United States Government Accountability Office

Report to Congressional Committees

May 2021

NUCLEAR TRIAD

DOD and DOE Face Challenges Mitigating Risks to U.S. Deterrence Efforts

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GAO-21-210

GAO@100 Highlights

Highlights of GAO-21-210, a report to congressional committees

May 2021

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Why GAO Did This Study

The 2018 Nuclear Posture Review indicates that DOD's highest priority is the nuclear deterrent, made up of sea, land, and air legs—referred to as the nuclear triad. DOD has reported that due to prior delays and challenges with aging nuclear triad systems, there is little to no margin for delaying replacement systems without incurring risk to the nuclear deterrent. Similarly, DOE faces a demanding schedule for infrastructure projects and programs for the life extension and production of warheads and bombs.

In this report, GAO examines (1) the challenges DOD and DOE face in meeting operational needs with existing triad systems; (2) the extent to which DOD and DOE triad acquisition programs face schedule risks, and the implications of delays; and (3) whether DOD and DOE have strategies to mitigate risks to the nuclear deterrent, including acquisition delays. To do this work, GAO analyzed DOD and DOE documentation, interviewed officials, and leveraged GAO work on acquisition best practices, triad systems, and the nuclear enterprise.

This is an unclassified version of a classified report we issued in June 2020, and specific classified information has been removed.

What GAO Recommends

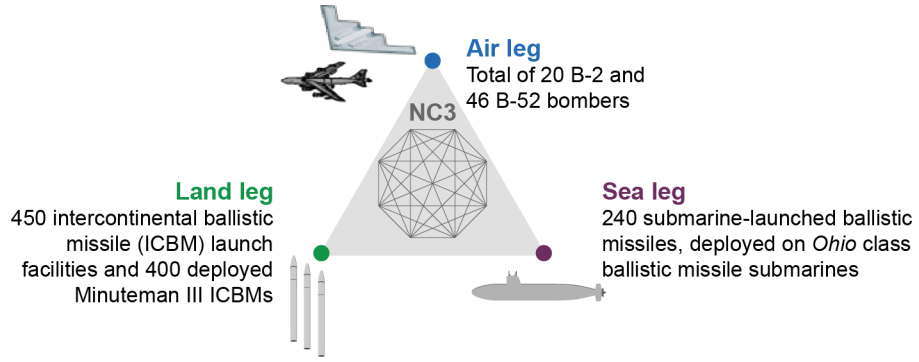
GAO is not making any recommendations because DOD and DOE have ongoing analyses related to a number of potential nuclear triad risk mitigation approaches. However, GAO has made recommendations in prior reports related to triad programs.

View GAO-21-210. For more information, contact Shelby S. Oakley at (202) 512-4841 or oakleys@gao.gov, Allison B. Bawden at (202) 512-3841 or bawdena@gao.gov, or Joseph W. Kirschbaum at 202-512-9971 or kirschbaumj@gao.gov.

What GAO Found

The Department of Defense (DOD) plans to replace or modernize existing triad platforms including submarines, intercontinental ballistic missiles, and bomber aircraft, as well as many of the nuclear command, control, and communication systems that facilitate control of them (see below). The Department of Energy (DOE) plans to modernize its nuclear infrastructure to life extend and produce warheads and bombs. DOD will be challenged to meet some U.S. Strategic Command (USSTRATCOM) operational needs with existing triad systems, shown below, through the end of their service lives. DOD must manage shortfalls in quantities of systems that it can field and capability limitations that reduce effectiveness of these systems. For example, the Navy will have to carefully manage resources to meet USSTRATCOM's operational requirements for the *Ohio* class submarine. Further, DOE faces a long-term sustainment challenge with one of its bombs, the B83-1.

Existing Nuclear Triad Platforms



NC3 = Nuclear Command, Control, and Communications

Source: GAO presentation of Department of Defense information. | GAO-21-210

DOD and DOE are working to replace triad systems nearing retirement, but these replacement programs face schedule risks that could exacerbate challenges with existing triad systems. Replacement programs have risk factors that include concurrency between phases of acquisition programs from development through production, immature technologies, and limited schedule margin. For example,

- The Ground Based Strategic Deterrent program includes limited schedule margin for testing, and if it fails a major test event it would likely delay initial fielding.
- The schedules for DOE's life extension programs are highly dependent on the availability of suitable facilities to manufacture, assemble, and assess bomb and warhead components. However, many DOE facilities needed for these efforts are outdated or obsolete, as more than half of DOE's facilities are over 40 years old.

DOD and DOE have limited ability to mitigate risks to the efficacy of the nuclear deterrent with their current strategy, and are beginning to consider alternatives.

Contents

Abbreviations

ALCM	air-launched cruise missiles
B-2	B-2A Spirit bombers
B-52	B-52H Stratofortress bombers
COVID-19	Coronavirus Disease 2019
DOD	Department of Defense
DOE	Department of Energy
GBSD	Ground Based Strategic Deterrent
ICBM	intercontinental ballistic missiles
LEP	life extension programs
LRSO	Long Range Standoff
MESA	Microsystems, Engineering, Science and Application
MIRV	Multiple Independently Targetable Reentry Vehicle
mods	modifications
NC3	nuclear command, control, and communication
NDAA	National Defense Authorization Act
NNSA	National Nuclear Security Agency
OUSD	Office of the Under Secretary of Defense
SLBM	submarine-launched ballistic missiles
START	Strategic Arms Reduction Treaty
TRL	technology readiness level
UPF	Uranium Processing Facility
USSTRATCOM	United States Strategic Command

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May 6, 2021

Congressional Committees

The Department of Defense (DOD) has repeatedly affirmed that nuclear deterrence is its number-one priority mission and highest investment priority.[1] The 2018 Nuclear Posture Review affirmed the central role of the nuclear deterrent in U.S. national security policy, stating that credible U.S. nuclear capabilities are essential elements in preventing adversary aggression.[2] However, most of the delivery systems that make up the U.S. strategic nuclear deterrent—a triad of intercontinental ballistic missiles (ICBM), submarine-launched ballistic missiles (SLBM), and nuclear-capable bomber aircraft—have been extended beyond their original service lives and, according to DOD, two of the three cannot feasibly be sustained beyond current plans. As such, DOD is executing replacement or modernization programs for each strategic system.

Similarly, the Department of Energy (DOE), which supports the nuclear deterrent by ensuring the safety and reliability of the nation's stockpile of nuclear bombs and warheads, is faced with maintaining aging systems, the oldest of which is over 40 years old. DOE recently completed a program to extend the life of one type of warhead in the stockpile and also has ongoing or planned efforts to replace or extend the life of remaining warheads and bombs for delivery by DOD systems.[3]

[1]Nuclear deterrence refers to deterring nuclear attack and preventing large-scale conventional warfare by using credible nuclear capabilities.

[2]Department of Defense, *Nuclear Posture Review (*February 2018). The Nuclear Posture Review is a periodic policy document created when directed by the President to outline national priorities related to nuclear weapons.

[3]DOE manages many stockpile-related activities through the National Nuclear Security Administration (NNSA), a separately organized agency within DOE that is responsible for the management and security of DOE's nuclear weapons, nuclear nonproliferation, and naval reactor programs.

DOD estimates that modernizing the nuclear triad will cost between about $280 billion and $350 billion between fiscal years 2019 and 2041.[4] This projected cost includes efforts to both modernize and replace the aging aircraft, submarines, and sea- and land-based missiles that comprise the three legs of the nuclear triad and many of the nuclear command, control, and communication (NC3) systems that facilitate control over these systems.

The 2018 Nuclear Posture Review states that, as a result of delaying the recapitalization of the nuclear triad repeatedly, there is now little-to-no margin for further delaying U.S. nuclear modernization programs and upgrading of the nuclear weapons infrastructure without harming the nation's deterrent. Further, DOD and DOE face these programmatic risks at a time in which global threat conditions present additional geopolitical and technological risks. For example, the rapid advancement and spread of military technologies have created a range of possible threats, adding additional complications from existing adversaries. The 2018 Nuclear Posture Review states that only by carefully managing programmatic risk to the replacement programs will the nation avoid nuclear deterrent shortfalls in the next decade.

In light of the importance of the deterrence mission and the negative consequences for the nation's nuclear deterrent in the event of schedule delays, we prepared this report under the authority of the Comptroller General to conduct evaluations that assist Congress with its oversight responsibilities. This report examines (1) the challenges, if any, DOD and DOE face in meeting the United States Strategic Command's (USSTRATCOM) current and expected operational needs with existing triad systems until retired or replaced; (2) the extent to which new DOD and DOE triad acquisition programs face schedule risks and the implications of any delays; and (3) the extent to which DOD and DOE have developed strategies beyond individual program risk-mitigation

[4]These figures are in fiscal year 2019 dollars, and include DOD costs. *Section 1043 Report to Congress for Fiscal Year (FY) 2019* (Nov. 26, 2018). Not later than 30 days after the submission of the President's budget to Congress, the President, in consultation with the Secretaries of Defense and Energy, is required to transmit a report to certain congressional committees for each fiscal year 2013 through 2024 that includes a detailed estimate of budget requirements associated with the 10-year costs to sustain and modernize nuclear triad delivery systems; nuclear command, control, and communications systems; and the nuclear weapons stockpile, as well as the methodology used to create the estimate. Additionally, GAO is to review the same reports for accuracy and completeness. 10 U.S.C. § 492a.

strategies to mitigate current and unexpected challenges, including schedule delays, with existing and replacement triad systems.

In order to determine whether DOD and DOE face challenges meeting USSTRATCOM's current and expected operational needs, we reviewed prior GAO work on the readiness, sustainment, and operations of the nuclear triad and the associated nuclear weapons.[5] We also reviewed recent DOD Quarterly Readiness Reports to Congress and Joint Forces Readiness Review Quarterly Reports to the Secretary of Defense; the United States Air Force Nuclear Deterrence Operations Core Function Support Plan; and the Office of the Secretary of Defense-issued Biennial Assessment and Report on the Delivery Platforms for Nuclear Weapons and the Nuclear Command and Control System, also called the Report on Platform Assessments.[6] We interviewed officials from the Office of the Under Secretary of Defense (OUSD) for Acquisition and Sustainment, OUSD for Policy, and the Joint Staff. Additionally, we received written responses to questions from the OUSD Acquisition and Sustainment's Nuclear Matters office, which is part of OUSD Acquisition and Sustainment.[7] We also met with officials from USSTRATCOM, the Navy, and the Air Force to identify challenges in meeting USSTRATCOM operational needs. We also reviewed DOE's current Weapons Reliability Report, which DOE produces to communicate the reliability of each warhead and bomb type in the stockpile to DOD. We discussed the content of the Weapons Reliability Report with cognizant Office of Defense Programs officials. In addition, we reviewed DOE's Stockpile

[5]GAO, *Nuclear Forces Readiness: Incomplete Readiness Reporting, Aging Delivery Systems, and Potential Delays in Replacement Systems Put Deterrent at Risk*, GAO-19-12C (Washington, D.C.: Mar. 20, 2019); *Defense Nuclear Enterprise: Systems Face Sustainment Challenges,and Actions Are Needed to Effectively Monitor Efforts to Improve the Enterprise*, GAO-20-9C (Washington, D.C.: Oct. 24, 2019); *Nuclear Weapons: DOD Assessed the Need for Each Leg of the Strategic Triad and Considered Other Reductions to Nuclear Forces*, GAO-16-372C (Washington, D.C.: May 18, 2016); *Nuclear Weapons: Annual Assessment of the Safety, Performance, and Reliability of the Nation's Stockpile*, GAO-07-243R (Washington, D.C.: Feb. 2, 2007); *Nuclear Weapons: NNSA Needs to Improve Guidance on Weapon Limitations and Planning for Its Stockpile Surveillance Program,* GAO-12-188 (Washington, D.C.: Feb. 8, 2012); *Columbia Class Submarine: Delivery Hinges on Timely and Quality Materials from an Atrophied Supplier Base*, GAO-21-136SU (Washington, D.C.: November 6, 2020); and *Nuclear Weapons: NNSA Should Evaluate the Role of the Enhanced Surveillance Program in Assessing the Condition of the U.S. Nuclear Stockpile*, GAO-16-549 (Washington, D.C.: Sept. 14, 2016).

[6]We reviewed DOD's biennial Report on Platform Assessments that was issued in 2018.

[7]OUSD for Acquisition and Sustainment provides oversight of DOD acquisition programs, including the nuclear triad acquisition programs, and sustainment of fielded systems.

Stewardship and Management Plan reports for fiscal years 2019 and 2020, which provides DOE's 25-year plan for stockpile sustainment and modernization.[8] We also discussed stockpile sustainment challenges with program managers.

To assess the extent to which DOD and DOE triad acquisition programs face schedule risks, we leveraged ongoing and recently completed GAO work on nuclear triad acquisition programs, including the *Columbia* class submarine and the Ground Based Strategic Deterrent (GBSD), and DOE and DOD life extension programs (LEP) and modernizations.[9] We also reviewed documentation from the military services and cognizant program offices for these efforts to identify potential schedule risks, including program dependencies on other efforts or compressed time frames for conducting key activities. We conducted interviews with each service and with cognizant DOD and DOE officials from acquisition programs and LEPs related to modernizing the existing triad systems to discuss program schedules and risks. We also referred to prior and ongoing GAO

[8]DOE issued the fiscal year 2021 Stockpile Stewardship and Management Plan in December 2020, after analysis for this review concluded.

[9]GAO, *Nuclear Weapons: NNSA Should Adopt Additional Best Practices to Better Manage Risk for Life Extension Programs*, GAO-18-129 (Washington, D.C.: Jan. 30, 2018); *Columbia Class Submarine: Immature Technologies Present Risks to Achieving Cost, Schedule, and Performance Goals*, GAO-18-158 (Washington; D.C.: Dec. 21, 2017); *Nuclear Command, Control, and Communications: Military Services Are Taking Steps to Modernize and Strengthen the System Architecture*, GAO-19-129C (Washington, D.C.: Oct. 17, 2018); *B61-12 Nuclear Bomb: Cost Estimate for Life Extension Incorporated Best Practices, and Steps Being Taken to Manage Remaining Program* Risks, GAO-18-456 (Washington, D.C.: May 31, 2018); *Columbia Class Submarine: Overly Optimistic Cost Estimate Will Likely Lead to Budget Increases*, GAO-19-497 (Washington, D.C.: Apr. 8, 2019); *Defense Acquisitions Annual Assessment: Drive to Delivery Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight* , GAO-20-439 (Washington, D.C.: June 3, 2020); *Nuclear Weapons: NNSA Has taken Steps to Prepare to Restart a Program to Replace the W78 Warhead Capability*, GAO-19-84 (Washington, D.C.: Nov. 30, 2018); *Nuclear Weapons: Action Needed to Address the W80-4 Warhead Program's Schedule Constraints*, GAO-20-409 (Washington, D.C.: July 23, 2020); *Nuclear Weapons: NNSA Should Further Develop Cost, Schedule, and Risk Information for the W87-1 Warhead Program,* GAO-20-207C (Washington, D.C.: Feb. 28, 2020)*; Nuclear Weapons: NNSA Should Further Develop Cost, Schedule, and Risk Information for the W87-1 Warhead Program*, GAO-20-703 (Washington, D.C.: Sept. 9, 2020); and GAO, *Nuclear Triad: DOD and DOE Face Challenges Mitigating Risks to U.S. Deterrence Efforts*, GAO-20-87C (Washington, D.C.: June 19, 2020). DOE and DOD undertake LEPs to refurbish or replace nuclear weapons' components to extend their lives, enhance their safety and security characteristics, and consolidate the stockpile into fewer weapon types to minimize maintenance and testing costs while preserving needed military capabilities.

work on other acquisition programs and GAO-identified best practices for acquisition programs.

In order to assess the extent to which DOD and DOE have strategies to mitigate current and future challenges, we reviewed individual program risk matrices and program documentation for the acquisition programs. We reviewed applicable DOD guidance documents, to include Nuclear Posture Reviews (2010 and 2018); and documentation related to USSTRATCOM operational requirements for nuclear weapons. In addition, we reviewed DOE's Weapons Reliability Report, the 2019 and 2020 Stockpile Stewardship and Management Plan reports, and the Report on Stockpile Assessments, which assesses whether there is a need to resume underground nuclear tests to ensure the safety, reliability, and performance of the nuclear stockpile. We also interviewed or obtained written responses from cognizant planning and operations officials from the Joint Staff; OUSD for Acquisition and Sustainment; OUSD for Policy; USSTRATCOM; and the services. We also interviewed DOE officials from the National Nuclear Security Administration (NNSA) Office of Defense Programs and program managers for the LEPs and reviewed recently completed GAO evaluations of DOE's work to ensure the availability of strategic materials and to modernize nuclear production infrastructure.[10]

We conducted this performance audit from November 2017 to March 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to

[10]GAO, *DOE Project Management: NNSA Should Ensure Equal Consideration of Alternatives for Lithium Production,* GAO-15-525 (Washington, D.C.: July 13, 2015); GAO-16-585; *National Nuclear Security Administration: Action Needed to Address Affordability of Nuclear Modernization Programs*, GAO-17-341 (Washington, D.C.: Apr. 26, 2017); *Modernizing the Nuclear Security Enterprise: A Complete Scope of Work Is Needed to Develop Timely Cost and Schedule Information for the Uranium Program*, GAO-17-577 (Washington, D.C.: Sept. 8, 2017); *Nuclear Weapons: NNSA Should Clarify Long-Term Uranium Enrichment Mission Needs and Improve Technology Cost Estimates*, GAO-18-126 (Washington, D.C.: Feb. 16, 2018); *Modernizing the Nuclear Security Enterprise: NNSA Is Taking Action to Manage Increased Workload at Kansas City National Security Campus*, GAO-19-126 (Washington, D.C.: Apr. 12, 2019); *Nuclear Weapons: Additional Actions Could Help Improve Management of Activities Involving Explosive Materials*, GAO-19-449 (Washington, D.C.: June 17, 2019); *Modernizing the Nuclear Security Enterprise: Uranium Processing Facility is on Schedule and Budget, and NNSA Identified Additional Uranium Program Costs*, GAO-20-293 (Washington, D.C.: Mar. 11, 2020); *Nuclear Weapons: NNSA Plans to Modernize Critical Depleted Uranium Capabilities and Improve Program Management,* GAO-21-16 (Washington, D.C.: Oct. 15,2020); and *Nuclear Weapons: NNSA Needs to Incorporate Additional Management Controls Over Its Microelectronics Activities*, GAO-20-357 (Washington, D.C.: June 9, 2020). We also have ongoing work on DOE's efforts to reestablish a lithium capability.

obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. We subsequently worked with DOD and DOE from July 2020 to May 2021 to prepare this unclassified version of the original classified report for public release. This public version was also prepared in accordance with these standards.

On March 13, 2020, as we were finalizing this report, the President declared a nationwide state of emergency as a result of the spread of the COVID-19 coronavirus. GAO adjusted its operating status in order to curb the spread of the virus, including closing rooms where work on classified information is conducted. DOD also adjusted its operating status. As a result, we suspended work on this report. This report does not reflect the effects of these COVID-19 measures on program schedules or progress, and, with the exception of statements based on more recently published GAO reports, is current as of March 2020.

This report is an unclassified version of a classified product that was issued in June 2020.[11] DOD and DOE deemed some information in our June report to be classified, which must be protected from loss, compromise, or inadvertent disclosure. Therefore, this report omits information about specific STRATCOM requirements, system capabilities, and specific information about some systems and processes, among other things. Although the information provided in this report is more limited, the report addresses the same objectives as the classified report and uses the same methodology.

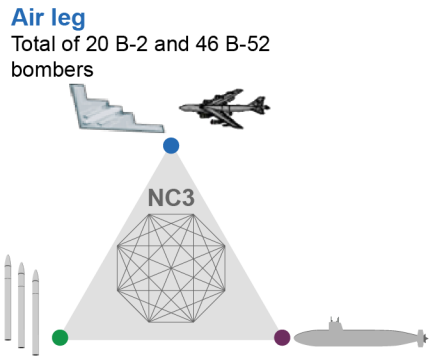
Background

The current U.S. strategic nuclear deterrent is spread among three legs—called a triad—as depicted in figure 1. We reported in 2016 that DOD evaluated the triad in support of the 2010 Nuclear Posture Review and concluded that each of the three legs has advantages and that retaining all three would help maintain strategic deterrence and stability.[12]

[11]GAO-20-87C.

[12]GAO-16-372C.

Figure 1: Current U.S. Nuclear Triad and Existing Systems



NC3 = Nuclear Command, Control, and Communications

Source: GAO presentation of Department of Defense information. | GAO-21-210

As shown in the figure, the triad includes a mix of ICBMs, SLBMs deployed on submarines, and bombers that are enabled by a network of nuclear command, control, and communication (NC3) systems. Each leg of the triad has attributes that make it unique. Despite the differences between the legs, the triad also contains overlapping attributes to help ensure that U.S. deterrence capabilities have the capacity to cover a range of adversary targets throughout a crisis or conflict. Each leg consists of delivery systems[13]—a missile, submarine, or bomber—and the nuclear weapon that can be transported to its intended target via the delivery system.

Each delivery system carries nuclear weapons designated either as a warhead, signified by a *W* (e.g. W88) or as a bomb, signified by a *B* (e.g. B83-1).[14] Throughout the history of nuclear weapons development, the United States has developed families of warheads based on a single-

[13]ICBMs, submarines, and bombers may also be referred to as delivery platforms, but as these terms have been used interchangeably in documentation, for the sake of consistency they are referred to in this report as delivery systems.

[14]Weapons that have certain engineering requirements because they must interface with a launch or delivery system are called warheads. Weapons that do not have these interface requirements, such as gravity bombs and atomic demolition munitions (now retired), are called bombs.

warhead design. Thus, some weapons in the U.S. stockpile were developed as modifications (or mods) to an already complete design. Different mods may have different components related to their operational characteristics, safety, or control features.

Land Leg

The United States has 454 launch facilities with 400 deployed Minuteman III ICBMs.[15] These weapons are on continuous alert, can be launched within minutes, and can strike their intended targets within 30 minutes of launch. Further, launch crews on specialized aircraft can remotely launch Minuteman III if launch control centers are not available. As a result, they are considered the most responsive leg of the triad. Minuteman III can carry two different types of nuclear warheads, W87-0 or W78, which are mated with the Mk21 and Mk12A reentry vehicles, respectively.[16] The Mk21 reentry vehicle is shown below in figure 2.

[15]Four of these launch facilities are test facilities.

[16]Minuteman III can carry between one and three warheads depending on the reentry vehicle and configuration used. A multiple warhead configuration is called a Multiple Independently Targetable Reentry Vehicle (MIRV) configuration. Each reentry vehicle has one fuze used to detonate the warhead.

Figure 2: W87-0 Warhead Contained within a Mk21 Reentry Vehicle

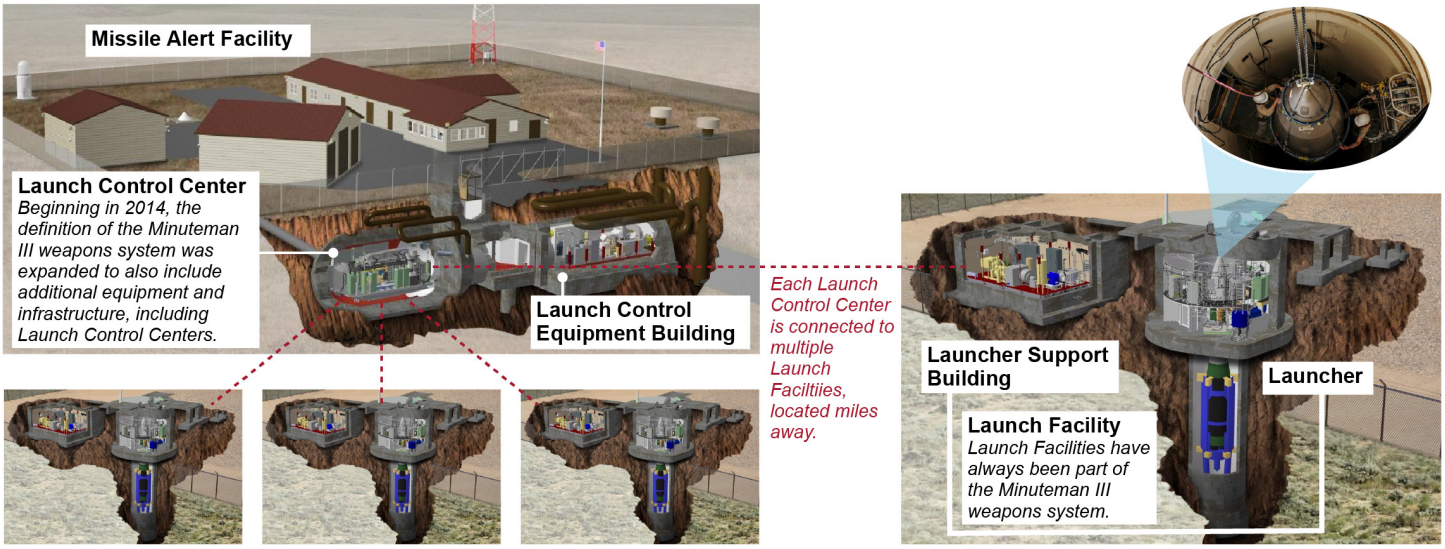
Source: U.S. Air Force. | GAO-21-210

Minuteman III entered service in the 1970s and was intended to have a 10-year service life. But it has since undergone several life extensions. The Air Force plans to sustain Minuteman III through 2030 and gradually draw down the weapon system before its anticipated retirement in 2036. The W78, which entered the stockpile in 1979, is the oldest weapon in the stockpile that has not undergone an LEP. DOE plans to continue to sustain the W78 for use on the Minuteman III until the mid-2030s, when it

will be replaced by the W87-1.[17] DOE has notional plans to replace the W87-0 in the mid-2030s. The W87-0 entered the stockpile in 1986 and underwent an LEP from 1994 through 2004.

The Minuteman III weapon system consists of many components beyond just the missile and warheads. As is shown in figure 3, the launch control centers and launch facilities, as well as the equipment and hardware in those areas, are also included.

Figure 3: Minuteman III Intercontinental Ballistic Missile Weapon System



Source: U.S. Air Force (information), U.S. Air Force photo by Airman 1st Class Braydon Williams (photo), and Northrop Grumman (images). | GAO-21-210

Sea Leg

The United States has 14 *Ohio* class nuclear ballistic missile submarines. Each submarine has 24 missile tubes, but only 20 tubes are capable of employing submarine-launched ballistic missiles. The United States chose to implement a force structure under the New Strategic Arms Reduction Treaty (START) Treaty (see discussion of arms control treaties below):

[17]GAO-20-703.

The New START Treaty with the Russian Federation allows a maximum of 240 missiles emplaced across the fleet.[18] Figure 4 depicts an *Ohio* class ballistic missile submarine.

Figure 4: *Ohio* Class Ballistic Missile Submarine

Source: Defense Visual Information Distribution Service (DVIDS). | GAO-21-210

The Navy designed these submarines to maximize stealth to prevent detection while on patrol at sea, an attribute that contributes to survivability and gives the United States a credible ability to retaliate if faced with an attack targeting the other legs of the triad.[19] The Navy began fielding *Ohio* class submarines in 1981, with a planned service life of 30 years.[20] In 1998, DOD decided to extend the service life of the *Ohio* class to 42 years, longer than any prior class of submarine. The Navy

[18]The formal title of the New START Treaty is *The Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms*.

[19]Under the New START Treaty, accountable warheads consist of warheads on deployed ICBMs, warheads on deployed submarine-launched ballistic missiles, and one nuclear warhead counted for each deployed heavy bomber.

[20]The *Ohio* class of submarines consists of 18 submarines; the first four, fielded between 1981 and 1984, were converted in the early 2000s from ballistic missile submarines to guided missile submarines carrying nonnuclear cruise missiles. These four submarines are no longer part of the nuclear deterrent.

plans to retire the first *Ohio* class submarine in 2027 and plans to retire one per year until 2041.

The Trident II D-5 missiles deployed on these submarines, pictured in figure 5, can carry two different types of nuclear warheads: the W88 and the W76.[21]

Figure 5: Trident II Submarine-Launched Ballistic Missile

Source: U.S. Navy. | GAO-21-210

The W88, the newest warhead in the nuclear stockpile, which entered service in 1989, is currently undergoing an alteration referred to as the W88 Alt 370. The W76 nuclear warhead entered the stockpile in 1978, and DOE completed an LEP in December 2018, resulting in a variant known as the W76-1.[22]

[21]The Trident II D-5 can be deployed in either a single or multiple warhead configuration.

[22]The Navy is in the process of deploying W76-1 warheads on the Trident II D-5 missile. During this transition, some W76-0 warheads will remain in the stockpile and deployed. In addition, DOE produced and delivered a low-yield W76 variant, known as the W76-2 in 2019 and 2020 and has closed out the program, according to agency documentation.

Air Leg

The United States has 66 nuclear-capable heavy bombers in the air leg of the nuclear triad, including 20 B-2A Spirit bombers (B-2) and 46 nuclear-capable B-52H Stratofortress bombers (B-52). Among nuclear triad delivery systems, these heavy bombers are unique in that DOD can deploy bombers forward during a crisis as a visible deterrent but can also recall them after takeoff if a crisis is deescalated.[23] The Air Force began operating the B-2 in 1997 and plans to sustain the bomber into the 2030s. A B-2 is shown in figure 6 below.

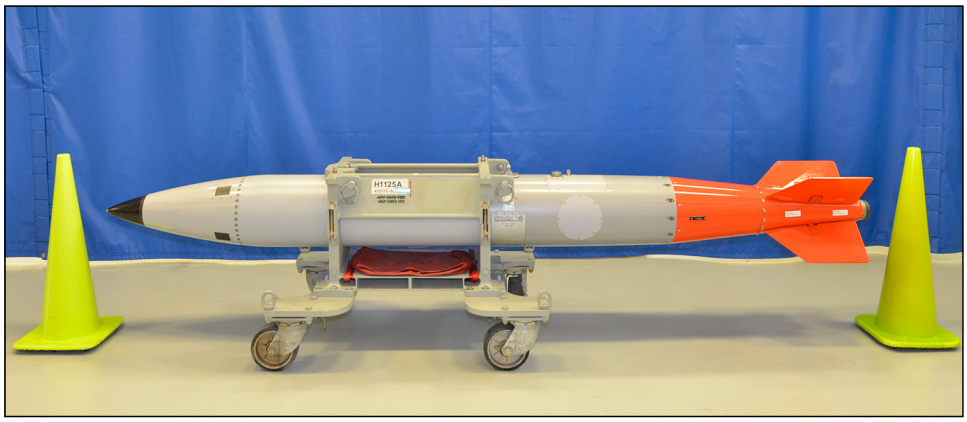
Figure 6: B-2 Bomber

Source: Defense Visual Information Distribution Service (DVIDS). | GAO-21-210

DOD and DOE are currently undertaking an LEP to produce a bomb referred to as the B61-12, depicted below.

[23]The air leg also relies on a network of aerial refueling tankers, including the KC-135 aircraft, to conduct operations. We did not include analysis of supporting systems for the triad in this report.

Figure 7: B61-12 Bomb



Source: Sandia National Laboratories. | GAO-21-210

The B61-12 will be carried by the B-2. DOE plans to consolidate and replace four of the five variants of the B61 that were in the active stockpile at the time the LEP began (the B61-3, B61-4, B61-7, and B61-10 mods) with the B61-12 variant. The B61-11 will be retained. While the B83-1 was planned for retirement, the 2018 Nuclear Posture Review provided that the B83-1 will be sustained until a suitable replacement is identified.

The Air Force began operating the current model of the B-52—B-52H—in 1961 with an original planned service life of 20 years, but the Air Force plans to keep it in service until at least 2050. A B-52 is shown in figure 8.

Figure 8: B-52 Bomber and Air-Launched Cruise Missile

Source: Defense Visual Information Distribution Service (DVIDS). | GAO-21-210

The B-52 uses air-launched cruise missiles (ALCM) equipped with a W80-1 nuclear warhead to strike targets from a distance—referred to as a standoff strike capability. After being launched, an ALCM can use its own engine and wings to reach its intended target. The Air Force began operating ALCMs in 1982. The original planned service life for ALCMs was 10 years. The Air Force extended the service life of ALCMs and plans to keep it in service until at least 2030. The Air Force intends to replace ALCM with a delivery system and warhead known, respectively, as the Long Range Standoff missile (LRSO) and the W80-4.[24]

Nuclear Command, Control, and Communications

NC3 systems provide the equipment, facilities, procedures, communications, and personnel through which the President exercises authority over the nuclear forces and critical national military and civilian command facilities. The NC3 enterprise supports communications, including survivable and enduring communications that can be transmitted before, during, and after a nuclear attack. As part of overall nuclear modernization efforts, the Air Force and Navy are developing a new generation of components to support the NC3 enterprise.

[24]We reported in 2019 that the Air Force has planned service life extension programs to replace numerous components facing aging and obsolescence issues to sustain ALCM until it is replaced (see GAO-20-9C). Also see GAO-20-409.

DOD, DOE, and the Nuclear Mission

DOD, through USSTRATCOM, is responsible for strategic nuclear deterrence and establishes operational and planning requirements for the Air Force and Navy. The Air Force and Navy provide the nuclear weapon delivery systems necessary to satisfy the multiple levels of operational requirements set by USSTRATCOM. In addition to having day-to-day operational requirements for some systems, USSTRATCOM sets requirements for the Air Force and Navy to field additional numbers of delivery systems within specific time frames.[25] This is referred to as force generation. The Air Force and the Navy also certify procedures, personnel, facilities, and warhead delivery systems to ensure that they meet standards for safety, security, and reliability. This process—called nuclear certification—is the final step necessary prior to a nuclear warhead delivery system acquiring operational status.[26]

DOE is responsible for designing, producing, and sustaining the nuclear warheads and bombs delivered by Air Force and Navy delivery systems. Since 1945, the United States has fielded more than 70 different nuclear bombs and warheads; currently, the U.S. nuclear weapons stockpile consists of eight such systems. These systems are either strategic or nonstrategic.[27]

The nuclear weapons stockpile is configured into “active” and “inactive” categories, and individual nuclear weapons are identified as being in one of six states of readiness across both categories. Active weapons maintained at the top readiness state are operationally deployed weapons; the number of these weapons deployed for strategic deterrence has been limited under arms control treaties, such as New START. Inactive weapons are normally maintained at a depot in a nonoperational

[25]Our description of USSTRATCOM operational requirements are based on information and documentation from that command.

[26]Initial operational capability is achieved when the defined operational organization has been equipped and trained and is determined to be capable of conducting mission operations.

[27]DOD identifies strategic weapons as those delivered by ICBMs, submarine-launched ballistic missiles, or heavy bombers. All other weapons are nonstrategic, or tactical, nuclear bombs delivered by nonstrategic aircraft—usually dual-capable aircraft that can be used for nuclear and conventional missions.

status.[28] DOE's stockpile stewardship efforts include assessing and maintaining existing bombs and warheads to ensure their continued safety, security, and reliability, as well as planning and managing LEPs, major alterations, and replacement programs to modernize warheads and bombs or extend their service lives.

The Nuclear Weapons Council is a joint DOD and DOE activity established by statute in 1986 and composed of senior-level officials from the two departments.[29] The council serves as the focal point for interagency activities to maintain and modernize the U.S. nuclear weapons stockpile. The council facilitates cooperation and coordination between DOD and DOE on nuclear weapons stockpile issues, reaches consensus on those issues, and aligns DOE's efforts to DOD requirements as they carry out their responsibilities for managing the U.S. nuclear weapons programs.

Arms Control Treaties

The United States has reduced its strategic nuclear forces in a manner consistent with arms control treaties with the Soviet Union and later the Russian Federation, including the 1991 Strategic Arms Reduction Treaty and the 2002 Strategic Offensive Reductions Treaty.[30] Further reductions in the nuclear stockpile were agreed upon in 2010 when the United States and the Russian Federation signed the New START Treaty.[31] This agreement limits the United States to the following quantities of deployed nuclear weapons and delivery systems:

[28]Inactive stockpile weapons are not available to be uploaded on a delivery vehicle. They have certain components removed, and other limited-life components of inactive stockpile weapons are not replaced unless the weapons are reactivated and moved to the active stockpile.

[29]See National Defense Authorization Act for Fiscal Year 1987, Pub. L. No. 99-661, § 3137(a)(1)(1986) (codified as amended at 10 U.S.C. § 179).

[30]The formal titles of these treaties are, respectively: *The Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Reduction and Limitation of Strategic Offensive Arms*, and *The Treaty Between the United States of America and the Russian Federation on Strategic Offensive Reductions*.

[31]*Treaty Between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitations of Strategic Offensive Arms*, Apr. 8, 2010, T.I.A.S. No. 11-205. The New START Treaty entered into force on Feb. 5, 2011. The treaty's original duration was 10 years (until Feb. 5, 2021), with the option for the parties to agree to extend it for up to an additional five years. The U.S. and the Russian Federation agreed on a five-year extension to keep the treaty in force until Feb. 5, 2026. T.I.A.S. No. 21-203.

- The New START Treaty limits the total number of accountable warheads to 1,550.[32] The treaty also places limits on the total number of deployed and nondeployed ICBM launchers, submarine-launched ballistic missile launchers, and nuclear-capable heavy bombers. The United States implemented the following force structure to comply with these limitations:[33]
- 400 deployed ICBMs, with 450 operational and 4 test launch facilities. The Air Force maintains 50 of the 450 launch facilities in a nondeployed status via the removal of the ICBM from these silos.
- 240 deployed submarine-launched ballistic missiles on ballistic missile submarines. Though each submarine was designed with 24 missile tubes, DOD rendered inoperable four launch tubes on each submarine, resulting in 14 submarines with 20 missile tubes each (for a total of 280), in which up to 240 missiles are loaded at any given time.
- 60 deployed heavy bombers. DOD maintains 20 B-2s and 46 B-52s as nuclear-capable heavy bombers.[34] To meet New START Treaty limits, six of these heavy bombers are nondeployed.

These quantity limitations in the New START Treaty provisions were extended until February 5, 2026.

2018 Nuclear Posture Review and the Hedge Strategy

The Nuclear Posture Review is a periodic, comprehensive review of U.S. nuclear policies that is initiated by presidential direction. The Nuclear Posture Review is one of several national-level strategy documents that helps inform DOD's future planning. There have been three prior versions—1994, 2001, and 2010. The most recent, issued in 2018, stated that the focus of that iteration was the nuclear policies, strategy, and corresponding capabilities needed to protect the country in a deteriorating threat environment. It is strategy-driven and provides guidance for the current and future nuclear forces. The 2018 Nuclear Posture Review also

[32]Under the New START Treaty, accountable warheads consist of warheads on deployed ICBMs, warheads as deployed on submarine-launched ballistic missiles, and a single warhead counted for each heavy bomber.

[33]The limitations under the treaty went into effect on February 2018, 7 years after the treaty entered into force. Under the treaty, each party has the right to determine the composition and structure of its strategic offensive arms within the limitations.

[34]For the purposes of this report, heavy bombers are referred to as bombers.

reaffirmed that the nuclear triad is the optimal approach for U.S. nuclear deterrence.

According to the 2018 Nuclear Posture Review, DOD and DOE can use a strategy referred to as the Hedge Strategy to mitigate the potential consequences of risks to the nuclear deterrent, which would mean (1) retaining an inventory of nondeployed bombs and warheads that can be added to existing delivery systems, called the weapons hedge, to address geopolitical threat or technical failure or (2) utilizing a responsive nuclear weapon production infrastructure that can quickly produce new or additional bombs and warheads.[35]

Acquisition of Replacement DOD Delivery Systems and DOE Bomb and Warhead Modernization Efforts

DOD is working to acquire replacement delivery systems for all of its currently fielded systems other than the B-52. DOE is also working to execute four LEPs or other modernizations for bombs and warheads, with additional future efforts anticipated. Ongoing efforts are all progressing on different time frames, but most are planned to begin fielding within the next 10 years. The currently fielded delivery systems and their replacement programs are depicted in table 1.

Table 1: Currently Fielded and Replacement Nuclear Triad Delivery Systems, Missiles, and Nuclear Weapons

Current delivery systems and missiles	Current nuclear weapons	Replacement delivery systems and missiles	Ongoing replacement nuclear weapon programs[a]
Ohio class ballistic missile submarine armed with Trident II D-5 submarine-launched ballistic missiles	W76-1[b] warhead W76-2 warhead W88 warhead	*Columbia* class ballistic missile submarine	W88 Alteration 370
B-52H bomber (B-52)		No replacement planned	
AGM-86B air-launched cruise missile (ALCM)	W80-1 warhead	Long Range Standoff missile (LRSO)[c]	W80-4 warhead
B-2A bomber (B-2)	B61-7 strategic bomb B61-11 strategic bomb B83-1 strategic bomb	B-21 bomber (B-21)	B61-12 strategic bomb[d]
Minuteman III intercontinental ballistic missile (ICBM)	W78 warhead W87-0 warhead	Ground Based Strategic Deterrent (GBSD) ICBM	W87-1 warhead[e]

Source: GAO analysis of Department of Defense (DOD) and Department of Energy (DOE) documentation. | GAO-21-210

[a]DOE and DOD have planned additional future modernization programs, but these programs have yet to be initiated.

[35]The 2018 Nuclear Posture Review also identifies risk mitigation actions intended to reduce the likelihood that challenges will emerge, including diplomatic actions, and the continued surveillance and testing of weapons and weapons systems to support the early detection of problems, as part of the approach for hedging against risk.

[b]DOE has recently completed the W76-1 life extension program (LEP), and the Navy is in the process of deploying these warheads on the Trident II D-5 missile. During this transition, some W76-0 warheads will remain in the stockpile and deployed.

[c]The LRSO will first be employed on the B-52 but could also be used on the B-21 following the aircraft's nuclear certification.

[d]The B61-12 LEP is intended to consolidate and replace four of the five variants of the B61 that were in the active stockpile at the time the LEP began (the B61-3, B61-4, B61-7, and B61-10). The B61-11 will be retained. The B61-12 is designed for use on the B-2, the F-15E, the F-16, the F-35, and the PA-200. While the B83-1 was planned for retirement, the 2018 Nuclear Posture Review provided that the B83-1 will be sustained until a suitable replacement is identified.

[e]GBSD will be fielded with the W87-0 and the W87-1. The W87-1 will replace the W78. DOE intends to undertake a program to replace the W87-0 in the mid-2030s.

DOD Will Be Challenged to Meet Some USSTRATCOM Operational Needs with Current Systems, and DOE Faces a Long-Term Sustainment Challenge

Both DOD and DOE face challenges with sustaining existing nuclear triad systems, which result in USSTRATCOM facing operational risk. These challenges pertain to the quantities of systems as well as the capabilities of those systems. Specifically, the Navy and Air Force face difficulties in meeting some of USSTRATCOM's operational requirements to be able to deploy additional quantities of systems above day-to-day requirements—called force generation—within given time frames. Further, some current triad systems have operational capability limitations that will only be mitigated once replacement systems are fielded.

Ohio Class Submarines Currently Face Force-Generation Challenges That Will Likely Persist Until *Columbia* Class Completes Fielding

The Navy faces challenges meeting USSTRATCOM's force-generation operational requirements, which are likely to persist until the *Columbia* class submarine completes fielding, because of factors including:

- delays in completing *Ohio* class submarine mid-life maintenance periods, known as Engineered Refueling Overhauls; [36]
- delays in completing Extended Refit Periods[37] and incremental refits; and

[36]Engineered Refueling Overhauls are major maintenance periods that occur once during the life of an *Ohio* class submarine and take each submarine offline for several years when the submarine's nuclear reactor is refueled and major maintenance occurs.

[37]Extended Refit Periods occur twice during an *Ohio* class submarine's life, and replace and refurbish the major components of the hull and internal systems.

- the complexity of upgrades that need to be planned for incorporation into already-tight maintenance and modernization schedules.

According to DOD data, the Navy has not been able to complete the lengthy *Ohio* class mid-life Engineered Refueling Overhauls within planned time frames for eight recent Engineered Refueling Overhauls dating back to 2009. Engineered Refueling Overhauls involve removing the nuclear weapons from the submarine, refueling the nuclear reactor, conducting extensive inspections, making structural repairs, and completing modernizations. The Navy planned for Engineered Refueling Overhauls to take approximately 27 months to complete. According to our analysis of DOD data, the duration of Engineered Refueling Overhauls has gradually extended beyond 27 months, with the longest Engineered Refueling Overhauls taking 40 months to complete.

In addition, other types of *Ohio* class maintenance activities have been taking longer than planned, according to information from the *Ohio* class submarine maintenance facilities. An Extended Refit Period is shorter in duration and less complex than an Engineered Refueling Overhaul but nevertheless takes submarines out of service for a given period. The Navy has recently conducted Extended Refit Periods on several *Ohio* class submarines and found these periods were longer than planned—10 to 11 months as opposed to the planned 5 to 9 months, according to Navy documentation and a senior Navy official. According to Navy officials, additional time has been necessary to refurbish aged or degraded systems on the submarine, and the duration of regular maintenance periods increased because of problems associated with aging.

Beyond the Extended Refit Periods, each submarine is also subject to regular in-port periods of approximately 1 month, called incremental refits, where they typically undergo maintenance. However, for the *Ohio* class the Navy has identified 25 maintenance activities—not including modernization efforts—that will take longer than the planned maintenance periods.

The Navy also has plans to replace or upgrade some *Ohio* class systems with more modern components, such as adding a new sonar array to each submarine. Navy officials told us that some of these upgrades are scheduled to take 5 to 6 months to complete and that they are not currently part of the planned Extended Refit Periods. As a result, these upgrades will have to have tightly controlled installation schedules so as not to further diminish the Navy's ability to generate additional

submarines if directed by USSTRATCOM. Until these activities are scheduled, the Navy will not be able to assess the effect on its ability to generate additional submarines if directed by USSTRATCOM.

According to Navy and USSTRATCOM officials, even after the Engineered Refueling Overhauls are completed, the Navy will continue to struggle to meet its force-generation operational requirements because the overall fleet size will decrease as the *Ohio* class starts to retire. Starting in fiscal year 2030, the Navy plans to have 10 operational submarines—four fewer submarines than the current fleet—for approximately a decade.

B-2 and B-52 Face Challenges with Availability

Air Force officials said that the bomber programs plan to manage upgrades and depot maintenance in order to ensure the aircraft can meet USSTRATCOM requirements. Air Force Global Strike Command officials also said that they expect to have sufficient numbers of ALCMs to meet USSTRATCOM requirements through the end of its service life in 2030. However, despite these assurances, each type of bomber faces challenges to its ability to consistently meet force-generation operational requirements during the next decade.

B-2

The Air Force must balance mission requirements with activities such as modernization, maintenance, training, and flight testing.[38] During these activities, a number of bombers are placed in an unavailable status.

The Air Force currently has several sustainment efforts and 12 ongoing modernization programs to increase the B-2's availability and effectiveness, some of which will last through at least fiscal year 2026. We have previously reported on B-2 sustainment and availability challenges and mitigation efforts.[39] For instance, in 2019 we found that the B-2 program has undertaken efforts to address sustainment challenges such as the availability of needed parts and monitoring, maintaining, and enhancing the B-2's stealth profile in conjunction with other sustainment and modernization activities. According to program officials, the Air Force has difficulty obtaining needed parts for the B-2 because the small fleet size of 20 aircraft cannot support a robust parts supplier base. The B-2 program, among other efforts, has worked with the Air Force's Supply Chain Management Wing to redesign obsolete hardware to reduce future parts availability concerns. Planned B-2

[38]Additional information on these issues is addressed in GAO-20-9C.

[39]GAO-20-9C.

modernizations are expected to improve the bomber's capabilities, including communications, targeting, and threat detection, but the associated installation periods contribute to the number of B-2s that are expected to be in an unavailable status.

B-52

The Air Force has B-52 aircraft modernization efforts planned over at least the next decade to improve aircraft availability and reliability in order to sustain the system through at least 2050. For example, the Air Force initiated a program to replace the current B-52 engines, which are experiencing age-related problems and are unsustainable after fiscal year 2030. The Air Force plans to complete the fielding of this capability in fiscal year 2034. However, according to B-52 Commercial Engine Replacement Program officials, they have yet to finalize the schedule for installing B-52 engines and will need to evaluate, along with Air Force Global Strike Command, the extent to which future B-52 availability can support notional installation plans. We will continue to monitor this program as part of our annual assessment of weapon systems and the Air Force's efforts to plan these installations.[40]

The Air Force will need to carefully plan these modernizations in order to maintain sufficient aircraft to meet the aircraft force-generation operational requirement.

DOE Faces Long-Term Sustainment Challenges for One Stockpile System

As of March 2020, DOD and DOE planned to retire and dismantle the B83-1 bomb in the 2020s. DOE and DOD are currently evaluating options for addressing B83-1 sustainment challenges.

[40]GAO-20-439.

DOD and DOE Replacement Programs Face Schedule Risks That Could Exacerbate Challenges with Existing Triad Systems

We found that every nuclear triad replacement program—including the B-21, LRSO, GBSD, and *Columbia* class submarine, and every ongoing bomb and warhead modernization program—faces the prospect of delays due to program-specific and DOD- and DOE-wide risk factors. These risk factors include an insufficient DOD nuclear certification workforce, limited DOE infrastructure capacity, and supply-chain risks. If realized, these delays would prolong DOD's operation of existing triad systems, which have pronounced shortcomings that were discussed earlier, and could result in delays to DOE programs. Further, fielding delays for replacement delivery systems and weapons could exacerbate challenges with the existing triad systems. Replacement nuclear triad delivery systems, missiles, and nuclear weapons are listed by leg below in table 2.

Table 2: Replacement Nuclear Triad Delivery Systems, Missiles, and Nuclear Weapon Life Extension Programs, by Leg

Air leg	Land leg	Sea leg
• B-21 bomber • Long Range Standoff missile • W80-4 warhead • B61-12 bomb	• Ground Based Strategic Deterrent • W87-1 warhead • Mk21A reentry vehicle	• *Columbia* class submarine • W76-1 warhead • W88 Alteration 370 warhead

Source: GAO analysis of Department of Defense and Department of Energy documentation. | GAO-21-210

Note: The Department of Energy completed the W76-1 life extension program in 2018.

Every DOD Triad Replacement Program Is at Risk of Schedule Delays

Each DOD triad acquisition program faces schedule risk factors, that we identified by comparing them with leading knowledge-based acquisition practices and our work on other major defense acquisition programs.[41] These risk factors for schedule delays include:

- concurrency between phases of acquisition programs from development through production;
- inadequate development of technologies;
- design challenges; and

[41]We previously reported on our knowledge-based acquisition practices. In particular, our body of work has found that when programs enter development with insufficient knowledge, negative effects can cascade throughout the acquisition cycle. These knowledge shortfalls, or gaps, often begin with program decisions to accept immature technologies at the start of system development but later manifest in other forms as the program approaches production. We found that programs that implement knowledge-based acquisition practices can realize better cost and schedule outcomes. GAO-20-439.

- limited schedule margin.

We also found misalignment between the production of two delivery systems and their associated warheads, as well as production quality challenges that could result in delays in fielding the full scope of planned capabilities. Additionally, DOD identified risks to program schedules, such as requirements changes and the aggressive pace of planned construction activities.

Air Leg: B-21, LRSO, and W80-4, and B61-12

B-21

We have previously reported on and have continuing work to monitor the B-21 and LRSO program schedules and risks.

W80-4

In June 2019, we reported that the W80-4 LEP will rely on newly manufactured high explosives for its main charge and that DOE has experienced challenges in restarting processes to manufacture these explosives.[42] Additionally, in our July 2020 report we found that NNSA introduced risk to the program by adopting a date for the delivery of the program's first production unit that is more than 1 year earlier than the date projected by the program's own schedule risk analysis.[43] We recommended that NNSA adopt a first production unit delivery date based on schedule risk analysis or document its justification for not doing so. NNSA disagreed with our recommendation, which we continue to believe is valid.

B61-12

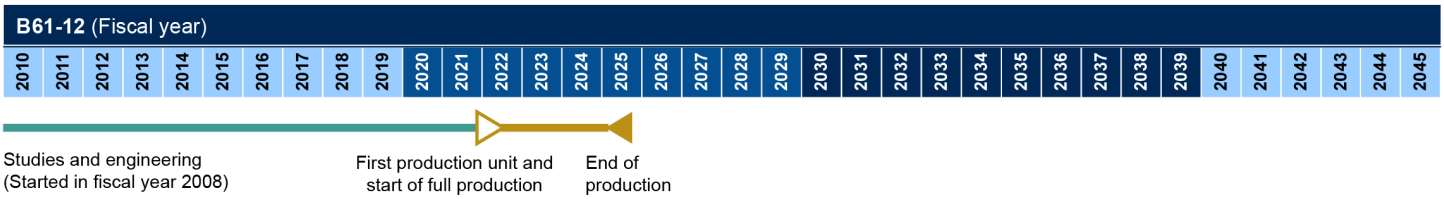
Figure 9 shows the B61-12 LEP schedule.[44]

[42]GAO-19-449. DOE officials have since said that they have overcome some of the technical challenges related to developing these high explosives but must still work with DOD to prioritize manufacturing.

[43]GAO-20-409.

[44]In our February 2016 report, we reported that the program manager and Air Force officials told us in October 2015 that the original LEP cost and schedule estimates ($4 billion and 2017 first production date) were rough order of magnitude estimates based on a smaller-scale effort, then under consideration as a design option, rather than the LEP currently being undertaken. In May 2011, we reported on these original estimates and noted that DOE and DOD were still studying design options for the B61 LEP and had not yet selected the B61-12 design.

Figure 9: B61-12 Life Extension Program Schedule



Source: GAO analysis of Air Force and Department of Energy data. | GAO-21-210

In September 2019, due to problems with a capacitor, NNSA revised its estimated first production unit delivery date for the program to the first quarter of fiscal year 2022. According to September 2019 congressional testimony by NNSA's Deputy Administrator for Defense Programs, the capacitor problem and resulting delay will increase the cost of the program by about $600 million to $700 million. The problem also affects the W88 Alt 370 program, as discussed below.

Land Leg: GBSD, W87-1, and Mk21A

GBSD

The Air Force plans to deliver the first production unit of the GBSD missile at the earliest feasible date and reach initial operational capability in fiscal year 2029. OUSD for Acquisition and Sustainment officials stated that the GBSD schedule is aggressive and compressed compared to prior ICBM programs.

According to the program's acquisition strategy, the Air Force is using multiple strategies to ensure on-time fielding, including financial incentives for the contractor to meet milestones. Nevertheless, program schedule delays are likely because of the following risks:

- **Immature technology**. To meet the planned 2028 delivery, the Air Force developed an acquisition approach that calls for the use of mature technologies. However, the Air Force requires the program's three critical technologies to be matured only to a technology readiness level (TRL) 6 by the end of the technology maturation and

risk reduction phase.[45] In order to reduce the risk of cost increases, schedule delays, or capability shortfalls, GAO-identified best practices call for maturing technologies to a TRL 7, meaning sufficiently mature to reduce risk in the engineering and manufacturing development phase prior to committing resources to development for manufacturing and fielding.[46] As these best practices state, proceeding into development with immature technologies can lead to cost increases and schedule delays. GBSD program officials acknowledge in the program's acquisition strategy that there is a risk that the program could be delayed if it does not demonstrate a mature design based on mature technologies.

- **Concurrent operation of Minuteman III and GBSD during the transition**. The Air Force plans to field GBSD into the same launch facilities currently used by Minuteman III, and will need to continue operating Minuteman III while fielding GBSD. According to Air Force documentation, this introduces additional complexity to the schedule for GBSD. The Air Force will need to coordinate GBSD deployment activities with Minuteman III operations, depot maintenance, and sustainment activities to ensure that ICBM operations are not interrupted. According to Air Force documentation, the service will be largely constrained to fielding GBSD into the 50 launch facilities with silos that are maintained empty per the U.S. force structure implemented in response to New START Treaty limits.[47] In order to keep no more than 400 deployed ICBMs during the transition, one

[45]TRLs are measured on a scale from 1 to 9, beginning with paper studies of a technology's feasibility and culminating with a technology fully integrated into a completed product. TRL 6 includes the demonstration of the technology in a relevant environment. TRL 7 includes a demonstration of a technology in its form, fit, and function within a realistic environment, and is the level of technology maturity that constitutes a low risk for starting a product development program. We are continuing to monitor GBSD critical technologies as part of our ongoing work on this program.

[46]GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects*, GAO-20-486, (Washington D.C.: Jan. 7, 2020). While our best practices work has shown that it is preferable for a program to reach a TRL 7 in order to begin development with a low risk, DOD's policy permits development to start at TRL 6. DOD's policy is based on a statute that generally prohibits a major defense acquisition program from receiving approval for development start until the milestone decision authority certifies—based on an independent review and technical risk assessment—that the technology in the program has been demonstrated in a relevant environment, known as TRL 6. 10 U.S.C. § 2366b(a)(2). A technology readiness assessment is conducted to determine whether the technology in the program has been demonstrated in a relevant environment.

[47]The GBSD acquisition strategy assumes that the New START treaty will continue to remain in effect during deployment and operation of GBSD.

Minuteman III ICBM must be removed from a launch facility silo prior to each GBSD being emplaced in a launch facility silo. As part of this process, the Air Force will remove Minuteman III equipment from the launch facilities. However, the integrated nature of the ICBM weapon system presents challenges for synchronizing transition activities. For example, Minuteman III's command and control elements are incompatible with GBSD and not able to simultaneously operate on the same network as GBSD systems. Air Force documentation states that significant care must be taken to plan and execute the launch facility transition to the GBSD network. However, the Air Force has yet to finalize the design for GBSD or determine what effect the transition from Minuteman III will have on operational capability. According to the Air Force, if transition activities are not synchronized, the ability to maintain sufficient missiles on alert may be compromised and could result in delays to the GSBD program schedule. We are continuing to monitor the GBSD program schedule as part of our ongoing work on this program.

- **Limited schedule margin for testing**. According to program documentation, the current GBSD schedule includes minimal margin for discovery of problems during testing. The GBSD program is early in development, and thus detailed test events have yet to be defined. However, the GBSD program's draft developmental testing schedule only includes 2 months to address deficiencies found in flight testing before the next test is expected to begin, including any resulting design changes. The program office has identified this as a risk because subsequent flight tests may be delayed if activities to address problems identified during testing take longer than 2 months. However, our work on other acquisition programs shows that testing is a process of discovery and that programs need time to incorporate necessary changes and retest.[48] Further, according to program documentation, if GBSD experiences a failure in a major test event, it would likely delay initial fielding and initial operational capability. The Air Force aims to mitigate risk during testing by conducting the more risky flight tests earlier in the program so that any deficiencies can be identified and corrected early in development.
- **Aggressive pace of construction activities**. The GBSD program will use the existing Minuteman III launch facilities and some existing infrastructure, but has yet to define the full scope of the effort required to convert a Minuteman III launch facility into the configuration needed for GBSD. The GBSD program plans to initiate 450 launch facility

[48]GAO, *Missile Defense: Opportunities Exist to Reduce Acquisition Risk and Improve Reporting on System Capabilities*, GAO-15-345 (Washington, D.C.: May 6, 2015).

conversions over the course of 9 years, averaging 50 conversions per year. The GBSD program's schedule is contingent on inheriting the launch facilities in a suitable condition. However, these facilities are currently facing a number of issues, such as water intrusion and structural deficiencies. The Air Force plans to have 57 launch facilities go through the Minuteman III programmed depot maintenance process each year in advance of GBSD fielding, with a plan to refurbish all launch facilities over an 8-year period. Air Force documentation also states that further remediation of any deterioration that has occurred at launch facilities will be accomplished as they are converted to the configuration necessary for GBSD. GBSD program office documentation indicates that it could take up to 6 months to complete the necessary restoration and conversion processes at each launch facility. However, the Air Force has yet to evaluate all of the launch facilities and, accordingly, the full scope of work necessary to prepare the facilities for use by the GBSD program has yet to be determined. If the Air Force does not resolve the issues with the launch facilities in advance of the transition to GBSD, additional time could be needed for construction, which could result in delays to GBSD fielding. As noted above, we are continuing to monitor GBSD as part of our ongoing work.

- **Changes to program requirements**. In May 2019, the Air Force increased the scope of the GBSD program to include efforts previously conducted under a separate major acquisition program—the Airborne Launch Control System Replacement. The increase in scope could present additional pressures on the program schedule. However the Air Force has yet to fully evaluate risks to the GBSD program. We are continuing to monitor risk to the GBSD as part of our ongoing work.

W87-1 and Mk21A Reentry Vehicle

The W87-1 is intended to replace the capabilities of the W78, provide safety and security improvements, and sustain the Air Force's ability to field two types of warheads on ICBMs. At the direction of the 2018 Nuclear Posture Review, the W87-1 program restarted in fiscal year 2019, after a 4-year pause initiated by the Nuclear Weapons Council in part because of budget constraints, and is now exploring feasibility and design options. Under DOE's preliminary schedule, the program will produce the first W87-1 in fiscal year 2030 and continue production through approximately 2038.[49] Since the GBSD program is expected to

[49]We recently issued a report on DOE's W87-1 replacement program. See GAO-20-703.

reach initial operational capability in fiscal year 2029, the GBSD program plans to field the missile initially with the W87-0, and will subsequently add the W87-1 as it becomes available.

W87-1 development must remain integrated with other elements of the GBSD weapons system—namely production of the Mk21A reentry vehicle, which will contain the W87-1 and will be mated with GBSD. The Air Force is planning to convert existing reentry vehicle aeroshells and is evaluating options to make additional aeroshells, with initial operating capability planned to align with the W87-1 in fiscal year 2030. These programs must exchange information at key points during development to avoid delays. The W87-1 program and the Mk21A programs are currently aligned, according to Air Force officials, and the Air Force intends to perform some early flight tests with the Mk21A to provide performance information to the W87-1 program. However, according to Air Force documentation, if the Mk21A and W87-1 programs do not remain aligned or adequately share information at key points, the Air Force may not discover problems with pairing the Mk21A reentry vehicle and the W87-1 warhead until shortly before it is deployed. This could result in inadequate performance of the weapon system or a need for system redesign that could have significant effects on either program's schedule. In addition, the Mk21A program will need timely mechanical and electronic information from the GBSD program in order to design a reentry vehicle with the appropriate capabilities. The Air Force has yet to determine when the Mk21A will be flight tested on GBSD, and intends to use the Mk21 for its initial GBSD flight tests, according to an Air Force document.

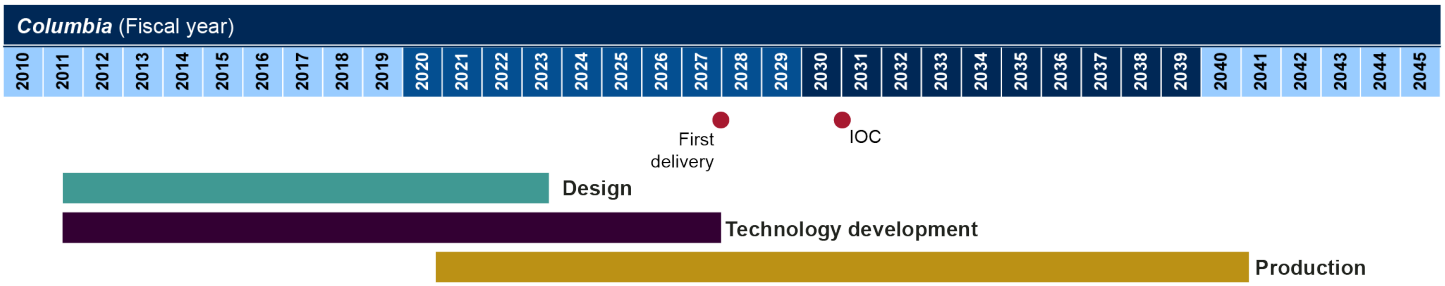
Sea Leg: *Columbia* class, W76-1, and W88 Alt 370

***Columbia* class submarine**

We have previously reported on several risks to an on-time delivery of the *Columbia* class submarine, including immature technologies, design challenges, production quality challenges, and an aggressive production schedule.[50] The Navy has acknowledged that the *Columbia* class program's 84-month construction schedule is aggressive and that it is important to minimize the risk of schedule delays. The Navy's planned schedule for the *Columbia* class is shown in figure 10.

[50]GAO-19-497 and GAO-18-158.

Figure 10: *Columbia* Class Submarine Program Schedule, Fiscal Years 2010 through 2045



IOC = Initial operational capability

Source: GAO analysis of Navy data. | GAO-21-210

Note: Technologies for this program are matured to a level that DOD considers mature. However, based on our work on best practices in weapon system acquisitions, we have previously recommended that mature technologies are those that have been developed into prototypes that represent the full form, fit, and function of the actual system and have been tested in a realistic environment such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft. We have previously identified that demonstrating technologies in an operational environment provides a higher level of technology understanding and reduces risk prior to starting product development. The Department of Defense has historically disagreed with this recommended practice.

- **Immature technologies**. We previously reported that additional development and testing are required to demonstrate the maturity of several technologies critical to performance. If any of these systems do not develop as planned, the Navy and the shipyards could be required to complete some redesign. Or, if risks manifest later, they may force costly workarounds or rework during ship construction. In 2017, the Navy awarded a contract for detail design; however, critical technologies remained unproven. We reported in June 2020 that some critical technologies remain immature.[51] Our work on shipbuilding best practices has found that proceeding into detail design and construction with immature technologies can lead to design instability, delays, and cost growth.[52]

[51]GAO-19-497. The Navy did not concur with GAO's assessment in that report about the number and status of *Columbia* class technologies. Under current law and DOD policy, DOD generally only needs to mature technologies to a TRL 6 by the start of detail design in the development phase.

[52]GAO, *Navy Shipbuilding: Past Performance Provides Valuable Lessons for Future Investments*, GAO-18-238SP (Washington, D.C.: June 6, 2018); and *Best Practices: High Levels of Knowledge at Key Points Differentiate Commercial Shipbuilding from Navy Shipbuilding*, GAO-09-322 (Washington, D.C.: May 13, 2009).

- **Design challenges**. In 2019, we reported that the Navy faces delays in completing the design of the submarine. The Navy has stated its priority is to achieve a high level of design completion by the start of formal lead submarine construction in October 2020 to mitigate the risk of costly rework and schedule delays due to design changes.[53] According to program officials, the program met its design maturity goal in advance of formal construction. However, the shipbuilder had not met the goal for design disclosures—a detailed design product—hampered in large part by implementation of a new design software tool.[54]
- **Production quality challenges**. Quality problems with materials produced by some suppliers—which, according to the Navy, were discovered by the shipbuilder and supplier representatives—have affected the *Columbia* program's early construction schedule, increasing the risk that formal construction will not proceed as planned. Going forward, the shipbuilder anticipates having to rely on some suppliers that will need improvement to meet quality expectations. The shipbuilder also identified specific products and processes that continue to present quality risks for the supplier base. Ongoing delays resulting from the additional time needed to repair or replace deficient materials highlight the risk that persistent quality problems that could affect the program's schedule and the timely delivery of the lead submarine.[55]
- **Aggressive production schedule**. We previously reported that the program has an aggressive schedule planned to enable delivering the lead submarine in time to begin patrols in fiscal year 2031. The Navy began building parts of the submarine in advance of its formal construction start. Following these early construction efforts, the Navy plans to build the lead submarine over 7 years—or 84 months.[56] We reported in December 2017 that this duration is shorter than what the Navy achieved on any recent lead submarine construction effort—including during high levels of Cold War submarine production.[57] The

[53]GAO-19-497 and GAO-18-158.

[54]GAO-21-257.

[55]GAO-21-257.

[56]This planned duration does not include the time the shipyard spent conducting advance construction activities. In order to reduce risk to the production schedule for the *Columbia* class, the Navy and the shipyards are building some selected components early before the start of the construction of the lead submarine—an effort called advance construction.

[57]GAO-18-158.

average construction time for the first of class submarine for the last four classes has been approximately 91 months. In addition, the Navy and the two shipyards will try to attain this level of schedule performance for the lead submarine while the shipbuilders also start work on the first few *Virginia* class submarines built in a new configuration, which adds complexity. In 2011, the Navy increased submarine production from starting work on one submarine to two submarines per year. *Virginia* class program officials told us that this increase resulted in recent cost and schedule growth at the shipyards. The shipyard may experience additional challenges associated with the start of additional construction activities on the lead *Columbia* class in October 2020—the third submarine to start construction that year. During the subsequent decade, the Navy and shipbuilders plan to build an adequate workforce to accommodate construction of both *Columbia* class and *Virginia* class submarines at the same shipyards. We will continue to monitor these efforts as part of our ongoing work on the *Columbia* class program.

W76-1 and W88 Alt 370

In December 2018, DOE completed warhead production for the W76-1 LEP for the Trident missile, the first LEP in which DOE undertook full-scale design activities for weapon systems since 1982.

In September 2019, due to problems with a capacitor—the same part affecting the B61-12 LEP—NNSA revised its estimated first production unit delivery date for the W88 Alt 370 program to the fourth quarter of fiscal year 2021. According to September 2019 congressional testimony by NNSA's Deputy Administrator for Defense Programs, the capacitor problem and resulting delay will increase the cost of the W88 Alt 370 program by about $120 million to $150 million.

Increased Demand for Limited DOD Enterprise-Wide Resources Could Also Cause Delays to Replacement Programs

Multiple recapitalization programs will be simultaneously vying for limited resources across DOD. This concurrent demand for resources—such as qualified nuclear certification personnel—adds additional risk of schedule delays for replacement programs.

According to DOD, it has begun to identify mitigation measures.

DOE Infrastructure Capacity and Supply-Chain Risks

DOE's LEP and modernization schedules are highly dependent on the availability of suitable facilities to manufacture, assemble, and assess bomb and warhead components. However, many of the DOE facilities needed for these efforts are outdated or obsolete, as more than half of DOE's facilities are over 40 years old, and a quarter date back to the

Manhattan Project era. According to DOE, the greatest risk to its missions is the state of the agency's aging infrastructure.[58] Previously, in 2019, we found that the next decade is particularly challenging for DOE's nuclear modernization efforts because the agency needs to ensure sufficient production capacity to execute LEPs and modernization programs while conducting major construction projects and programs to modernize its uranium and plutonium capabilities, among others.[59] These capabilities are critical to support component manufacturing for DOE's LEPs and modernization programs. For example, the W87-1 nuclear warhead will be composed of all newly manufactured components. As a result, DOE will need to utilize numerous manufacturing capabilities in support of this effort, including the production of plutonium pits, and the facilities and capabilities must be ready to support the work. An unexpected failure or work interruption at a critical facility—such as the 3-year operational pause at Los Alamos National Laboratory's Plutonium Facility-4, which currently produces limited quantities of plutonium pits—could significantly affect modernization production schedules.[60]

In addition, any breakdown in the supply chain for materials or parts could also significantly delay DOE's schedule. Specifically, DOE is challenged to recreate many specialized materials and components that it has not produced in many decades and faces challenges in obtaining and testing specialized materials and parts from commercial suppliers. For example, DOE had to delay production of the W76-1 warhead when it encountered problems in manufacturing one important material. In March 2009, we reported that DOE lost knowledge of how to manufacture the material because it kept few records of the process when the material was made in the 1980s, and almost all staff with expertise on production retired or left the agency, leaving the production process for this material dormant

[58]Department of Energy, National Nuclear Security Agency Office of Safety, Infrastructure and Operations, *Master Asset Plan 2019* (Washington, D.C.; 2017).

[59]GAO-19-126.

[60]In 2013, Los Alamos National Laboratory, in consultation with NNSA, paused operations at Plutonium Facility-4 due to concerns with the criticality safety program. The decision to pause operations was made to remedy issues associated with staffing, operational discipline, and safety documentation. The laboratory maintained its ability to certify the safety and reliability of the nuclear weapons stockpile during this period. By late 2016, the plutonium facility resumed all operations that had been paused in 2013. For additional information about DOE's plans for pit production, see GAO-20-703.

for about 25 years.[61] In June 2019, we identified similar challenges facing DOE as it resumes production of specialized explosive materials needed in about 100 different components used in nuclear weapons.[62] In October 2020, we described similar challenges facing DOE as it reestablishes its supply of high purity depleted uranium and its capability to produce components using a depleted uranium-niobium alloy.[63] DOE is currently reconstituting capabilities for other materials, including lithium.

Furthermore, DOE must test and qualify a large number of commercially supplied parts for use in nuclear weapon components, which is a complex undertaking and can lead to delays. Delays in the B61-12 LEP and W88 Alt 370 resulting from the inability to use a commercially supplied capacitor may also affect the availability of facilities and engineering staff for the W80-4 LEP. Delays, in turn, to the W80-4 LEP could create cascading delays in subsequent programs.

Delays in DOD Replacement Programs Could Exacerbate the Challenges of Current Triad Systems

If triad replacement programs are fielded late, it would prolong the period in which DOD would face force-generation challenges and capability limitations. Additionally, such delays could result in further reductions to the number of nuclear forces that USSTRATCOM could employ and more severe capability limitations if adversary defenses continue to advance, including:

Under the current retirement schedule for the *Ohio* class submarine, if the *Columbia* class does not achieve the initial fielding date of fiscal year 2031 as planned—or if any of the subsequent deliveries planned through 2040 are delayed—the Navy will have insufficient submarines available to meet the additional USSTRATCOM force-generation operational requirement of a total of 10 submarines. *Ohio* class sustainment program officials said that options to further extend the *Ohio* class would be costly, and officials from the Office of the Chief of Naval Operations characterized the potential of further extensions as highly unlikely. Further, any delays to fielding *Columbia* class submarines would also delay the Navy's deployment of the advanced survivability capabilities of that submarine class while the threat environment continues to evolve.

[61]GAO, *Nuclear Weapons: NNSA and DOD Need to More Effectively Manage the Stockpile Life Extension Program*, GAO-09-385 (Washington, D.C.: Mar. 2, 2009).

[62]GAO-19-449.

[63]GAO-21-16.

According to the 2018 Nuclear Posture Review, delays in the GBSD program, accompanied by a rapid age-out of the ICBM force, would reduce the scale of attack required for an adversary to threaten much of U.S. deterrence forces in a first strike attack. The Air Force projects a steady decline in the number of Minuteman IIIs available through the mid-2030s. Air Force officials stated that, although they do not anticipate age-out to be more precipitous than projected, there is uncertainty about Minuteman III's ground systems and command and control systems that add risk to the weapon system. If realized, these risks could become an additional driver of age-related unavailability for Minuteman III.

DOD and DOE Have Limited Ability to Mitigate Risks to the Efficacy of the Nuclear Deterrent with Current Strategy, and Are Beginning to Consider Alternatives

DOD is increasingly reliant on the Hedge Strategy to mitigate risk to the efficacy of the nuclear deterrent. However, we found that DOD and DOE will have a limited ability to address these risks because each department faces challenges in implementing the Hedge Strategy as outlined in the 2018 Nuclear Posture Review.

Specifically, DOD and DOE will face limitations to implementing this strategy because of challenges with triad systems prior to the fielding of replacements, as discussed above, and because the departments face:

- tradeoffs, for example by using weapons less well-suited to meet mission objectives if DOD makes substitutions between triad weapons;
- overlapping periods of shortfalls in delivery system quantities until they are replaced or modernized; and
- insufficient infrastructure to produce bombs and warheads quickly.

DOD and DOE are beginning to evaluate additional risk mitigation approaches, but some of these efforts, if implemented, could take years to complete.

DOD Is Increasingly Reliant on the Hedge Strategy to Mitigate Risk

DOD plans to use the Hedge Strategy to address an increased scope of risk occurring since the previous 2010 Nuclear Posture Review.

USSTRATCOM officials explained that the concept of the Hedge Strategy is not new, but changes to the strategic environment—for example, improved adversary capabilities—caused DOD to expand the categories of risks that could be potentially mitigated by this strategy in its 2018 Nuclear Posture Review. According to USSTRATCOM officials, prior to the 2018 Nuclear Posture Review, DOD considered the concept of the Hedge Strategy to mitigate potential geopolitical and technological risks to

the nuclear triad, as shown in table 3. However, the 2018 Nuclear Posture Review identified two additional categories of risk that DOD could mitigate using the Hedge Strategy: programmatic and operational. Based on our analysis of the triad in this report, we found that DOD currently faces all four categories of risk for which it could implement the Hedge Strategy as mitigation.

Table 3: 2018 Nuclear Posture Review Risk Categories

Categories of risk that can be mitigated by the Hedge Strategy	Description of categories of risk
Programmatic[a]	• Legacy nuclear systems could age-out earlier or more precipitously than anticipated. • Fielding of planned replacement systems could be delayed. • Key nuclear materials may not be able to be produced in the quantities needed.
Technological	• Technical failures could prevent the use of a part of the nuclear triad. • An adversary could have a technological breakthrough that creates a new threat.
Operational[a]	• Operational shortfalls could reduce the effectiveness of the U.S. nuclear forces, including reduced availability of the deployed forces and any unmet requirement needed to sustain effective deterrence.
Geopolitical	• New adversaries could emerge or adversaries could expand their nuclear forces.

Source: GAO analysis of 2018 Nuclear Posture Review and analysis of Department of Defense and Department of Energy documentation. | GAO-21-210

[a]These categories of risk were first associated with the Hedge Strategy in the 2018 Nuclear Posture Review.

According to the 2018 Nuclear Posture Review, in the event that programmatic, technological, operational, or geopolitical risks are realized, DOD could implement the Hedge Strategy to mitigate risk. If implemented through use of the weapons hedge, non-deployed bombs and warheads held in reserve can be fielded on nuclear triad systems, in two ways:

1. generating additional ICBMs, submarines, or bombers; or
2. adding additional warheads to ICBMs by using a Multiple Independently Targetable Reentry Vehicle (MIRV) configuration (shown in figure 11).

DOD can use these two options to generate supplemental nuclear forces to augment or replace legs of the triad and minimize the consequences of risks to the nuclear deterrent.

Figure 11: Mk12A Reentry Vehicle in a Multiple Independently Targetable Reentry Vehicle (MIRV) Configuration

Source: GAO. | GAO-21-210

The MIRV approach would increase the number of warheads that can be used to cover targets, even if the total number of ICBMs available is reduced because each warhead can be sent to a different target. While adding MIRVs to the ICBM force would provide the additional ability to cover targets if necessary, there are limitations to this approach. For example, using MIRVs on the Minuteman IIIs would necessitate a change

of standing U.S. policy; the 2010 Nuclear Posture Review indicated that the United States would no longer deploy MIRVs on the Minuteman III.[64]

USSTRATCOM Can Make Substitutions within the Triad Using Weapons Hedge Assets, but This May Require It to Use Less-Effective or Less-Appropriate Weapons

USSTRATCOM officials said that DOD can use operational flexibility both if employing the weapons hedge—which is the inventory of non-deployed bombs and warheads— or as an everyday mechanism for mitigating risk. In general, operational flexibility is a characteristic of U.S. defense capabilities that allows USSTRATCOM to consider all available nuclear and nonnuclear weapons when tailoring plans for different adversaries and threats, and it is exercised as a regular part of the planning process. In using operational flexibility, USSTRATCOM can offer options for substituting one weapon for another to achieve mission objectives.

One example is accepting the consequences of “overflight”. Depending on the target country, some delivery systems—like submarines—can be positioned so that these missiles do not have to fly over third-party countries while delivering their weapons. By contrast, ICBM locations are fixed and thus have less flexibility. So depending on the target country an ICBM may have to fly over third party countries, which can raise geopolitical or diplomatic issues. DOD’s use of heavy bombers may also present overflight concerns as they travel through non-U.S. airspace toward intended targets.

Overlapping Shortfalls in Delivery System Quantities and Capabilities Constrain DOD’s Ability to Mitigate Risks

Additional information has been redacted because it contained classified information.

DOE Can Support the Weapons Hedge but Does Not Have the Infrastructure Necessary to Produce Bombs and Warheads Quickly and Is Assessing Options

In the event that DOD implements the Hedge Strategy, DOE maintains hedge weapons that can serve as ready weapons within prescribed activation time frames. As with the active stockpile, DOE conducts regular surveillance of weapons in the inactive stockpile. In addition, DOE maintains sufficient reserves of limited-life components to respond to generation requirements within required time frames and maintains a reserve of nuclear components from dismantled weapons that could potentially be reused.

[64]The 2018 Nuclear Posture Review does not include discussion of MIRVs that reflects a change to the 2010 Nuclear Posture Review.

According to the 2018 Nuclear Posture Review, the second approach to implementing the Hedge Strategy is to have a robust nuclear weapon production infrastructure that has the design, engineering, and manufacturing capabilities needed to quickly produce new or additional weapons to address changes to the threat environment. This would allow DOD to have additional flexibility to respond to risks. However, DOE cannot currently implement this approach because its nuclear infrastructure declined during the past decades and it cannot respond quickly to new weapon production demands. In addition, DOD stated in the 2018 Nuclear Posture Review that, due to the state of the current DOE weapons production infrastructure, it will implement the Hedge Strategy using the weapons hedge rather than relying on a responsive infrastructure.

The 2018 Nuclear Posture Review highlighted the need for DOE to modernize its weapons production infrastructure, an effort that will take decades and will require significant investments in multiple areas of material and component production. In addition, to accomplish this, DOE will need to improve its performance in contract and project management—an area for which DOE has been on GAO's High-Risk List since its inception in 1990.[65] DOE has no margin for further delay in recapitalizing the infrastructure needed to produce strategic materials and components for nuclear weapons, according to the 2018 Nuclear Posture Review and DOE documentation. We have reported on challenges DOE has faced in managing several infrastructure and production efforts, as well as the options DOE is assessing to address key infrastructure needs, discussed below:

Uranium Processing

One critical modernization project is DOE's construction of the Uranium Processing Facility to replace outdated, deteriorating facilities currently used at the Y-12 National Security Complex to process enriched uranium, a key material used in nuclear weapons. We reported in 2017 that cost estimates for this facility rose sharply.[66] In its initial 2007 cost estimate, DOE projected the facility to cost between $1.4 billion and $3.5 billion. By 2012, DOE had increased its estimate to between $4.2 billion and $6.5

[65]GAO, *High-Risk Series: Substantial Efforts Needed to Achieve Greater Progress on High-Risk Areas*, GAO-19-157SP (Washington, D.C.: Mar. 6, 2019) and *High-Risk Series: Dedicated Leadership Needed to Address Limited Progress in Most High-Risk Areas,* GAO-21-119SP (Washington, D.C.: Mar. 2, 2021). Every 2 years, we report on federal programs and operations that are vulnerable to waste, fraud, abuse, and mismanagement, or that need broad reform.

[66]GAO-17-577.

billion and planned to complete the facility by the end of 2025. In March 2020, we reported that NNSA officials expect to complete the Uranium Processing Facility project by the end of 2022 for $6.5 billion—the higher end of their 2012 estimate. However, this updated estimate does not include $850 million in additional spending from fiscal years 2016 through 2026 to support modernizing other needed uranium processing capabilities, integrating those capabilities with the Uranium Processing Facility, improving the infrastructure of existing buildings, and transitioning out of other buildings.[67] As of December 2019, three of the seven Uranium Processing Facilities sub-projects were complete, and four were ongoing.

Plutonium Pits

To support the W87-1 program and subsequent modernization programs, DOE is refurbishing its capabilities at Los Alamos National Laboratory to produce no fewer than 30 plutonium pits per year during 2026. DOE also plans to repurpose a partially constructed facility at the Savannah River Site to produce an additional 50 pits per year by 2030. In September 2020, we reported that we could not assess the extent to which NNSA will be ready to produce 80 pits per year because NNSA's plutonium program office is still developing a schedule for the pit production effort. We recommended that NNSA pursue a high-quality, reliable approach to schedule development to provide assurance of sufficient pits for the W87-1 program.[68] However, an independent assessment commissioned by DOD concluded that "no available option can be expected to provide 80 pits per year by 2030."[69] The independent assessment also noted the significant challenges DOE faced in completing projects of a similar scale, observing that its study found no DOE project costing more than $700 million completed in less than 16 years. We plan to assess DOE's efforts to establish its pit production capability pursuant to a provision in a

[67]GAO-20-293.

[68]GAO-20-703.

[69]Institute for Defense Analysis, *Independent Assessment of the Plutonium Strategy of the National Nuclear Security Administration*, IDA Paper P-10524 (Alexandria, Va: March 2019). The Nuclear Weapons Council affirmed to Congress in 2014 that it needs DOE to develop a capability to produce 50 to 80 pits per year. Federal law requires NNSA to produce no less than 10 war reserve pits during 2024, no less than 20 war reserve pits during 2025, no less than 30 war reserve pits during 2026, and to produce no less than 80 war reserve pits during 2030. 50 U.S.C. § 2538a.

committee report accompanying an appropriations bill for fiscal year 2020.[70]

Tritium

DOE faces a long-term challenge in maintaining a production capability for tritium, a key limited-life material that is critical to the functioning of nuclear weapons. Tritium is obtained either by recycling remaining tritium from old systems or through the irradiation of lithium target rods in a nuclear power reactor to create new tritium. According to DOE's 2020 Stockpile Stewardship and Management Plan, DOE has the capability to meet planned workload and mission deliverables. However, DOE requires that the nuclear power reactors that irradiate the lithium target rods be powered with unobligated uranium, meaning that the uranium, as well as the technology and equipment used to enrich it, must be of U.S. origin. DOE's current supply of this uranium is projected to be exhausted by approximately 2038 to 2041. DOE is currently studying alternatives to reestablish a domestic uranium enrichment capability to supply low-enriched uranium for tritium production, among other uses, as we reported in February 2018 and December 2020.[71]

Lithium

As we reported in July 2015, the United States relies on lithium production capabilities housed in a facility that is rapidly deteriorating and suffering from concrete failure.[72] DOE has since begun preparing to construct a new lithium processing facility. According to preliminary estimates, the facility could be completed by September 2031 at a cost of $955 million to $1.65 billion. We are currently reviewing these plans. Until the facility is available, DOE developed a bridging strategy to fill the interim supply gaps. We are currently evaluating DOE's strategy for lithium production pursuant to a provision in a committee report

[70] H.R. Rep. No. 116-83, at 120 (2019) (accompanying the Energy and Water Development and Related Agencies Appropriations Act, 2020, H.R. 2960, 116th Cong. (2019)) and S. Rep. No. 116-236, at 417 (2020) (accompanying the National Defense Authorization Act for Fiscal Year 2021, S. 4049, 116th Cong. (2020)).

[71] GAO, *Uranium Management: Actions to Mitigate Risks to Domestic Supply Chain Could Be Better Planned and Coordinated*, GAO-21-28 (Washington, D.C.: Dec. 10, 2020) and GAO-18-126.

[72] GAO-15-525.

accompanying a Senate national defense authorization bill for fiscal year 2020.[73]

Explosives

As we reported in June 2019, there are about 100 different nuclear weapon components that contain explosive materials, some of which are highly specialized and limited in supply.[74] For example, only a single container of one specialized material remains. DOE officials and contractor representatives said that the agency is working to replenish the supply of such materials, but the agency faces challenges because some specialized explosive materials were created decades ago, and the knowledge base to successfully produce them is now gone. Moreover, even if DOE can replicate the "lost recipes" for specialized explosive materials, it faces the challenge of finding suppliers willing and able to provide small quantities of specialized raw materials that meet the exacting standards required for use in nuclear weapons.

Depleted Uranium

According to the Fiscal Year 2020 Stockpile Stewardship and Management Plan, DOE has a long-term requirement for high-purity depleted uranium feedstock to meet national security needs.[75] While DOE has a large quantity of depleted uranium in a gaseous form, it does not have an active capability to convert the gas into the high-purity feedstock material for conversion to depleted uranium metal. DOE estimates a shortfall of usable depleted uranium in the 2029-2031 time frame. We recently reported on DOE's plans to reestablish its depleted uranium supply and its capabilities to produce depleted uranium-niobium alloy needed for certain components. We found that delays in these plans could slow or halt nuclear modernization programs in the next decade.[76]

Radiation-Hardened Microelectronics

Radiation-hardened microelectronics are essential components of nuclear weapons. DOE's Microsystems, Engineering, Science and Application (MESA) facilities are its only trusted source of radiation-hardened microelectronics for stockpile modernization. According to the 2019 Stockpile Stewardship and Management Plan, some of the facilities are

[73]S. Rep. No. 116-48, at 388 (2019) (accompanying the National Defense Authorization Act for Fiscal Year 2020, Pub. L. 116-92, 116th Cong. (2019)).

[74]GAO-19-449.

[75]U.S. Department of Energy, *Fiscal Year 2020 Stockpile Stewardship and Management Plan: Report to Congress* (July 2019).

[76]GAO-21-16.

beyond their intended 25-year design life and, without sustained investment and eventual large-scale recapitalization, the MESA complex will experience failures due to aging and will become obsolete. We recently issued a report on DOE's efforts to recapitalize its microelectronics production capability, and recommended that NNSA incorporate additional management controls for its microelectronics activities to increase assurance that its activities are efficiently executed and monitored.[77]

DOD Is Beginning to Evaluate Approaches to Mitigate Risks Facing the Triad

In DOD's effort to implement the 2018 Nuclear Posture Review, the Deputy Secretary of Defense tasked certain DOD components to conduct a number of analyses related to mitigating operational, programmatic, technological, and geopolitical risks to the nuclear forces. These analyses could result in the department expanding its actions that it could use as part of the approach for the Hedge Strategy. DOD has recently begun these analyses.

Agency Comments

We provided a draft of the full, classified version of this report to DOD and DOE for review and comment. Both DOD and DOE provided technical comments, which were incorporated as appropriate.

We are providing copies to the appropriate congressional committees; the Secretary of Defense; the OUSD for Acquisition and Sustainment; the Chairman of the Joint Chiefs of Staff; the Commander, USSTRATCOM; the Acting Secretary of the Air Force; the Acting Secretary of the Navy; the Secretary of Energy; and the Acting Administrator of the National Nuclear Security Administration.

[77]GAO-20-357.

If you or your staff have any questions about this report, please contact us at (202) 512-4841 or oakleys@gao.gov; (202) 512-3841 or bawdena@gao.gov; or (202) 512-9971 or kirschbaumj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix II.

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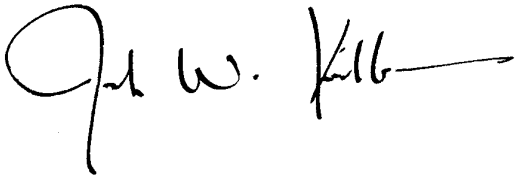

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Appendix I: Objectives, Scope, and Methodology

In this report we examined (1) the challenges, if any, the Department of Defense (DOD) and Department of Energy (DOE) face in meeting U.S. Strategic Command's (USSTRATCOM) current and expected operational needs with existing triad systems until retired or replaced; (2) the extent to which new DOD and DOE triad acquisition programs face schedule risks and the implications of any delays; and (3) the extent to which DOD and DOE have developed strategies beyond individual program risk-mitigation strategies to mitigate current and unexpected challenges, including schedule delays, with existing and replacement triad systems.

For the purposes of this review, we limited our scope to strategic nuclear weapons systems that have operational requirements defined in documentation provided by USSTRATCOM. We omitted from our review supporting systems, including support vehicles such as aerial refueling tankers or security forces helicopters; weapon storage areas; training equipment; or maintenance facilities. We also excluded nuclear-capable tactical aircraft, as we limited our scope to DOD's strategic nuclear capabilities.

In order to assess the extent to which DOD and DOE face challenges meeting USSTRATCOM's current and expected operational needs, we reviewed prior GAO work on the readiness, sustainment, and operations of the nuclear triad and the associated nuclear weapons.[1] We also reviewed recent versions of the DOD Quarterly Readiness Report to Congress; recent Joint Forces Readiness Review Quarterly Reports to the Secretary of Defense (April-June 2017 and October-December 2018), the United States Air Force Nuclear Deterrence Operations Core Function Support Plan (fiscal year 2017 and fiscal year 2020); and the Office of the Secretary of Defense—issued 2018 Biennial Assessment and Report on

[1]GAO, *Nuclear Forces Readiness: Incomplete Readiness Reporting, Aging Delivery Systems, and Potential Delays in Replacement Systems Put Deterrent at Risk*. GAO-19-12C. (Washington, D.C.: Mar. 20, 2019).; *Defense Nuclear Enterprise: Systems Face Sustainment Challenges and Actions Are Needed to Effectively Monitor Efforts to Improve the Enterprise*, GAO-20-9C (Washington, D.C.: Oct. 24, 2019); *Nuclear Weapons: DOD Assessed the Need for Each Leg of the Strategic Triad and Considered Other Reductions to Nuclear Forces*, GAO-16-372C (Washington, D.C.: May 18, 2016); *Nuclear Weapons: Annual Assessment of the Safety, Performance, and Reliability of the Nation's Stockpile*, GAO-07-243R (Washington, D.C.: Feb. 2, 2007); *Nuclear Weapons: NNSA Needs to Improve Guidance on Weapon Limitations and Planning for Its Stockpile Surveillance Program*, GAO-12-188 (Washington, D.C.: Feb. 8, 2012); and *Nuclear Weapons: NNSA Should Evaluate the Role of the Enhanced Surveillance Program in Assessing the Condition of the U.S. Nuclear Stockpile*, GAO-16-549 (Washington, D.C.: Sept. 14, 2016).

the Delivery Platforms for Nuclear Weapons and the Nuclear Command and Control System, also called the Report on Platform Assessments.[2] We interviewed officials from the Office of the Under Secretary of Defense (OUSD) for Acquisition and Sustainment and OUSD Policy offices, and the Joint Staff, and we received written responses to questions from the OUSD for Acquisition and Sustainment's Nuclear Matters office. We also interviewed and received written responses from USSTRATCOM. For the *Ohio* and *Columbia* class submarines, we interviewed officials from the Office of the Chief of Naval Operations; Navy Strategic Systems Programs; the Trident Refit facilities that maintain the *Ohio* class submarines, and the program offices. We also analyzed documentation related to *Ohio* class sustainment. For Air Force programs, we interviewed and received written responses from the Air Force Nuclear Weapons Center; Air Force Global Strike Command; and several program offices. For the nuclear bombs and weapons, we reviewed DOE's current Weapon Reliability Reports, which DOE produces to communicate the reliability of each warhead and bomb type in the stockpile to USSTRATCOM. We discussed the content of the Weapon Reliability Reports with cognizant National Nuclear Security Administration Office of Defense Programs officials. In addition, we reviewed DOE's fiscal year 2019 and 2020 Stockpile Stewardship and Management Plan reports, which provides DOE's 25-year plan for stockpile sustainment and modernization. We also discussed stockpile sustainment challenges with program managers.[3]

To assess the extent to which DOD and DOE triad acquisition programs face schedule risks, we analyzed DOD documentation, including program schedules and risk matrices and other documentation from the services and cognizant offices. We also leveraged our ongoing and recently completed work on nuclear triad acquisition programs, including the

[2]DOD's Report on Platform Assessments is a biennial product per 10 U.S.C. § 492 that was most recently issued in 2018.

[3]We had initially included nuclear command, control, and communication (NC3) enterprise systems in our report, but due to recent changes to the DOD policy, the level of classification for some NC3 enterprise system information may be elevated beyond the level of this report so this information was not included. GAO has previously reported on NC3 acquisitions and has ongoing work in this area. *Nuclear Command, Control, and Communications: Some Acquisition Programs Face Challenges That Could Delay Required Capabilities, and the Department of Defense Is Preparing for Transition of Operations to New Satellite Networks*, GAO-19-568RC (Washington, D.C.: Sept. 30, 2019)

Columbia class submarine, Ground Based Strategic Deterrent (GBSD),[4] DOE Life Extension Programs (LEPs), and DOE warhead modernization efforts.[5] In addition, we leveraged our prior work on acquisition best practices to identify potential program approaches that were inconsistent with our knowledge-based acquisition practices. We also conducted interviews with cognizant offices of each service and program managers for the bomb and warhead modernization programs. We conducted interviews with the cognizant DOD and DOE acquisition program officials related to modernizing the existing triad systems and overseeing acquisition and sustainment efforts related to the nuclear triad.

In order to assess the extent to which DOD and DOE have strategies to mitigate current and future challenges, we reviewed DOD program risk matrices and program documentation for the acquisition programs. We reviewed applicable DOD policy and guidance documents, to include the 2010 and 2018 Nuclear Posture Reviews and the 2018 Nuclear Posture

[4]GAO*, Columbia Class Submarine: Immature Technologies Present Risks to Achieving Cost, Schedule, and Performance Goals*, GAO-18-158 (Washington; D.C.: Dec. 21, 2017); *Nuclear Command, Control, and Communications: Military Services Are Taking Steps to Modernize and Strengthen the System Architecture*, GAO-19-129C (Washington, D.C.: Oct. 17, 2018); *Columbia Class Submarine: Overly Optimistic Cost Estimate Will Likely Lead to Budget Increases*, GAO-19-497 (Washington, D.C.; Apr. 8, 2019); *Columbia Class Submarine: Delivery Hinges on Timely and Quality Materials from an Atrophied Supplier Base,* GAO-21-257 (Washington, D.C.: Jan. 14, 2021); *Nuclear Triad: DOD and DOE Face Challenges Mitigating Risks to U.S. Deterrence Efforts*, GAO-20-87C (Washington, D.C.: June 19, 2020); and *Defense Acquisitions Annual Assessment: Drive to Delivery Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight* , GAO-20-439 (Washington, D.C.: June 3, 2020). Due to the higher level of classification, this report does not include some information obtained in GAO's ongoing work on the B-21 bomber or the Long Range Standoff Weapon.

[5]DOE and DOD undertake LEPs to refurbish or replace nuclear weapons' components to extend their lives, enhance their safety and security characteristics, and consolidate the stockpile into fewer weapon types to minimize maintenance and testing costs while preserving needed military capabilities. GAO, *Nuclear Weapons: NNSA Should Adopt Additional Best Practices to Better Manage Risk for Life Extension Programs*, GAO-18-129 (Washington, D.C.: Jan. 30, 2018); *B61-12 Nuclear Bomb: Cost Estimate for Life Extension Incorporated Best Practices, and Steps Being Taken to Manage Remaining Program* Risks, GAO-18-456 (Washington, D.C.: May 31, 2018); *Nuclear Weapons: NNSA Has Taken Steps to Prepare to Restart a Program to Replace the W78 Warhead Capability*, GAO-19-84 (Washington, D.C.: Nov. 30, 2018); *Nuclear Weapons: Action Needed to Address the W80-4 Warhead Program's Schedule Constraints*, GAO-20-409 (Washington, D.C.: July 23, 2020); *Nuclear Weapons: NNSA Should Further Develop Cost, Schedule, and Risk Information for the W87-1 Warhead Program,* GAO-20-207C (Washington, D.C.: Feb. 28, 2020)*; and Nuclear Weapons: NNSA Should Further Develop Cost, Schedule, and Risk Information for the W87-1 Warhead Program*, GAO-20-703 (Washington, D.C.: Sept. 9, 2020).

Review implementation tasks; and documentation related to USSTRATCOM operational requirements. In addition, we reviewed DOE's Weapon Reliability Reports, Stockpile Stewardship and Management Plan, and the Report on Stockpile Assessments, which assess whether there is a need to resume underground nuclear tests to ensure the safety, reliability, and performance of the nuclear stockpile. We also interviewed cognizant planning and operations officials from the Joint Staff; the Office of the Under Secretary of Defense for Acquisition and Sustainment; the Office of the Under Secretary of Defense for Policy; Air Force Nuclear Weapons Center; Air Force Global Strike Command; Office of the Chief of Naval Operations; Navy Strategic Systems Program; and individual Air Force and Navy program offices. We also interviewed DOE officials from the Office of Defense Programs and program managers for the LEPs and warhead modernization programs. We also reviewed recently completed GAO evaluations of DOE's work to ensure the availability of strategic materials and to modernize nuclear production infrastructure.[6]

We conducted this performance audit from November 2017 to March 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We subsequently worked with DOD and DOE from July 2020 to May 2021 to

[6]GAO, *DOE Project Management: NNSA Should Ensure Equal Consideration of Alternatives for Lithium Production,* GAO-15-525 (Washington, D.C: July 13, 2015); *DOE Project Management: NNSA Needs to Clarify Requirements for Its Plutonium Analysis Project at Los Alamos*, GAO-16-585 (Washington, D.C: Aug. 9, 2016); *National Nuclear Security Administration: Action Needed to Address Affordability of Nuclear Modernization Programs*, GAO-17-341 (Washington, D.C: Apr. 26, 2017); *Modernizing the Nuclear Security Enterprise: A Complete Scope of Work Is Needed to Develop Timely Cost and Schedule Information for the Uranium Program*, GAO-17-577 (Washington, D.C: Sept. 8, 2017); *Nuclear Weapons: NNSA Should Clarify Long-Term Uranium Enrichment Mission Needs and Improve Technology Cost Estimates*, GAO-18-126 (Washington, D.C: Feb. 16, 2018); *Modernizing the Nuclear Security Enterprise: NNSA Is Taking Action to Manage Increased Workload at Kansas City National Security Campus*, GAO-19-126 (Washington, D.C: Apr. 12, 2019); *Nuclear Weapons: Additional Actions Could Help Improve Management of Activities Involving Explosive Materials*, GAO-19-449 (Washington, D.C: June 17, 2019); *Modernizing the Nuclear Security Enterprise: Uranium Processing Facility Is on Schedule and Budget, and NNSA Identified Additional Uranium Program Costs*, GAO-20-293 (Washington, D.C: Mar, 11, 2020); *Nuclear Weapons: NNSA Plans to Modernize Critical Depleted Uranium Capabilities and Improve Program Management,* GAO-21-16 (Washington, D.C: Oct. 15, 2020); and *Nuclear Weapons: NNSA Needs to Incorporate Additional Management Controls Over Its Microelectronics Activities*, GAO-20-357 (Washington, D.C: June 9, 2020).

prepare this unclassified version of the original classified report for public release. This public version was also prepared in accordance with these standards. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

This report is an unclassified version of a classified product that was issued in June 2020, and does not include any classified information.[7] Therefore, this report omits information determined to be classified by DOD or DOE regarding specific STRATCOM requirements and system capabilities, among other things. Although the information provided in this report is more limited, the report addresses the same objectives as the classified report and uses the same methodology.

On March 13, 2020, as we were finalizing this report, the President declared a nationwide state of emergency as a result of the spread of the COVID-19 coronavirus. GAO adjusted its operating status in order to curb the spread of the virus, including closing rooms where work on classified information is conducted. DOD also adjusted its operating status. As a result, we suspended work on this report. This report does not reflect the effects of these COVID-19 measures on program schedules or progress, and, with the exception of statements based on more recently published GAO reports, is current as of March 2020.

[7]GAO-29-87C.

Appendix II: GAO Contacts and Staff Acknowledgments

GAO Contacts

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