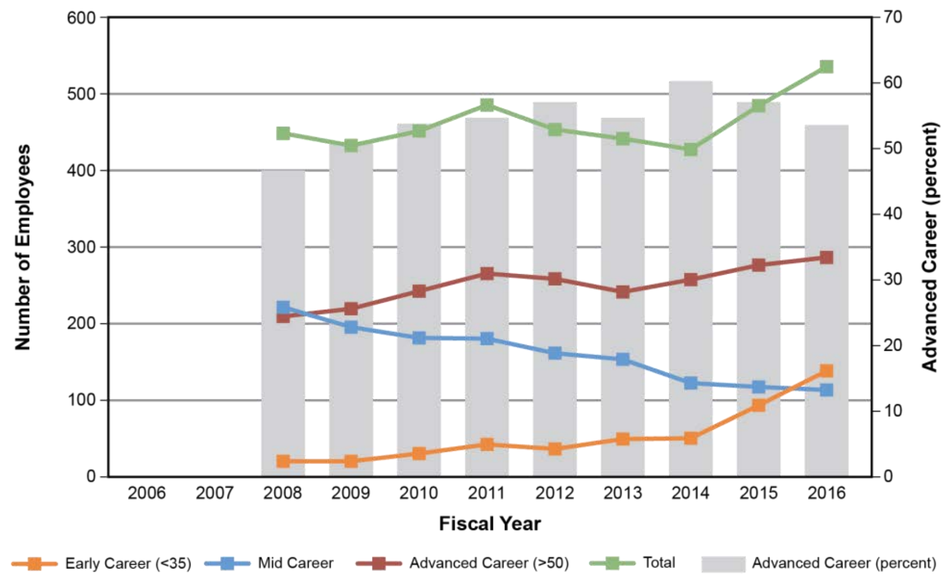
Figure E–50. Age of SRTE employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The Savannah River Tritium Enterprise's primary concern is the number of employees in the 0- to 5-year category that left. This is primarily attributable to them pursuing other opportunities.

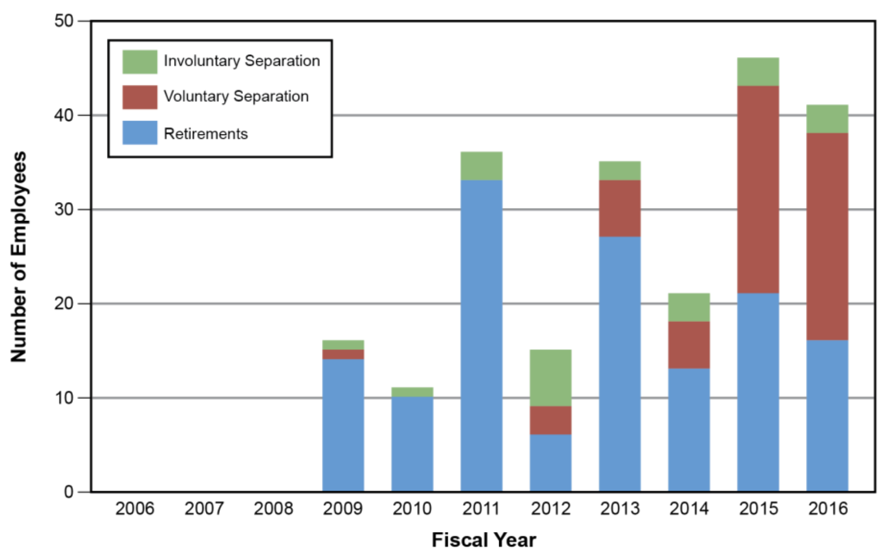
Figure E–51. Years of service of SRTE employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

This chart illustrates the demographic changes in the Savannah River Tritium Enterprise since 2008 (prior-year data cannot be captured accurately because of changes in the human resources system). An increasing percentage of employees are aging into the advanced-career category, and an increasing percentage of early-career employees have been hired to address attrition, pipeline needs, and new work scope. The percentage of mid-career employees is decreasing. This is only partially explained by aging into the advanced-career category; many employees have sought other opportunities.

Figure E–52. SRTE trends by career stage

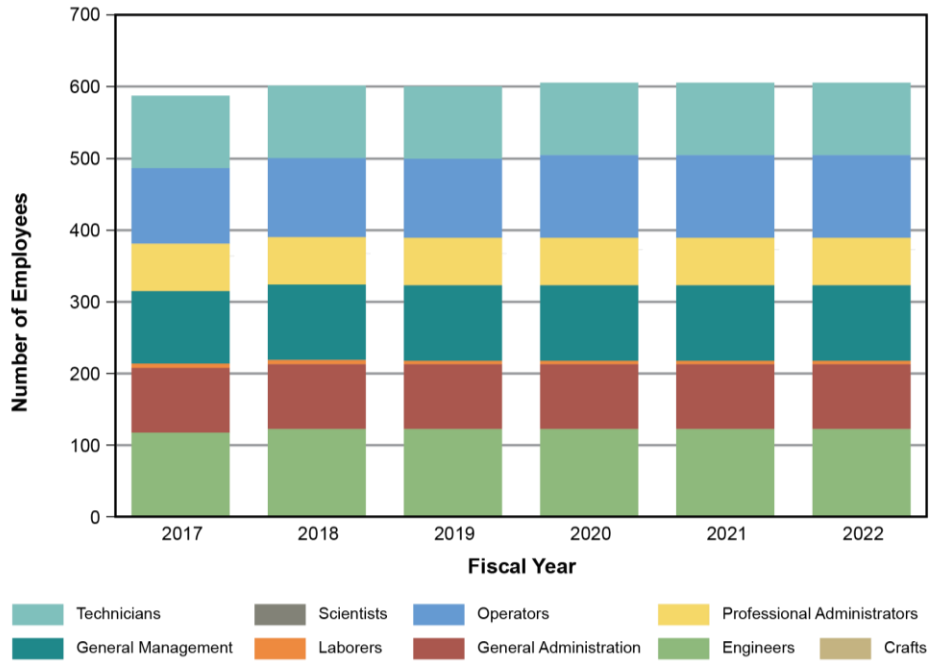


Notes:

Savannah River Tritium Enterprise (SRTE) continues to experience a rise in attrition from retirements and employees pursuing other opportunities.

SRTE forecasts its future attrition based on historical data and workforce retirement eligibility.

Figure E–53. SRTE employment separation trends



Notes:

The staffing profile is relatively flat overall but does not reflect the recent increase from historical staffing levels (see Figure E–52). Through an aggressive hiring plan, Savannah River Tritium Enterprise (SRTE) achieved a net increase of 83 staff in FY 2016 to address attrition, pipeline needs, and new work scope. This elevated staffing level will continue (and increase slightly) throughout the Future Years Nuclear Security Program period as a result of increases in facility maintenance and recapitalization, mission workload to support the stockpile, and tritium extractions. Critical process and infrastructure equipment must be maintained at maximum capacity during the peak gas transfer system loading years (*i.e.*, FY 2020 to FY 2024).

SRTE is carefully managing attrition and critical skills, to account for the onboarding time for training, qualification, and clearance processing. Addressing attrition is a challenge because of the expected increase in retirements and the startup of two nearby nuclear reactors that will occur in the same timeframe.

Figure E–54. Total projected SRTE workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

E.3.4 Y-12 National Security Complex

E.3.4.1 Mission Overview

Every weapon in the U.S. nuclear stockpile has components manufactured, maintained, or dismantled by Y-12. Y-12 is NNSA's Uranium Center of Excellence and is the Nation's only source for enriched uranium components for nuclear weapons. For the legacy stockpile, Y-12 manufactures uranium components for nuclear weapons, cases, and other weapons components and evaluates and tests these components. Through its LEP activities, Y-12 produces refurbished, replaced, and upgraded weapon components to modernize the enduring stockpile. In addition, Y-12 serves as the main storage facility for Category I/II quantities of highly enriched uranium (HEU); conducts dismantlement, storage, and disposition of HEU; and supplies HEU for use in naval reactors.

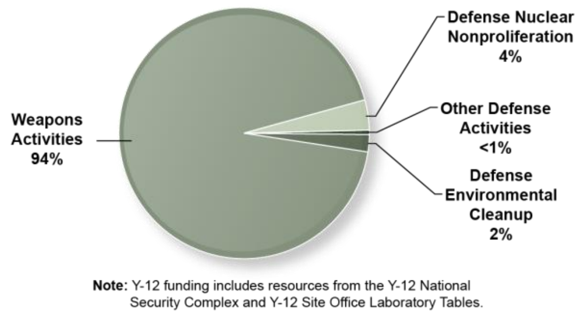
- Location: Oak Ridge, Tennessee
- Total Employees: 4,678
- Type: Multi-program nuclear weapons production facility
- Website: www.y12.doe.gov
- Contract Operator: Consolidated Nuclear Security, LLC, a corporate subsidiary of Bechtel National, Lockheed Martin Services, ATK Launch Systems, and SOC, LLC
- Responsible Field Office: NNSA Production Office

Y-12 Accomplishments

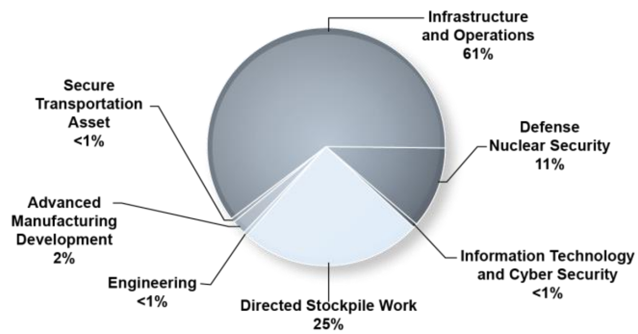
- *Exceeded baseline on all weapons deliverables.*
- *Completed W69 canned subassembly dismantlements.*
- *Began mass excavation for the Uranium Processing Facility.*
- *Completed design for new Emergency Operations Center.*

E.3.4.2 Funding

FY 2018 Request – Site Funding by Source
(Total Y-12 FY 2018 Request = $1,675.6 Million)



FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($1,580.5 Million)*



E.3.4.3 Site Capabilities

The key mission capability areas for Y-12 are primarily in three areas: uranium and canned subassembly production, lithium, and material and process R&D. Key to all these capabilities is the supporting infrastructure providing power, water, and other critical services.

Uranium and Canned Subassembly Production Capability

- **Capability.** Y-12 produces uranium weapon components to refurbish the Nation's nuclear stockpile. Y-12 also recycles and reprocesses the Nation's existing supply of enriched uranium. The recycled metal also serves as feedstock for the Navy's nuclear-powered submarines and aircraft carriers, for commercial power reactors that generate U.S. electricity, for medical isotope production, and for some domestic and foreign research reactor programs. Y-12 also helps recover and secure at-risk nuclear materials around the globe. The Highly Enriched Uranium Materials Facility at Y-12 houses the Nation's cache of weapons-grade uranium. The Uranium Processing Facility now under construction will be a state-of-the-art facility for enriched uranium operations that are currently performed in Building 9212.
- **Challenges.** In order to continue supporting all uranium missions, Y-12 must address its aging infrastructure. Buildings 9215 and 9204-2E are aging and require sustainment through the Extended Life Program. Enriched uranium capabilities must be maintained while the Uranium Processing Facility is constructed, requiring relocation of enriched uranium functions to other Y-12 facilities, and for startup and proving of replacement technologies before uranium programmatic operations cease in Building 9212 by 2025. Y-12 must also complete the reduction of material-at-risk quantities in current processing facilities by consolidating storage into the Highly Enriched Uranium Materials Facility.
- **Strategies and Path Forward.** The Uranium Processing Facility will replace most of the HEU production functions currently performed in Building 9212. The uranium strategy also includes upgrades and advanced technologies that will be started in existing Buildings 9204-2E and 9215.

Lithium Capability

- **Capability.** Y-12 provides material purification, material preparation, component fabrication and inspection, salvage operations, and storage for lithium operations to support LEPs, JTAs, and complementary work. Without enriched lithium, the country's nuclear deterrent could not be maintained.

- **Challenges.** Current lithium capabilities are housed in Building 9204-2, a Manhattan Project facility built in 1943. The facility infrastructure is well beyond its expected life and is deteriorating rapidly. The process equipment is oversized for today's missions and deteriorating rapidly and has significantly exceeded life expectancy. In addition, lithium production capabilities will be strained even more due to material availability issues and future increases in mission goals. The age of the infrastructure and the limited material supply pose significant risks to meeting mission deliverables.
- **Strategies and Path Forward.** Due to the serious degradation of the existing lithium production infrastructure and limited material supply, implementation of the lithium strategy requires NNSA to sustain the current infrastructure, sustain the supply to meet customer demand, mature and deploy technologies to replace hazardous process, and develop and deploy the new lithium production capability line item project to replace Building 9204-2 process capabilities.

Material and Process Research and Development Capability

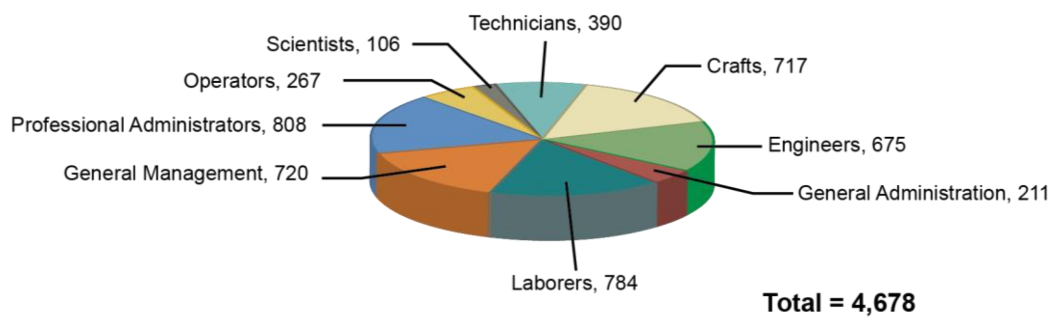
- **Capability.** Y-12's Development Division serves as the focal point for the development and preservation of uranium and lithium materials sciences and manufacturing technologies. R&D activities include material and metallurgical synthesis, forming, evaluation techniques and processes, material purification, and material characterization. R&D activities include material and metallurgical synthesis, forming, evaluation techniques and processes, material purification, and material characterization. Advanced technologies have been developed and are at varying stages of deployment readiness for enriched uranium and lithium.
- **Challenges.** Aging electrical, water distribution, and other process support systems in Y-12's infrastructure put mission work at risk as the infrastructure continues to age.
- **Strategies and Path Forward.** Y-12 is evaluating potential strategies to sustain and ensure material and process R&D capabilities, including moving operations and engineers and scientists to more modern facilities. Y-12 is implementing electrical and water system recapitalization projects to address these issues.

E.3.4.4 Additional Accomplishments

- Broke ground for the Uranium Processing Facility Construction Support Building and began mass excavation for the Uranium Processing Facility.
- Completed the W69 canned subassembly dismantlement.
- Removed more than 9 metric tons of uranium from Area 5.
- Produced and shipped all required nuclear material for the Naval Reactors Program ahead of schedule and within cost.
- Reduced site risk by updating the roofing on Buildings 9206, 9204-4, and 9201-5 to eliminate water penetration and prevent rainwater-induced structural failure.
- Developed an Extended Life Program for Buildings 9215 and 9204-2E to sustain the infrastructure and capabilities necessary to support critical uranium mission activities that were not included in the Uranium Processing Facility design.

E.3.4.5 Y-12 National Security Complex Workforce

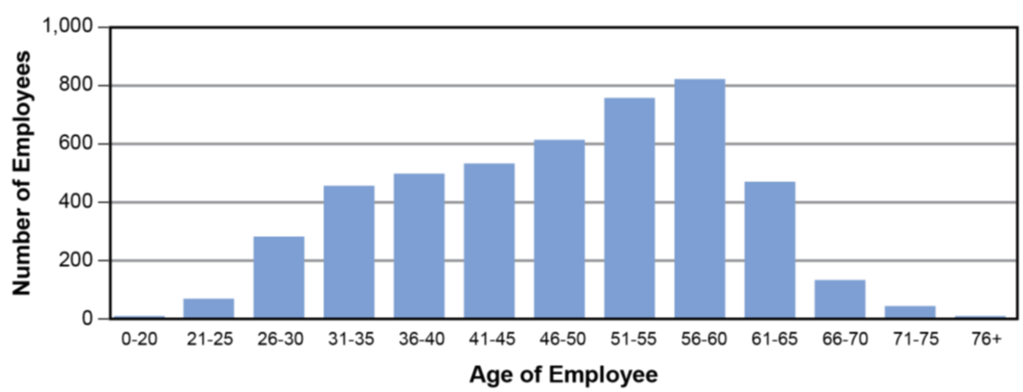
Y-12 has 4,678 employees, with an average age of approximately 48 and an average of 13 years of service. Approximately 45 percent of Y-12's employees are eligible to retire. From the end of FY 2014 to the end of FY 2016, Y-12 hired 1,006 employees and experienced 903 separations, for a net gain of 103. The majority of voluntary separations were from employees aged 56 years and above, mainly from retirement. Y-12 experienced a significant number of involuntary separations among those with 5 or fewer years of service, primarily the result of a work scope transition of the Uranium Processing Facility to Bechtel National. Prior to FY 2016, retirements had increased since FY 2009, while involuntary separations are higher relative to other sites. Early-, mid-, and advanced-career employees have remained relatively stable, with periods when slight increases or decreases occurred. Y-12 anticipates a stable workforce over the FYNSP period.



Notes:

The workforce increased in FY 2016 because of an increase in work scope. There are no irregularities.

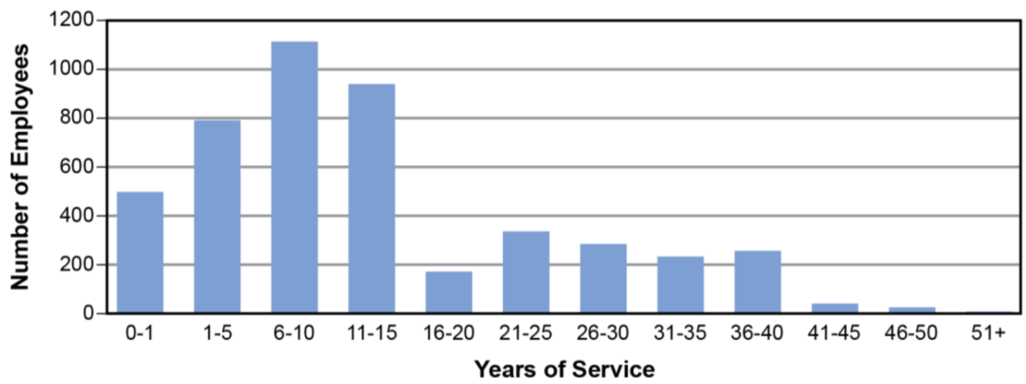
Figure E–55. Y-12 total workforce by Common Occupational Classification System



Notes:

The age demographics indicate that Y-12 is steadily replacing its aging workforce, with an average age of 48.2 years old and 52.3 percent of employees being age 50 or less. The percentage of retirement-eligible employees is based on the number of participants eligible to participate in the defined benefit pension plans.

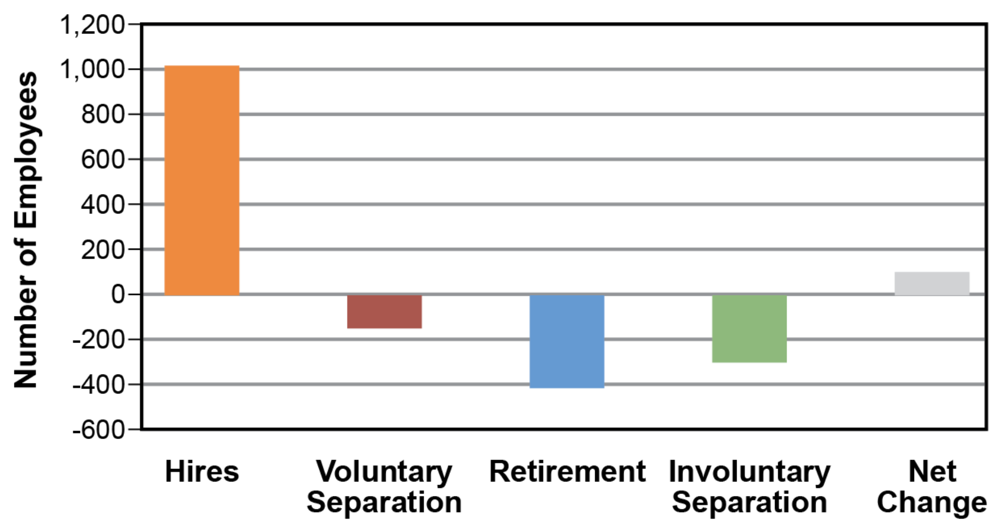
Figure E–56. Y-12 employees by age



Notes:

The average years of service at Y-12 is 13 years, with 51.5 percent of the workforce having 10 years of service or less. This indicates that Y-12 is replenishing its workforce for future needs. At this time, attrition remains relatively low, thereby facilitating Y-12's ability to retain a skilled workforce.

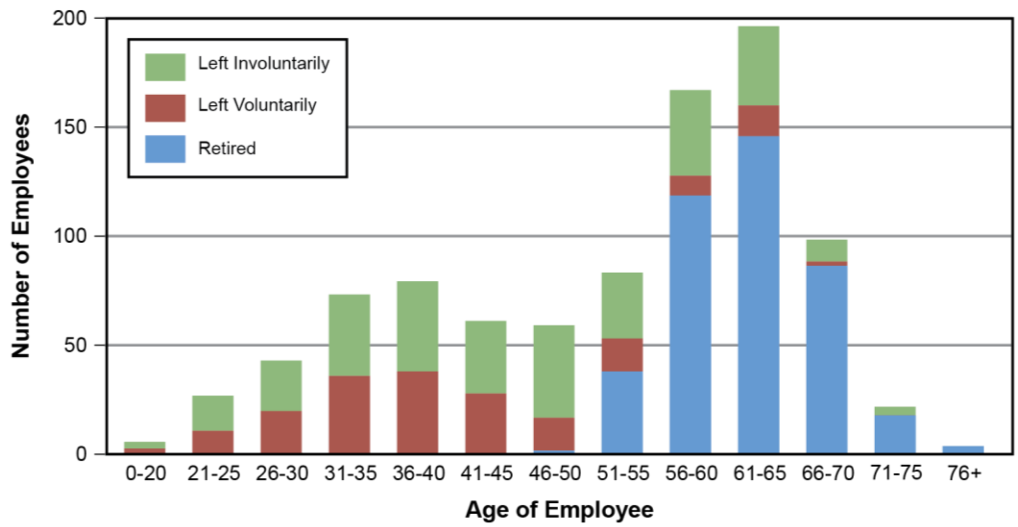
Figure E–57. Y-12 employees by years of service



Notes:

During FY 2015, the scope to design and build the Uranium Processing Facility transitioned to Bechtel National. With this transition, 169 employees left the Consolidated Nuclear Security, LLC, Y-12 payroll and joined Bechtel National.

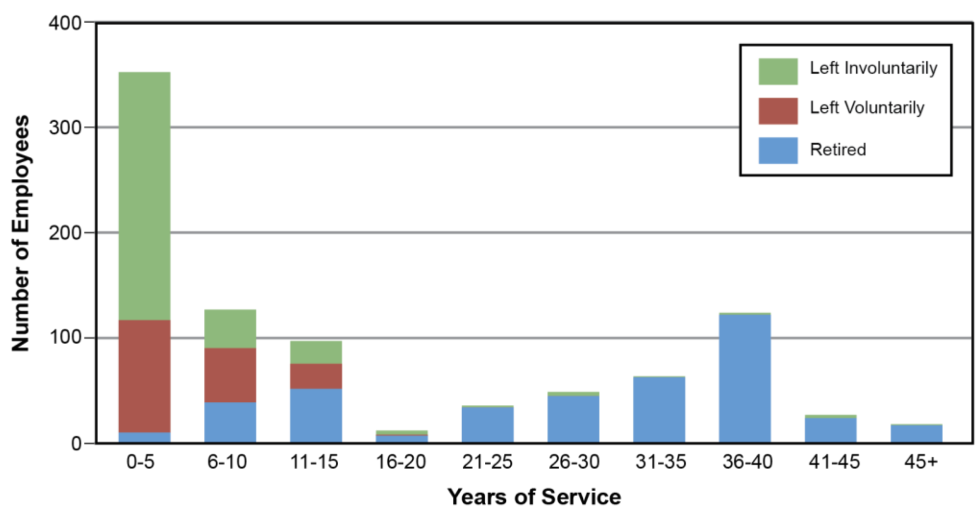
Figure E–58. Change in last two fiscal years (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

During FY 2015, the scope of work for the Uranium Processing Facility transitioned to Bechtel National. A total of 58 employees elected to retire from Consolidated Nuclear Security, LLC, Y-12 and joined Bechtel National. There are no irregularities, with 62 percent of the separations being age 51 and above. Many of these are the result of retirements, which are expected in older age groups. The largest group of terminations was employees age 61 to 65.

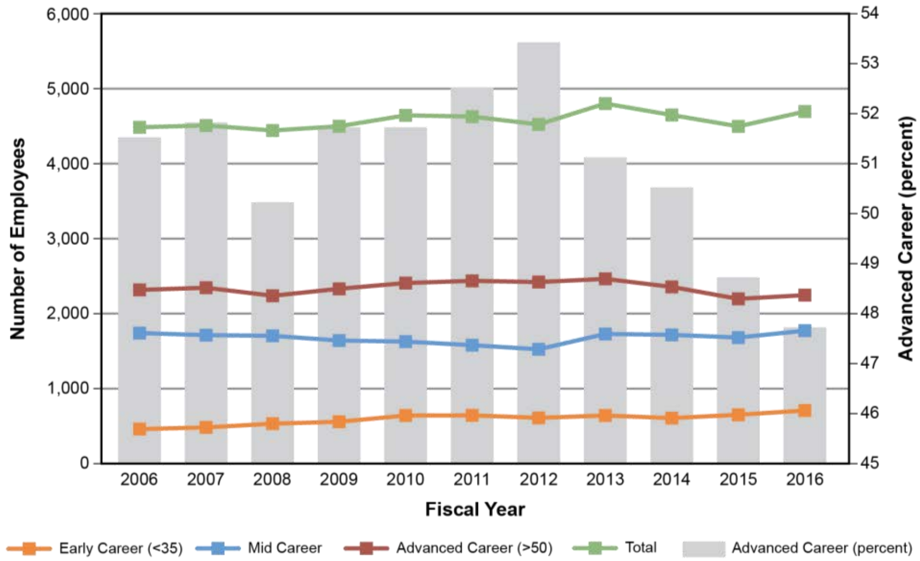
Figure E–59. Age of Y-12 employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

Most voluntary separations are employees with fewer than 5 years of service, and most retirees leave with 36 to 40 years of service. During FY 2015, the scope of work for the Uranium Processing Facility was transitioned to Bechtel National. In FY 2015, 111 employees who transitioned to Bechtel National as part of the Uranium Processing Facility had 0 to 5 years of service.

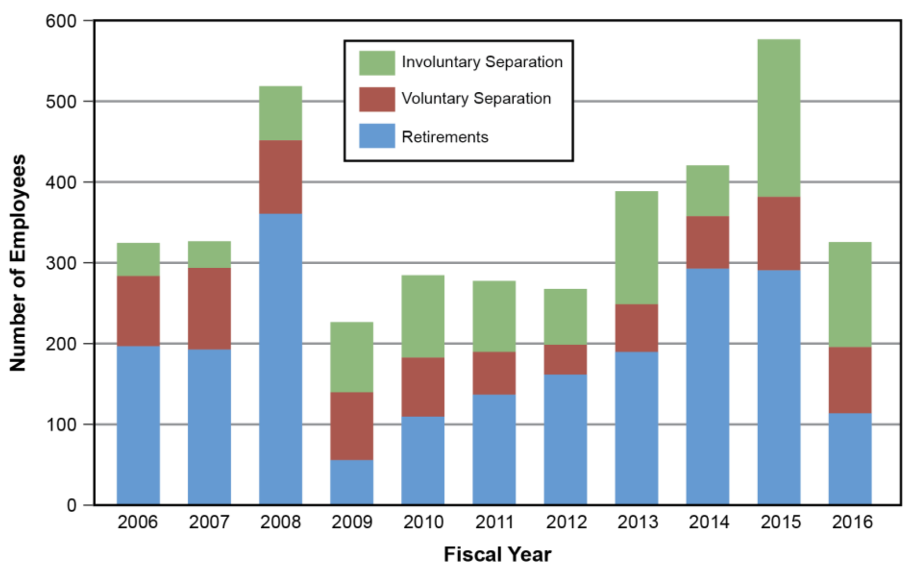
Figure E–60. Years of service of Y-12 employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The data reflect an influx of employees in the early-career bracket and a decrease in the number of employees in the advanced-career bracket, which indicates that the workforce is being replenished.

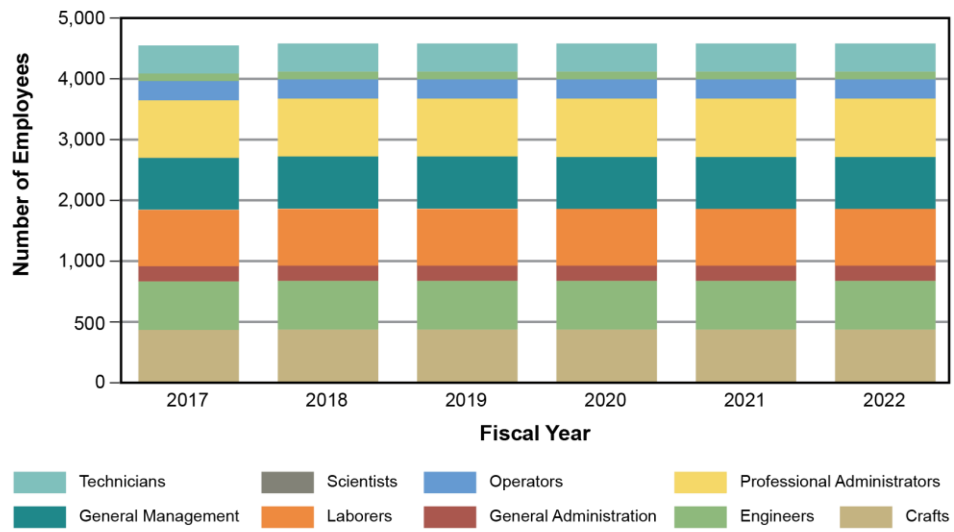
Figure E–61. Y-12 trends by career stage



Notes:

In FY 2008, a voluntary incentive program was offered, which accounts for the high number of retirements in that year. Effective July 1, 2014, Consolidated Nuclear Security, LLC, became the new managing contractor for both Y-12 and Pantex. A Voluntary Separation Program was offered beginning April 24, 2014, with terminations effective no later than June 30, 2014. The Voluntary Separation Program at Y-12 resulted in 105 terminations.

Figure E–62. Y-12 employment separation trends



Notes:

With the new contract in place for the operations of Pantex and Y-12, cost efficiencies and workforce optimization will be realized through systems and operational integration and other planned cost-savings initiatives. This is reflected in the workforce projections for both Pantex and Y-12.

Figure E–63. Total projected Y-12 workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

E.4 The National Security Site

E.4.1 Nevada National Security Site

E.4.1.1 Mission Overview

The Nevada National Security Site is the primary location within the NNSA complex where high-hazard experiments with radiological and other high-hazard materials are conducted. It is the only location in the United States authorized to conduct subcritical experiments with both HE and weapons-relevant quantities of plutonium.

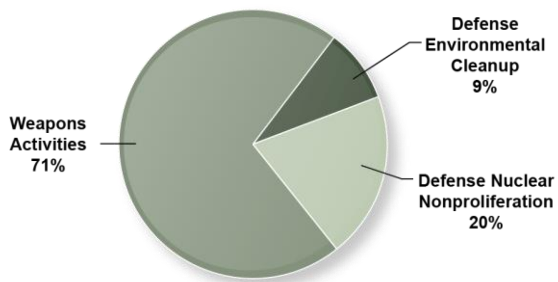
- Location: Las Vegas, Nevada
- Additional Operating Capabilities: Offices at LANL, LLNL, and SNL; Remote Sensing Laboratory at Nellis Air Force Base and Andrews Air Force Base; and the Special Technologies Laboratory in Santa Barbara, California
- Total Employees: 2,052
- Type: Multi-program experimental site
- Website: www.nnss.gov and www.nv.energy.gov
- Contract Operator: National Security Technologies Services, LLC, a corporate subsidiary of Honeywell International, Jacobs Engineering Group, and Stoller Newport News Nuclear

Nevada National Security Site Accomplishments

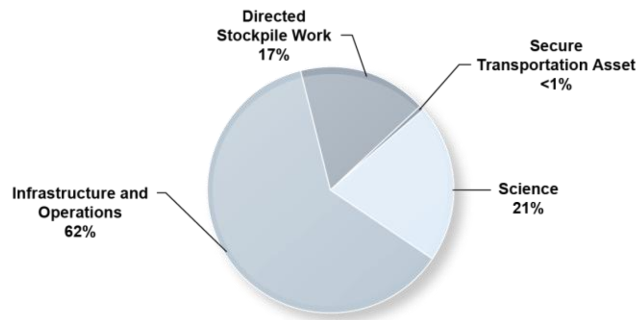
- *Diagnostic development – broadband laser ranging and advanced imaging*
- *U1a.05 drift extension*
- *Joint Actinide Shock Physics Experimental Research (JASPER) Experimental Program*
- *Dense Plasma Focus*
- *X-ray images at Flash X-Ray source*
- *Small dynamic launcher*
- *Enhanced capabilities for subcritical experiments Critical Decision-1 documents*
- *Source Physics Experiments*
- *End-to-End Warhead Monitoring Campaign*

E.4.1.2 Funding

FY 2018 Request – Site Funding by Source
(Total Nevada National Security Site FY 2018 Request = $408.7 Million)



FY 2018 Future Years Nuclear Security Program Request for Weapons Activities *($289.0 Million)*



E.4.1.3 Site Capabilities

The Nevada National Security Site supports stockpile stewardship through plutonium and surrogate subcritical experiment execution, data capture and post-processing, diagnostic R&D, and reanalysis of legacy underground test data. The Nevada National Security Site's capabilities and key experimental facilities that directly support ongoing assessments of the Nation's stockpile include the following:

- The Device Assembly Facility (DAF) supports nuclear weapon experimental capabilities and is one of two facilities in the nuclear security enterprise that allows collocation of HE and SNM, permits staging of large quantities of SNM in independent buildings, and provides the backbone to support various missions. For stockpile stewardship, the facility's glove box, downdraft table, and radiography capabilities support assembly of SNM targets for Joint Actinide Shock Physics Experimental Research (JASPER), as well as SNM and HE packages for subcritical experiments at the U1a Complex (U1a). The DAF also hosts the unique National Criticality Experiments Research Center (NCERC), which is a unique asset. NCERC supports a mix of critical and subcritical benchmark quality experiments, as well as detector development, inspector and first responder training, criticality safety training, and handling of damaged nuclear weapons. NCERC contains the largest collection of nuclear critical mass assembly machines in the western hemisphere. These assemblies can be broadly categorized as benchmark critical assemblies, general-purpose assemblies, and fast burst assemblies, which were designed to accommodate a broad range of experiments.
- Subcritical experiments at U1a focus on early explosion-time hydrodynamic (fluid-like flow) characterization of plutonium and plutonium surrogates in weapon-relevant geometries The Nevada National Security Site, LLNL, LANL, and SNL plan to enhance U1a to enable well-diagnosed, early- and late-time radiographic and neutron reactivity measurements on hydrodynamic tests. The new data will facilitate assessment of the effects of aging and manufacturing processes on stockpile weapons. The goal *via* the Enhanced Capabilities for Subcritical Experiments program is to have these enhancements in place for the development phase of the W80-4 (the cruise missile warhead replacement) and interoperable warheads. These programmatic infrastructure investments will improve the understanding of the implosion characteristics of weapon primaries and the capability to certify modernized weapons.

- JASPER is a two-stage light gas gun for studying the behavior of plutonium and other materials at high pressures, temperatures, and strain rates. Experiments on both plutonium and surrogates are conducted at this nuclear facility. Data are obtained on national security materials of various compositions, manufacturing processes, surface preparation, ages, and phases under weapon-like conditions and in extreme states. Such data provide new multi-phase plutonium equation of state models or weapons design codes.
- The Nevada National Security Site also includes a variety of administrative, R&D, mixed laboratory, calibration, and diagnostic development facilities for national security missions.

Hydrodynamic and Subcritical Experiments at Weapon Scale

- **Capability.** Evolving development of transformational diagnostics for subcritical and hydrodynamic experiments: photon Doppler velocimetry, optical ranging, surface imaging, soft x-ray imaging, holography, dynamic pyrometry and emissivity, dynamic x-ray diffraction, and prompt neutron and x-ray detectors.
- **Challenges.** Increasing the tempo, variety, and sophistication of subcritical experiments and enhanced capability for subcritical experiments by exploring major improvements in experiment and U1a operations efficiencies.
- **Strategy and Path Forward.** Implement multi-user U1a operating model and an integrated, logic-linked framework schedule to optimize critical path contributors. Invest in U1a, DAF, and transportation for future subcritical experiments.

Weapons Science Experiments Using High-Hazard Materials

- **Capability.** Maturing capabilities in shock and compression experiments, dynamic phase change studies, capture of thermodynamic and constitutive properties data, platform and source development, and materials diagnostic R&D on JASPER, the Special Technologies Laboratory "Boom Box," the Dynamic Science Launcher, and Z.
- **Challenges.** Breakthroughs in materials science are somewhat limited by the number and rate of experiments and staffing constraints.
- **Strategy and Path Forward.** Leverage site-directed R&D initiated new diagnostics and mature these diagnostics; optimize diagnostics for multi-platform use (*e.g.*, hydrodynamic experiments, subcritical experiments, and JASPER using photon Doppler velocimetry or pyrometry.

Nuclear Criticality Safety Research and Training

- **Capability.** The NCERC has a substantial SNM inventory and expertise to support a variety of nuclear security missions, including nuclear criticality safety research and training, nuclear emergency response, nuclear nonproliferation, and support for Government agencies that request access to significant quantities of nuclear material in numerous configurations. Operations at the NCERC include experiments to measure a wide variety of nuclear properties to meet sponsor needs.
- **Challenges.** The Nevada National Security Site has no significant challenges for this capability.
- **Strategy and Path Forward.** This capability will be maintained and used to meet U.S. Government needs.

Key Experimental Facilities at Nevada National Security Site

U1a Complex (U1a)

- U1a is an underground laboratory used for subcritical experiments–physics experiments that contribute to assessment of the U.S. nuclear weapons stockpile and confidence in the ability to predict performance of weapons going through modernization.
- These experiments support Department of Energy/National Nuclear Security Administration's Stockpile Stewardship Programs, created to maintain the safety and effectiveness of the U.S. nuclear weapons stockpile.

Device Assembly Facility (DAF)

- DAF is a nuclear facility that supports nuclear weapon experimental capabilities.
- DAF supports assembly of special nuclear material (SNM) targets for JASPER as well as SNM and high explosive packages for subcritical experiments at U1a.
- DAF also hosts the National Criticality Experiments Research Center, which is a unique asset supporting a mix of critical and subcritical benchmark quality experiments, as well as detector development; inspector, first responder, and criticality safety training; and handling of damaged nuclear weapons.

Joint Actinide Shock Physics Experimental Research Facility (JASPER)

- The JASPER facility at the Nevada National Security Site is a two-stage light gas gun for studying the behavior of plutonium and other materials at high pressures, temperatures, and strain rates.
- The highly precise data obtained contribute to the creation of more accurate, multi-phase plutonium equation of state models and enable the calibration of nuclear weapons design codes.
- JASPER plays an integral role in the assessment of the Nation's nuclear weapons stockpile.

E.4.1.4 Accomplishments

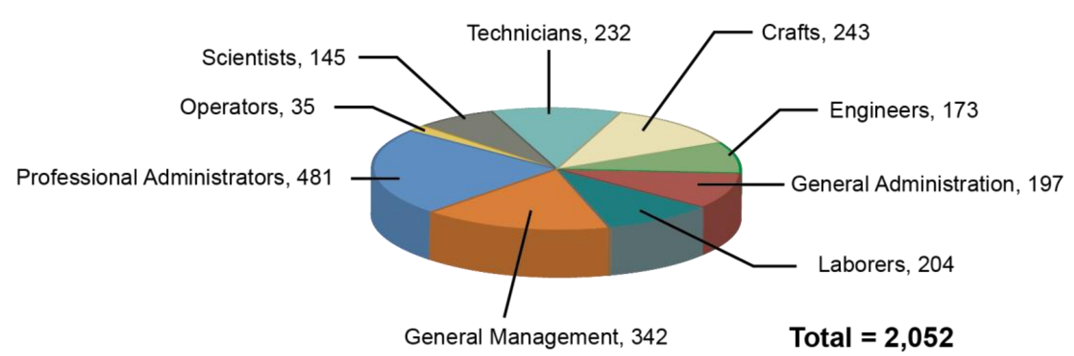
- Diagnostic development – broadband laser ranging. The Nevada National Security Site continued collaborating with the national security laboratories to develop the broadband laser ranging hydrodiagnostic as the next transformational experimental probe. When paired with photon Doppler velocimetry, broadband laser ranging will provide unprecedented velocity and position measurements of imploding surfaces.
- U1a.05 drift extension. Completed the mining and construction of the underground U1a.05 drift extension. The new backdoor drift into the zero room will allow fielding of increasingly sophisticated subcritical experiments with use of 6-foot vessels for at least the next 5-year period.
- JASPER Experimental Program. Conducted 11 JASPER experiments, including 5 graded density impactor experiments to provide precise plutonium property data under dynamic conditions.
- Dense Plasma Focus. Used the pulsed neutron source at the Dense Plasma Focus to support a proof-of-principle experiment to measure a fissile decay curve as an early demonstration of the concept for neutron diagnosed subcritical experiments to address plutonium aging at U1a.
- X-ray images at Flash X-Ray. In collaboration with LLNL, LANL, and SNL, acquired double pulse radiographic images on LLNL's Flash X-Ray accelerator for a key LLNL national milestone to support LEP design options.
- Small dynamic launcher. Completed the setup of a small dynamic launcher to enhance knowledge and skill preservation and support the development of diagnostics for dynamic material property experiments early in their technology readiness level (*e.g.*, prior to installation on JASPER). This platform will train next-generation diagnosticians, scientists, data analysts, and diagnostic

engineers as a practicum on how to plan, execute, and analyze experiments prior to working on larger-scale facilities.

- Cooperative experiments and R&D with the Office of Defense Nuclear Nonproliferation included Source Physics Experiments to improve capability to detect and characterize underground nuclear explosions and the End-to-End Warhead Monitoring Campaign. Conducted tests *via* the End-to-End National Center for Nuclear Security Campaign as part of a comprehensive effort by the Office of Defense Nuclear Nonproliferation R&D and the Office of Nuclear Verification to support technology development and field testing for future arms control initiatives.
- Vendor Data Collection Event. Conducted this event at the Radiological/Nuclear Countermeasures Test and Evaluation Complex. The activity provided the test bed to the Department of Homeland Security's Domestic Nuclear Detection Office and its vendors, allowing retrieval of necessary data to facilitate future technology development.

E.4.1.5 Nevada National Security Site Workforce

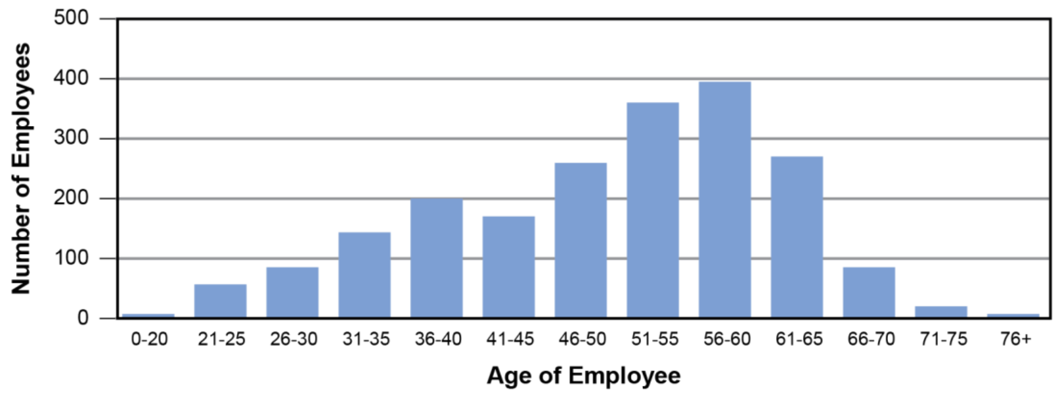
The Nevada National Security Site has 2,052 employees, with an average age of 50 years and an average of 12 years of service. Approximately 44 percent of the Nevada National Security Site's employees are eligible for retirement. The population is heavily concentrated between the ages of 46 and 65. The average years of service is 12, with most of the workforce having 0 to 15 years. Since the end of FY 2014, the site hired 365 employees and experienced 474 separations, resulting in a net loss of 109. Over the past few years, the M&O partner implemented a self-select voluntary separation program and reduction-in-employment, as it realigned the organization and reprioritized missions. These programs, along with imposed hiring controls, affect separations and hiring data. Over the past several years, the site has seen a decline in mid-career employees while advanced-career and early-career employees remained relatively consistent despite some changes. The Nevada National Security Site expects a slight increase in employees over the FYNSP period.



Notes:

The total workforce decreased slightly (by 80 employees) between the end of FY 2014 and the end of FY 2016 (see FY 2016 SSMP). However, between the end of FY 2015 and the end of FY 2016, the workforce did increase slightly as a result of a decrease in the voluntary and involuntary separations and an increase in staffing. Of the total workforce at the end of FY 2016, 26.8 percent are in technical positions.

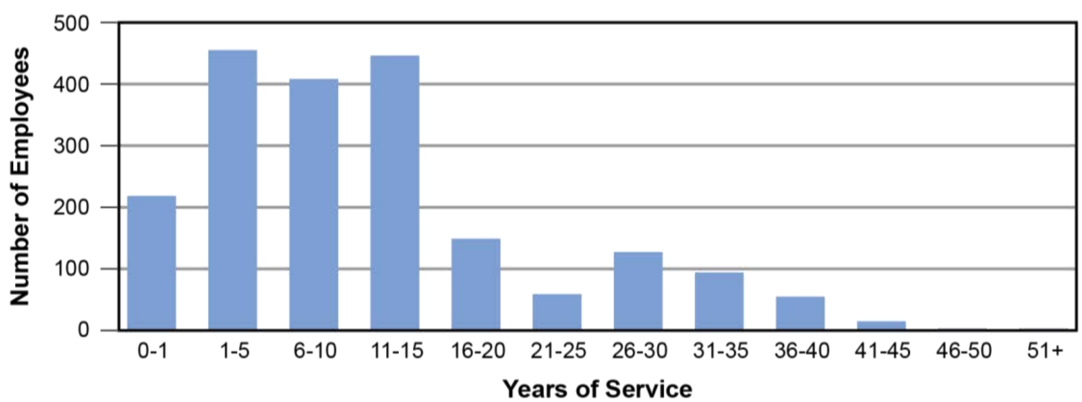
Figure E–64. Nevada National Security Site total workforce by Common Occupational Classification System



Notes:

The age of the workforce is still heavily concentrated between ages 46 and 65. The percentage of retirement-eligible staff significantly increased from 30 percent in FY 2015 to 44 percent in FY 2016. The number of retirements is expected to increase in FY 2017 because of the transition to a new contract operator. Moreover, as the "baby boomer" population retires, the average age and percentage of retirement-eligible employees should decrease year to year. In FY 2016, the Nevada National Security Site implemented strategic college graduate hiring goals and company-level internship programs that have increased the technical talent pipeline and the number of employees in lower age categories.

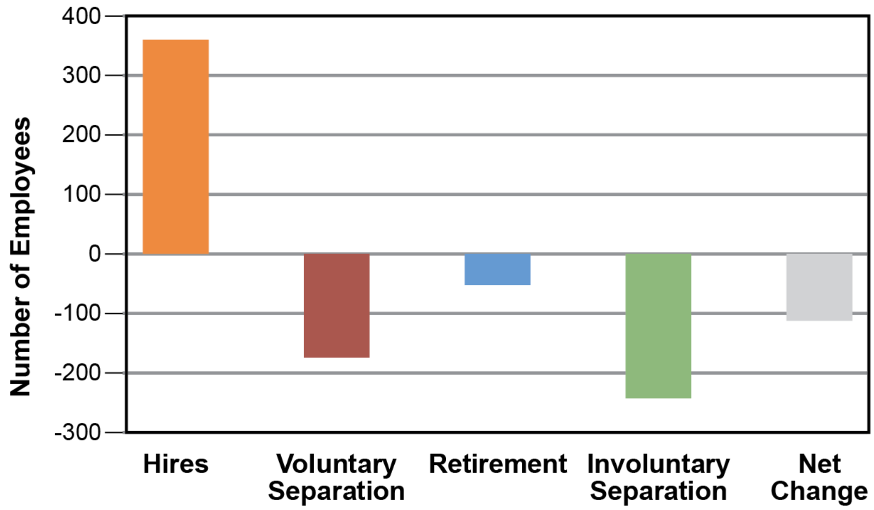
Figure E–65. Nevada National Security Site employees by age



Notes:

The years of service are still heavily concentrated between 1 and 15 years. Many individuals with long service left with the voluntary reduction in force in FY 2015 or retired in FY 2016. The average years of service is the same as in FY 2015 and, when correlated with average age, reflects a need to hire for experience. Over half of employees with 6 to 15 years of service are 51 years of age and older. The need to hire for experience decreased in FY 2016, and this is expected to continue through FY 2017. The Nevada National Security Site has implemented strategic college hiring goals and company-level internship programs, which have increased the technical talent pipeline and the number of employees in the lower years of service categories.

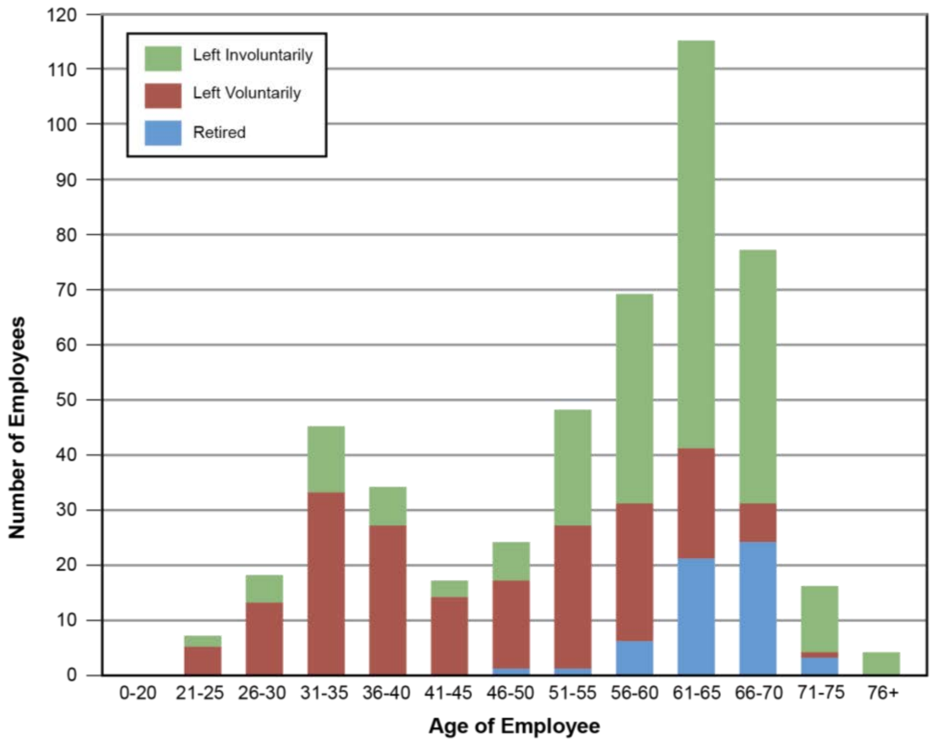
Figure E–66. Nevada National Security Site employees by years of service



Notes:

A negative net change in the number of employees occurred between the end of FY 2014 and the end of FY 2016 as the result of the increase in voluntary separations because of the FY 2015 self-select voluntary separation program, despite an increase in hiring. However, removal of the hiring restrictions led to an increase in hires in FY 2016, especially in the third and fourth quarters. Retirements increased in FY 2016 and are expected to increase in subsequent years as a result of the greater number of employees who are retirement eligible and the transition to a new contract operator.

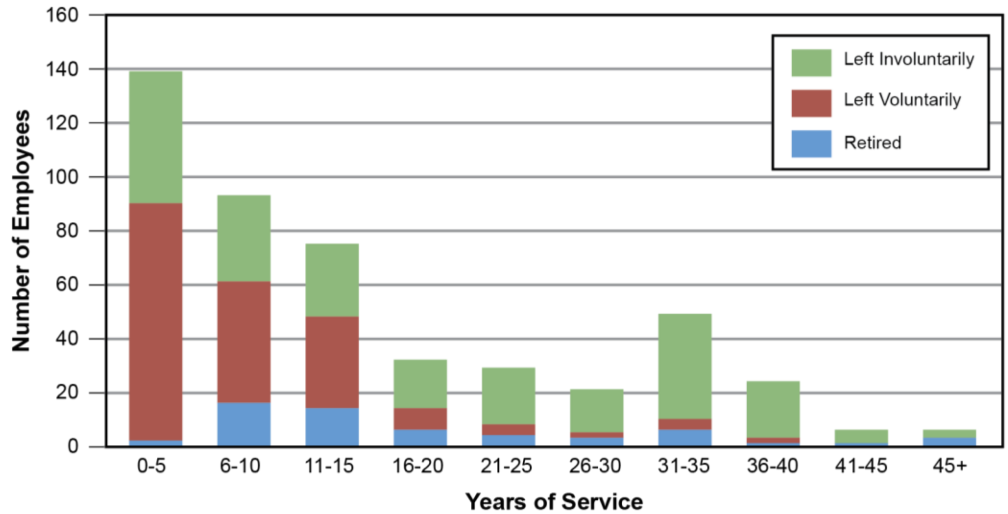
Figure E–67. Change in last two fiscal years (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

Advanced-career employees had the largest percentage of voluntary and involuntary separations. In FY 2015, the majority of voluntary separations (both for technical positions and overall) were the result of a resignation and career advancement opportunity. This is consistent with industry survey data as the primary reason employees separate voluntarily and is expected to increase as the economy continues to improve. Most individuals who left "involuntarily" in FY 2015 with the reduction-in-employees (RIE) were over 55 years of age. The average age of individuals who left with the RIE was 64. In FY 2015, 7.1 percent retired either early or as expected. In FY 2016, the majority of voluntary separations were also the result of a resignation and career advancement opportunity. In FY 2016, 20.7 percent retired either early or as expected. The reason for the difference in retirement rates between the two fiscal years is that most retirement-eligible employees left with the FY 2015 voluntary RIE. Voluntary turnover and retirements are expected to increase in FY 2017 because of the percentage eligible to retire and the transition to a new contract operator.

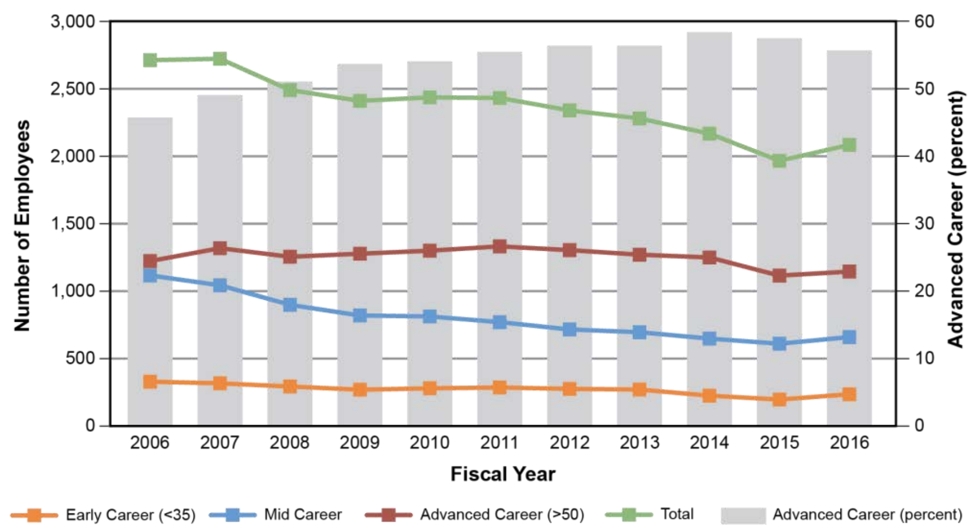
Figure E–68. Age of Nevada National Security Site employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

A large percentage of employees with years of service between 0 and 15 left the company voluntarily. Approximately 47 percent of employees left within the first 5 years of service.

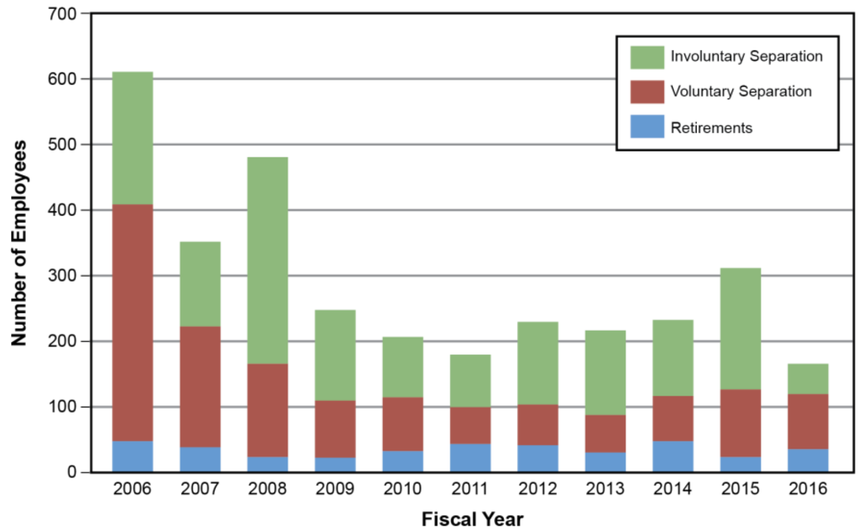
Figure E–69. Years of service of Nevada National Security Site employees who left service (end of fiscal year 2014 to end of fiscal year 2016)



Notes:

The percentage of employees in their early-, mid-, and advanced-career has remained relatively consistent with previous years. The largest percentage of employees are in the advanced career stage, reflecting the high average age of the workforce. Many of the new hires/positions are at the advanced-career stage. The relative stability of the workforce in the advanced-career stage reflects a need to hire for experience. The early- and mid-career workforce increased from FY 2015 by approximately 22 percent. The Nevada National Security Site has implemented strategic college hiring goals and company-level internship programs to rebuild talent pipelines, particularly for technical positions.

Figure E–70. Nevada National Security Site trends by career stage

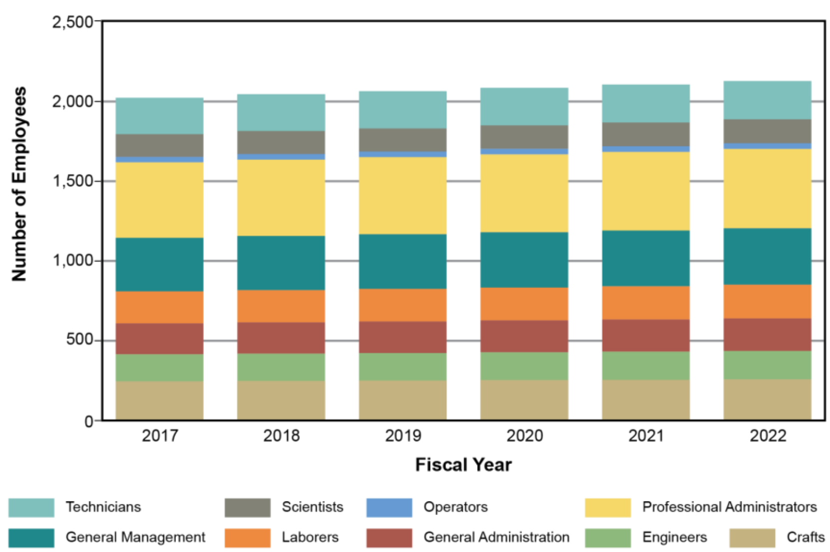


Notes:

The July 2006 contract change influenced the number of voluntary departures during that year.

Retirements increased in FY 2016 and are close to the average number of retirees during the past 9 years. The number of retirements in FY 2015 was lower because many retirement-eligible employees took part in the self-select voluntary separation program (shown as "involuntary" in the chart above). The number of "voluntary" separations is lower than in FY 2015 but higher than several of the prior years. Voluntary turnover and retirements are expected to increase in FY 2017 because of the percentage eligible to retire and the transition to the new contract operator. The Nevada National Security Site tracks the reason for all terminations, especially terminations of technical staff, and will continue to analyze the data for trends and to focus on attracting, training, and retaining employees, especially in early- and mid-career, hard-to-fill technical and critical skills positions.

Figure E–71. Nevada National Security Site employment separation trends



Notes:

The contract operator will continue to use subcontractors and staff augmentation to address the peak workload.

Figure E–72. Total projected Nevada National Security Site workforce needs by Common Occupational Classification System over Future Years Nuclear Security Program period

Appendix F
Glossary

3+2 Strategy—The strategy to reduce the size of the stockpile, increase interoperability, reduce the number of warhead types, and provide flexibility to reduce the risk of geopolitical surprise.

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 to 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.

Construction Resource Planning List—A nuclear security enterprise-wide project list of approved and proposed construction projects that indicates rough orders of magnitude for the total project cost and schedule. Near-term approved projects (usually within the Future Years Nuclear Security Program) are in more advanced stages of development. Proposed projects are pre-conceptual and have not been fully scoped. The project list is reevaluated each budget year, and schedules shift based on mission need and funding availability.

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 typical levels a DOE project typically progresses through, which serve as major milestones approved by the Chief Executive for Project Management. Each critical decision 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.

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.

downselect—The process of narrowing the range of design options during the *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.

exascale computing—The use of computer systems capable of at least a thousand petaFLOPS or a quintillion (10^{18}) floating point operations per second.

first production unit—The first completed item 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.

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.

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, improving security, and addressing defects.

lightning arrestor connector—Advanced interconnect nuclear safety devices designed to limit voltage during lightning strikes and in 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, 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.

national security laboratory—Los Alamos National Laboratory, Sandia National Laboratories, or Lawrence Livermore National Laboratory.

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, the trafficking, and the enrichment of the material.

nuclear security enterprise—The physical infrastructure, technology, and workforce at the national security laboratories, the nuclear weapons production facilities, 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 facility—The Kansas City National Security Campus, Pantex Plant, Y-12 National Security Complex, or Savannah River Site. It also includes Los Alamos National Laboratory and Sandia National Laboratories, with respect to some specific weapons production activities.

Other Program Money—Funding found outside of a life extension program (LEP) funding line (in other program lines) but that is directly (uniquely) attributed to the LEP. The 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 *6.x Process* consists of sub-phases, which basically correspond to Phases 1 through 6.

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.

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.

radiation case—A vessel that confines the radiation generated in a staged weapon.

reservoir—A vessel that contains 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 a NNSA weapon system on randomly selected, newly retrofitted weapons to determine the effect of the retrofit on the weapon system 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 and is activated by energy from the primary.

service life—The duration of time 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 assembling, testing, transporting, and delivery of 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 a comprehensive nuclear explosive test ban.

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, 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, of newly produced weapons, or of those 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 where it can be adopted and used by U.S. industry. The gap between research and commercialization is often referred to as the "valley of death."

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 where 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.

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 that is produced in nuclear reactors by the action of neutrons on lithium nuclei.

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 the 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 D5 Fleet Ballistic Missile.

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.

Appendix G
List of Acronyms and Abbreviations

3D	three-dimensional
AF&F	arming, fuzing, and firing
ALCM	air-launched cruise missile
Alt	alteration
AoA	Analysis of Alternatives
ASC	Advanced Simulation and Computing
ASCR	Advanced Scientific Computing Research
ATDM	Advanced Technology Development and Mitigation
ATS	Advanced Technology System
CAPE	Cost Assessment and Program Evaluation
CBI	Capabilities Based Investments
CD	critical decision
CHE	conventional high explosive
CMD	Component Manufacturing Development
CMRR	Chemistry and Metallurgy Research Replacement
CO_2	carbon dioxide
COCS	Common Occupational Classification System
CoLOSSIS	Confined Large Optical Scintillator Screen and Imaging System
CORAL	Collaboration of Oak Ridge, Argonne, and Livermore
CSA	canned subassembly
CTS	Commodity Technology System
DARHT	Dual Axis Radiographic Hydrodynamic Test
DOD	Department of Defense
DOE	Department of Energy
DSW	Directed Stockpile Work
DUF_4	depleted uranium tetrafluoride
DUF_6	depleted uranium hexafluoride
ECI	Exascale Computing Initiative
ECP	Exascale Computing Project
ECSE	Enhanced Capabilities for Subcritical Experiments
EMAC	Enterprise Modeling and Analysis Consortium
ERM	Enterprise Risk Management
ESAR	Engineering, Stockpile Assessments, and Responsiveness
FFRDC	Federally Funded Research and Development Center

FSE	Federal Salaries and Expenses
FTE	full-time equivalent
FY	fiscal year
FYNSP	Future Years Nuclear Security Program
G2	Program Management Information System Generation 2
GAO	Government Accountability Office
GTS	gas transfer system
HE	high explosives
HED	high energy density
HEPF	High Explosives Pressing Facility
HERMES	High Energy Radiation Megavolt Electron Source
HEU	highly enriched uranium
HPC	high performance computing
ICBM	intercontinental ballistic missile
ICE	independent cost estimate
ICF	Inertial Confinement Fusion Ignition and High Yield
IDC	integrated design code
IHE	insensitive high explosive
ISO	International Organization for Standardization
IT	information technology
IW	interoperable warhead
JASPER	Joint Actinide Shock Physics Experimental Research
JTA	joint test assembly
JTD	Joint Technology Demonstrator
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
LEU	low-enriched uranium
LEU-Mo	low-enriched uranium-molybdenum
LLNL	Lawrence Livermore National Laboratory
LRSO	long range standoff
M&O	management and operating
MAR	material-at-risk
MaRIE	Matter-Radiation Interactions in Extreme
MESA	Microsystems and Engineering Science Applications
MGT	Mobile Guardian Transporter
MicroFab	MESA microsystems fabrication
Mod	Modification
MRL	manufacturing readiness level
MRR	Material Recycle and Recovery

NCERC	National Criticality Experiments Research Center
NDAA	*National Defense Authorization Act*
NDSE	Neutron Diagnosed Subcritical Experiments
NEA	Nuclear Enterprise Assurance
NEP	nuclear explosive package
New START	New Strategic Arms Reduction Treaty
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NPAC	Office of Nonproliferation and Arms Control
NRC	Nuclear Regulatory Commission
NSCI	National Strategic Computing Initiative
OMB	Office of Management and Budget
Omega	Omega Laser Facility
OPM	Office of Personnel Management
Pantex	Pantex Plant
PCF	Predictive Capability Framework
PDD	Presidential Decision Directive
petaFLOPS	quadrillion floating point operations per second
PF-4	Plutonium Facility
R&D	research and development
RDCS	Research and Development Certification and Safety
RDT&E	Research, Development, Test, and Evaluation
RLUOB	Radiological Laboratory Utility Office Building
SAR	*Selected Acquisition Report*
SFI	significant finding investigation
SGT	Safeguards Transporter
SiFab	Silicon Fabrication
SLBM	submarine-launched ballistic missile
SNL	Sandia National Laboratories
SNM	special nuclear material
SRS	Savannah River Site
SRTE	Savannah River Tritium Enterprise
SSMP	Stockpile Stewardship and Management Plan
STA	Secure Transportation Asset
ST&E	science, technology, and engineering
TA	Technical Area
TATB	triaminotrinitrobenzene
TPBARs	tritium-producing burnable absorber rods
TRIM	Tritium Responsive Infrastructure Modifications
TRL	technology readiness level
TRU	transuranic
TVA	Tennessee Valley Authority

U.S. Code	United States Code
U1a	U1a Complex
UK	United Kingdom
USSTRATCOM	U.S. Strategic Command
Y-12	Y-12 National Security Complex
Z	Z pulsed power facility

Appendix H
List of Figures and Tables

List of Figures

List of Tables

DOE/NA-0058

A Report to Congress

Fiscal Year 2018 Stockpile Stewardship and Management Plan

November 2017

U.S. Department of Energy
National Nuclear Security Administration
1000 Independence Avenue, SW
Washington, DC 20585