



March 2023

NUCLEAR WEAPONS

Technical Exceptions and Limitations Do Not Constrain DOD's Planning and Operations

Accessible Version

GAO Highlights

Highlights of [GAO-23-105671](#), a report to congressional committees

Why GAO Did This Study

Most nuclear weapon types currently in the stockpile were designed and produced over 30 years ago. To extend weapon and component design lives, the United States is in the midst of the most extensive nuclear weapons stockpile modernization effort since the Cold War era. Maintaining and enhancing the safety, security, reliability, and performance of the U.S. nuclear stockpile is part of NNSA's mission. Through its surveillance program, NNSA continually assesses each nuclear weapon to determine the safety and reliability of the stockpile. NNSA and its laboratories prepare reports for each weapon type, indicating that it is satisfactory for release to the military services, and describes, among other things, the weapon's exceptions and limitations.

Senate Committee Report 117-39 includes a provision for GAO to update existing work on nuclear weapons limitations. The objectives of this review included describing (1) the current types of nuclear weapons exceptions and limitations; (2) the extent to which they are planned to be addressed through modernization programs; and (3) the extent to which exceptions and limitations constrain DOD's ability to store, maintain, or operate weapons.

GAO reviewed NNSA and DOD documentation describing exceptions and limitations and how they are planned to be addressed through modernization and mitigation. GAO also interviewed knowledgeable DOD and NNSA officials.

View [GAO-23-105671](#). For more information, contact Allison Bawden at (202) 512-3841 or bawdena@gao.gov.

March 2023

NUCLEAR WEAPONS

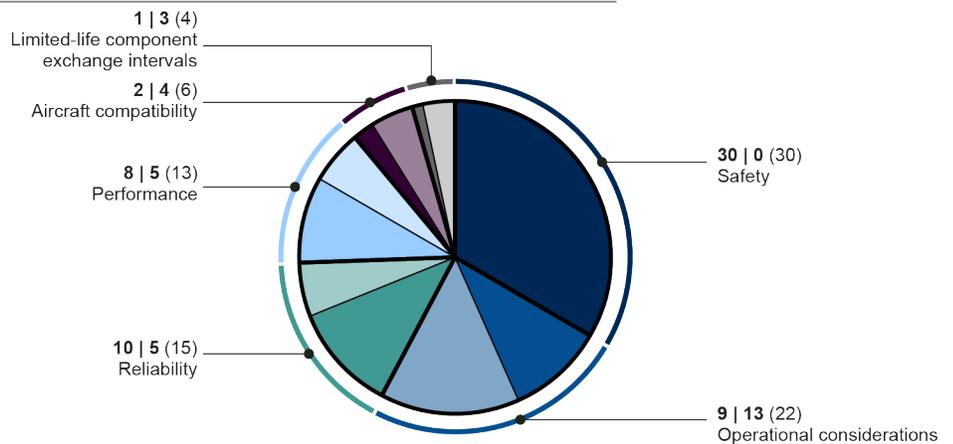
Technical Exceptions and Limitations Do Not Constrain DOD's Planning and Operations

What GAO Found

The National Nuclear Security Administration (NNSA) currently identifies 90 technical nuclear weapons exceptions and limitations in six categories (see fig.). In partnership with its nuclear weapons design laboratories, NNSA maintains, enhances, and reports on the safety and reliability of nuclear weapons. NNSA issues major assembly releases (MAR) to the Department of Defense (DOD) when nuclear weapons are released to the military services. MARs describe, among other things, exceptions to weapons' ability to meet DOD's requirements and limitations to their deployment or handling. NNSA and DOD officials said that none of the exceptions and limitations rise to a level that would require a weapon to be removed from the stockpile.

Figure: Number of Nuclear Weapons Exceptions and Limitations by Category

Number of nuclear weapons exceptions | limitations by category (total)



Source: National Nuclear Security Administration. | GAO-23-105671

Data table for Figure: Number of Nuclear Weapons Exceptions and Limitations by Category

Category	Exceptions	Limitations	Total
Safety	30	0	30
Operational considerations	9	13	22
Reliability	10	5	15
Performance	8	5	13
Aircraft compatibility	2	4	6
Limited-life component exchange intervals	1	3	4

Source: National Nuclear Security Administration. | GAO-23-105671

NNSA officials told GAO that ongoing and planned modernization programs are expected to address as many nuclear weapon exceptions and limitations as feasible. Laboratory representatives said that they work with NNSA and DOD to

weigh the risks posed by exceptions and limitations against the design costs associated with addressing exceptions and limitations through modernization.

According to DOD officials, current nuclear weapons exceptions and limitations do not constrain their ability to store, maintain, or operate nuclear weapons. In some cases, DOD has accepted exceptions or limitations because they concern scenarios with a low probability of occurrence. In other cases, DOD has developed mitigation strategies to reduce risk, including maintenance safety protocols, secure storage and transport, and joint testing. According to DOD officials, the current and projected stockpile size and composition enables DOD to develop flexible operational plans. However, future flexibility may decline because of stockpile aging.

Contents

GAO Highlights		ii
	Why GAO Did This Study	ii
	What GAO Found	ii
Letter		1
	Background	5
	NNSA Identifies 90 Nuclear Weapons Exceptions and Limitations in Six Categories	11
	NNSA and DOD Plan to Address Some Exceptions and Limitations through Weapon Modernization Programs	14
	Current Nuclear Weapons Exceptions and Limitations Do Not Constrain DOD	15
	Agency Comments	18
	Appendix I: Crosswalk between Exception and Limitation Categories Reported by the NNSA in 2023 and Limitation Categories Reported by GAO in 2012	20
	Appendix II: GAO Contacts and Staff Acknowledgments	23
	GAO Contacts	23
	Staff Acknowledgments	23
Tables		
	Table 1: Types of Nuclear Weapons in the U.S. Stockpile, as of March 2022	8
	Table 2: Most Recent Issuance Dates for the National Nuclear Security Administration’s (NNSA) Nuclear Weapons Major Assembly Releases (MAR), as of March 2023	10
	Table 3: Crosswalk between 2023 NNSA Reported Exceptions and Limitations Categories and 2012 GAO Reported Limitation Categories	21
Figure		
	Data table for Figure: Number of Nuclear Weapons Exceptions and Limitations by Category	ii
	Figure 1: Number of Nuclear Weapon Exceptions and Limitations by Category, as of March 2023	13
	Data table for Figure 1: Number of Nuclear Weapon Exceptions and Limitations by Category, as of March 2023	13

Abbreviations

Alt	alteration
DOD	Department of Defense
DOE	Department of Energy
Livermore	Lawrence Livermore National Laboratory
Los Alamos	Los Alamos National Laboratory
NNSA	National Nuclear Security Administration
MAR	major assembly release
Sandia	Sandia National Laboratories
USSTRATCOM	U.S. Strategic Command

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March 9, 2023

Congressional Committees

Arms control agreements, other policies, and geopolitical shifts have led the United States to maintain nuclear deterrence with a smaller stockpile, consistent with limits in these agreements.¹ Most types of nuclear weapons currently in our nation's stockpile were designed and produced over 30 years ago. To extend weapon and component design lives, the United States is in the midst of the most extensive effort to modernize the stockpile since the Cold War. Throughout this modernization effort, it is critical to ensure that the stockpile remains safe, secure, reliable, and effective.

Maintaining and enhancing the safety, security, reliability, and performance of the U.S. nuclear weapons stockpile is part of the mission of the National Nuclear Security Administration (NNSA).² NNSA manages the stockpile in partnership with contractor-managed and -operated sites that are collectively known as the nuclear security enterprise. These sites include national security laboratories and nuclear weapons production facilities.

NNSA and its sites design, produce, and maintain nuclear weapons to meet requirements established by the Department of Defense (DOD) in collaboration with NNSA. These requirements fall into two main categories: (1) military characteristics, which define key operational, nuclear yield, and maintenance requirements; and (2) the stockpile-to-target sequence, which is the range of physical environments in which the

¹In 2010, the United States and the Russian Federation signed the New START Treaty, which can remain in force until 2026. According to the 2022 Nuclear Posture Review, the United States will field and maintain strategic nuclear weapons in compliance with the New START Treaty limits as long as the treaty remains in force. *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; T.I.A.S. No. 21-203; U.S. Department of Defense, *2022 National Defense Strategy of The United States of America, Including the 2022 Nuclear Posture Review and 2022 Missile Defense Review* (Washington, D.C.: Oct. 27, 2022).

²NNSA is a separately organized agency within the Department of Energy (DOE) responsible for the nation's nuclear weapons, nonproliferation, and naval reactors programs.

weapon should be able to perform as it travels from stockpile storage to a potential target.

Lawrence Livermore National Laboratory (Livermore), Los Alamos National Laboratory (Los Alamos), and Sandia National Laboratories (Sandia) are the NNSA sites responsible for designing nuclear weapons, and these sites prepare a major assembly release (MAR) when they determine that a nuclear weapon type of their design is satisfactory for release to the military services. Among other things, the MAR contains a list of the weapon's technical exceptions and limitations. NNSA defines a MAR exception as a characteristic or parameter that does not meet a requirement in the military characteristics or stockpile-to-target sequence document. NNSA defines a MAR limitation as a characteristic or parameter that significantly affects logistics, deployment, employment, storage, or handling but does not explicitly violate a requirement. Some exceptions and limitations are unique to a specific weapon type or version within a type, and others may occur in multiple weapon types.³

NNSA may periodically update or release a new MAR for a variety of reasons, including the introduction into the stockpile of a weapon type undergoing an alteration (alt) or life extension program, which are collectively referred to in this report as modernization programs.⁴ When NNSA updates a weapon's MAR, existing exceptions and limitations may either be removed, updated, or remain unchanged. Modernized weapons may also have new exceptions or limitations documented in a MAR.

Senate Report 117-39 accompanying a bill for the National Defense Authorization Act for Fiscal Year 2022 includes a provision for us to

³Some weapons have multiple versions. For example, there are currently three versions of the W76 nuclear warhead and five versions of the B61 nuclear bomb. These versions can differ in several ways, including modernized components, nuclear yield, and operational characteristics.

⁴An alt is a material change to a nuclear weapon or its components that does not alter the weapon's operational capability. Minor alts are typically limited in scope and are not considered modernization programs; however, major alts, such as the W88 Alt 370, are more akin to a life extension program. A life extension program, which can take a decade or more to complete, is a refurbishment intended to extend the lifetime of a weapon for an additional 20 to 30 years.

update our 2012 report on nuclear weapons limitations.⁵ This 2023 report describes (1) the current number and types of identified nuclear weapons exceptions and limitations; (2) the extent to which NNSA and DOD plan to address exceptions and limitations through weapons modernization programs; and (3) whether current weapons exceptions and limitations constrain DOD's ability to store, maintain, or operate the weapons.

To determine the current number and types of identified nuclear weapons exceptions and limitations, we reviewed NNSA documentation and guidance and interviewed agency officials. Specifically, we reviewed and analyzed the most recent MAR issued for each nuclear weapon type in the nuclear stockpile. We reviewed each MAR to determine the number of and categories for nuclear weapon exceptions and limitations. Los Alamos' MARs itemized exceptions and limitations separately and further separated them into six categories. We conducted a content analysis to identify and categorize Livermore's exceptions and limitations, which were reported differently in its MARs. Specifically, two analysts independently reviewed Livermore's MARs to identify each area of concern as an exception or limitation and determine which category applied. To determine the applicable category, the analysts used available information from Los Alamos' MARs, NNSA's MAR Tool, Sandia National Laboratories' (Sandia) Performance Limitations and Environments of Concern documents, and interviews with agency officials. The analysts then compared their individual analyses and resolved any differences by conferring with each other and further consulting the available agency information.

In addition, we reviewed the 2020 and 2021 Weapons Reliability Reports;⁶ the fiscal years 2019, 2020, and 2021 Report on Stockpile

⁵In 2012, we made eight recommendations, including that NNSA, in collaboration with DOD, expand guidance to include all limitations and clearly describe their potential impacts and determine if the findings of the joint military requirements review can be used to eliminate certain requirements. We have closed each of these recommendations as implemented. GAO, *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).

⁶NNSA produces the Weapons Reliability Report to communicate the reliability of each weapon type in the stockpile to DOD.

Assessments;⁷ and joint guidance on nuclear weapons activities.⁸ We also interviewed officials from NNSA's Offices of Defense Programs, Stockpile Management and Stockpile Modernization; representatives from Livermore, Los Alamos, and Sandia; members from the Navy and Air Force project officers groups; and officials from DOD's Office of Nuclear Matters to discuss the details of weapons exceptions and limitations.⁹

To determine the extent to which NNSA and DOD plan to address exceptions and limitations through weapons modernization programs, we reviewed NNSA and DOD documentation. Specifically, we reviewed the most recent MAR for nuclear weapon types that have recently been modernized or are currently undergoing modernization. In addition, we reviewed the Commander of U.S. Strategic Command's (USSTRATCOM) stockpile assessment to identify ways in which DOD anticipates modernization to affect currently identified exceptions and limitations. Further, we corresponded with USSTRATCOM officials to determine what exceptions and limitations they anticipate being addressed through modernization. Finally, we interviewed NNSA officials and laboratory representatives to discuss what exceptions and limitations they anticipate being addressed through modernization.

To identify the extent to which exceptions and limitations constrain DOD's ability to store, maintain, or operate the weapons, we reviewed NNSA and DOD documentation. Specifically, we reviewed the MAR for each weapon type to identify DOD requirements and exceptions or limitations to those requirements. In addition, we reviewed the USSTRATCOM Commander's stockpile assessments from fiscal years 2019, 2020, and 2021 to identify

⁷Federal law requires that the Secretaries of Energy and Defense submit a package of reports prepared by the directors of the three national security laboratories and the Commander of U.S. Strategic Command (USSTRATCOM). The reports provide the officials' assessments of the safety, reliability, and performance of each weapon type in the nuclear stockpile and the military effectiveness of the stockpile. The reports include an assessment about whether it is necessary to conduct an underground nuclear test to resolve any identified issues. The United States has not conducted an underground nuclear test since 1992. The Secretaries of Energy and Defense are required to submit these reports unaltered to the President, along with the conclusions they have reached as to the safety, reliability, performance, and military effectiveness of the nuclear stockpile. 50 U.S.C. § 2525.

⁸Department of Defense Instruction 5030.55, *DOD Procedures for Joint DOD-DOE Nuclear Weapons Life-Cycle Activities* (Jan. 25, 2001). The procedures in this instruction are designed to serve as a general model for DOD and DOE to manage nuclear weapons development, sustainment, and retirement programs.

⁹The project officers groups are working-level bodies that coordinate activities between NNSA and DOD for a particular weapon type.

whether and how USSTRATCOM accepts or mitigates nuclear weapons exceptions and limitations. We also interviewed officials from NNSA's Office of Defense Programs, DOD's Office of Nuclear Matters, and Navy and Air Force project officers groups that are joint DOD and Department of Energy (DOE) working groups—and corresponded with USSTRATCOM officials—to determine the effect that exceptions and limitations have on DOD's day-to-day operations and strategic planning.

We conducted this performance audit from January 2022 to March 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. We are separately issuing a classified annex to this report that provides additional details on each weapon type's exceptions and limitations.¹⁰ The annex will be available upon request to those with the appropriate clearance and a validated need to know.

Background

Responsibilities for the Nuclear Mission

NNSA's Office of Defense Programs oversees the agency's mission to maintain and modernize the nuclear stockpile through the Stockpile Stewardship and Management Program.¹¹ To fulfill this mission, the office is responsible for the manufacture, maintenance, refurbishment, surveillance, and dismantlement of nuclear weapons. These functions are

¹⁰GAO, *Classified Annex for GAO-23-105671: Technical Details on Nuclear Weapons Exceptions and Limitations*, GAO-23-106548C (Washington, D.C.: Mar. 9, 2023).

¹¹NNSA began modernizing the W76-0 nuclear warhead in 1998. NNSA completed this modernization—the W76-1—in 2018 and a follow-on modernization—the W76-2—in 2019. Current modernization plans for nuclear warheads and bombs include the B61-12, W88 Alt 370, W80-4, and W87-1, and the schedules for these programs extend through the 2030s. NNSA also plans to develop a new warhead, the W93, during this time. For the purposes of our report, older weapons currently undergoing modernization are referred to as legacy weapons, while completed modernization programs result in modernized weapons.

performed across the nuclear security enterprise. The nuclear security enterprise is comprised of

- three national security laboratories where nuclear weapons are designed—Livermore, Los Alamos, and Sandia;¹² and
- five nuclear weapons production facilities—the Kansas City National Security Campus in Missouri, the Pantex Plant in Texas, the Savannah River Site in South Carolina, the Y-12 National Security Complex in Tennessee, and the Nevada National Security Site.¹³

Livermore, Los Alamos, and Sandia are design laboratories responsible for the safety and reliability of the nuclear explosive package and nonnuclear components in nuclear weapons. They also support surveillance, assessment, and refurbishment of the nuclear weapons stockpile. Livermore, Los Alamos, and Sandia are responsible for systems engineering for the stockpile.¹⁴ Sandia also has responsibility for developing, testing, and producing nonnuclear components, which may have a limited life and require periodic replacement as part of regular maintenance activities.

The DOD focal point for the modernization and sustainment of the U.S. nuclear stockpile is the Office of Nuclear Matters, under the Office of the Assistant Secretary of Defense for Nuclear, Chemical, and Biological Defense Programs. Nuclear Matters is responsible for leading and integrating interagency efforts through the Nuclear Weapons Council to ensure the continued credibility of the U.S. nuclear deterrent.

USSTRATCOM has primary responsibility for targeting nuclear weapons, preparing the U.S. strategic nuclear war plan, and executing the plan, if ordered by the President. USSTRATCOM is also responsible for strategic nuclear deterrence, and it establishes operational and planning

¹²Most modern nuclear weapons consist of three sets of components—a primary, a secondary, and a set of nonnuclear components—enclosed in a case. When detonated, the primary transfers energy to the secondary, significantly increasing the weapon's explosive force, or yield. Together, the primary and secondary are referred to as the nuclear explosive package.

¹³While Los Alamos and Sandia are considered design laboratories, both also have production missions.

¹⁴Systems engineering is a disciplined process to transform top-level capability requirements into detailed, lower-level design requirements that can be achieved with available resources.

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.

The Nuclear Weapons Council, established by law in 1986, serves as a joint DOD/DOE organization to facilitate high-level coordination to secure, maintain, and sustain the nuclear stockpile.¹⁵ It serves as the focal point for interagency activities to maintain the U.S. nuclear stockpile.¹⁶ The Nuclear Weapons Council charters project officers groups for each weapon type to provide a technical forum for weapon development and management activities. The project officers groups are working-level bodies that coordinate activities between NNSA and DOD for a particular weapon type.¹⁷ Each group has a Lead Project Officer from either the Navy or Air Force, depending on which of these military services maintains and operates that weapon type. Representatives from the cognizant military service and national laboratories are also members of the project officers groups. Officials told us that the groups meet quarterly but may also convene on an ad hoc basis, as needed.

The current U.S nuclear weapons stockpile consists of seven weapon types. Some weapon types can have multiple versions, such as the B61, as a result of different military requirements or because of prior or ongoing modernization programs.¹⁸ Table 1 shows the weapon types in the stockpile, their dates of entry into the stockpile, and the laboratories and military services responsible for each weapon type.

¹⁵Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1987, Pub. L. No. 99-661, § 3137, 100 Stat. 3816, 4065 (1986).

¹⁶The Council is made up of six members—the Under Secretary of Defense for Acquisition and Sustainment; the Vice Chairman of the Joint Chiefs of Staff; DOE's Under Secretary for Nuclear Security (dual-hatted as the NNSA Administrator); the Under Secretary of Defense for Policy; the Under Secretary of Defense for Research and Engineering; and the Commander of USSTRATCOM.

¹⁷Project officers groups coordinate the development of compatibility assurance of a designated nuclear weapon system and its associated interfaces.

¹⁸The B61 bomb currently has five versions in the active stockpile—the -3, -4, -7, -11 and -12. When the B61-12 modernization program is complete, it will replace all but the -11 versions. NNSA produced the first B61-12 unit in November 2021.

Table 1: Types of Nuclear Weapons in the U.S. Stockpile, as of March 2022

Warhead or bomb	Description	Military service that maintains and operates weapon	Design laboratories responsible for weapon safety and reliability	Date of entry into stockpile
B61-3, -4	Gravity bomb	Air Force	LANL, SNL	1979 (-3), 1979 (-4)
B61-7, -11	Gravity bomb	Air Force	LANL, SNL	1985 (-7), 1996 (-11)
B61-12 ^a	Gravity bomb	Air Force	LANL, SNL	2022
W76-0 ^b	Submarine-launched ballistic missile warhead	Navy	LANL, SNL	1978
W76-1, -2	Submarine-launched ballistic missile warhead	Navy	LANL, SNL	2008 (-1), 2019 (-2)
W78	Intercontinental ballistic missile warhead	Air Force	LANL, SNL	1979
W80-1	Air-launched cruise missile warhead	Air Force	LLNL, SNL	1982
B83-1	Gravity bomb	Air Force	LLNL, SNL	1993
W87-0	Intercontinental ballistic missile warhead	Air Force	LLNL, SNL	1986
W88	Submarine-launched ballistic missile warhead	Navy	LANL, SNL	1989

Legend: LANL = Los Alamos National Laboratory; LLNL = Lawrence Livermore National Laboratory; SNL = Sandia National Laboratories

Source: National Nuclear Security Administration. | GAO-23-105671

^aNNSA is consolidating the -3, -4, and -7 versions of the B61 bomb into a single B61-12 version through an ongoing modernization program, at which point these legacy versions will be retired. The B61-11 will remain active alongside the B61-12 and continue to have its own major assembly release.

^bNNSA plans to retire the W76-0 and remove it from the stockpile as modernized weapons replace it.

Nuclear Weapons Requirements and Assessment

Nuclear weapon requirements consider both military needs as well as NNSA’s capabilities to meet those needs. DOD establishes stockpile-to-target sequence and military characteristic requirements for nuclear weapons in collaboration with NNSA. The project officers groups facilitate collaboration between NNSA and DOD to help ensure that legacy and modernized weapons meet these requirements. For instance, NNSA and DOD officials said that the project officers groups prioritize requirements as NNSA’s laboratories design and implement modernization programs. Additionally, the project officers groups convey the technical capabilities and limitations to DOD’s Office of Nuclear Matters, the Nuclear Weapons Council, USSTRATCOM, and the military services.

Nuclear weapons age and may deteriorate over time and are continually evaluated to help ensure their safety and reliability.¹⁹ NNSA and its laboratories continually assess the nuclear stockpile to determine whether the weapons meet DOD's requirements. Through its surveillance program—which include material, component, and systems-level tests—NNSA assesses weapon reliability and detects and anticipates any potential risks to safety or reliability in the stockpile.²⁰ These risks can arise because of aging or can result from design or manufacturing defects in weapons. NNSA also obtains critical information on the condition of the stockpile, such as aging effects on yield performance, through computer modeling and simulation programs using historic data from underground testing and data from modern experimentation.

Each weapon type in the nuclear stockpile is evaluated annually for safety, reliability, performance, and military effectiveness. The directors for each of the national security laboratories and the Commander of USSTRATCOM are to provide annual reports on stockpile assessments to the Secretaries of Energy and Defense and to the Nuclear Weapons Council. NNSA's surveillance program informs the laboratories' portions of the annual assessment.

The design laboratories will reissue a MAR when they identify a new exception or limitation or when DOD modifies a weapon's requirements. In addition, these laboratories will issue new MARs for modernized weapons that have requirements or attributes that are distinct from those of the legacy weapon system. Table 2 provides the dates of the most recent MARs for weapons in the stockpile, as of March 2023.

¹⁹NNSA assesses reliability annually in the Weapons Reliability Report. NNSA's current assessment of the reliability of the nuclear stockpile is based on nuclear and nonnuclear information from the agency's Stockpile Stewardship Program at Livermore, Los Alamos, and Sandia.

²⁰Sites across the nuclear security enterprise play a role in conducting stockpile surveillance.

Table 2: Most Recent Issuance Dates for the National Nuclear Security Administration's (NNSA) Nuclear Weapons Major Assembly Releases (MAR), as of March 2023

MAR weapon	Most recent issuance
B61-3, -4, -7 and -11 ^a	July 2020
B61-12 ^b	April 2022 (initial issue)
W76-0 ^c	September 2020
W76-1	June 2020
W76-2	May 2019 (initial issue)
W78	June 2020
W80-1	January 2021
B83-1	August 2022
W87-0	May 2021
W88 ^d	December 2021

Source: NNSA. | GAO-23-105671

Note: NNSA periodically updates a weapon's MAR for a variety of reasons, including when a new exception or limitation is identified or requirements are modified.

^aOnce the B61-12 is fully deployed, the B61-3, -4 and -7 will be retired. The B61-11 will remain active alongside the B61-12 and continue to have its own MAR.

^bNNSA has issued the initial MAR for the B61-12 in accordance with its milestone requirements.

^cNNSA plans to retire the W76-0 and remove it from the stockpile.

^dThe most recent W88 MAR includes information addressing NNSA's modernization program for the weapon.

According to officials from NNSA and the project officers groups, identifying new exceptions and limitations that would prompt the laboratories to reissue a MAR is an iterative process. When laboratories identify risks or uncertainties in meeting requirements through their weapons surveillance efforts, they report their findings to the cognizant project officers group to discuss the effect that the issue may have on the weapon meeting military characteristics or stockpile-to-target sequence requirements. In coordination with the cognizant project officers groups, the national laboratories determine whether these risks and uncertainties are exceptions or limitations. Project officers group members told us that exceptions and limitations can be addressed through modernization programs, but DOD generally mitigates or accepts them. When it is determined that an issue should be categorized as an exception or limitation, the project officers group presents its findings to the Nuclear Weapons Council.

NNSA Identifies 90 Nuclear Weapons Exceptions and Limitations in Six Categories

In its most recent MARs, NNSA identifies a total of 90 exceptions and limitations to the nuclear stockpile in six categories. Specifically, there are 60 identified exceptions and 30 limitations across the stockpile, as of March 2023. For additional detail on changes to the number of exceptions and limitations since our 2012 report, see appendix I.²¹ Our analysis indicates that these exceptions and limitations are distributed among the following categories, as described below in order of frequency:

- **Safety.** According to our review of NNSA's MARs, NNSA identifies 30 safety exceptions and no safety limitations across the nuclear stockpile. All U.S. nuclear weapons have design requirements that the probability of an unintended nuclear detonation must not exceed one in a billion in normal environments; one in a million in abnormal environments; and one in a million in the event of a one-point initiation of the weapon's high explosives.²² All weapons in the stockpile have a common safety exception for a specific combination of abnormal conditions. Other exceptions exist for an array of abnormal conditions that do not meet these probability standards or lack the technical basis to assert that standards are met.
- **Operational considerations.** According to our review of NNSA's MARs, NNSA identifies nine exceptions and 13 limitations affecting

²¹In appendix I, we discuss why the number of exceptions and limitations has changed since our February 2012 report (i.e., [GAO-12-188](#)). For example, in our February 2012 report, we wrote that NNSA had identified 52 limitations, and we assigned them to 10 categories. At that time, NNSA did not separately define an exception or limitation, instead reporting all instances in which weapons did not meet requirements as limitations, and did not categorize reported limitations. However, NNSA released a tool in August 2019 on separately reporting exceptions and limitations and included in the tool four categories of exceptions and limitations that laboratories are to use in their MARs: safety, reliability, performance, and operational considerations. This tool also specifies the minimum content necessary for each MAR, including requirements document citations; performance (yield); weapons' exceptions and limitations; and reasons for MAR issuance or reissuance. The joint Los Alamos-Sandia MARs use two categories to report limitations and exceptions in addition to the four included in the tool: limited-life component exchange intervals and aircraft compatibility.

²²An abnormal environment is one that is not expected to occur during nuclear explosive operations and associated activities. For example, an abnormal environment may be an exposed nuclear explosive package—due to maintenance or damage—that experiences extreme weather conditions, such as lightning.

operational considerations across the nuclear stockpile. Operational considerations exceptions and limitations indicate that weapon types do not meet the military characteristic requirements for specific stockpile-to-target sequence environments. Such exceptions and limitations may affect the circumstances in which a weapon may be used.

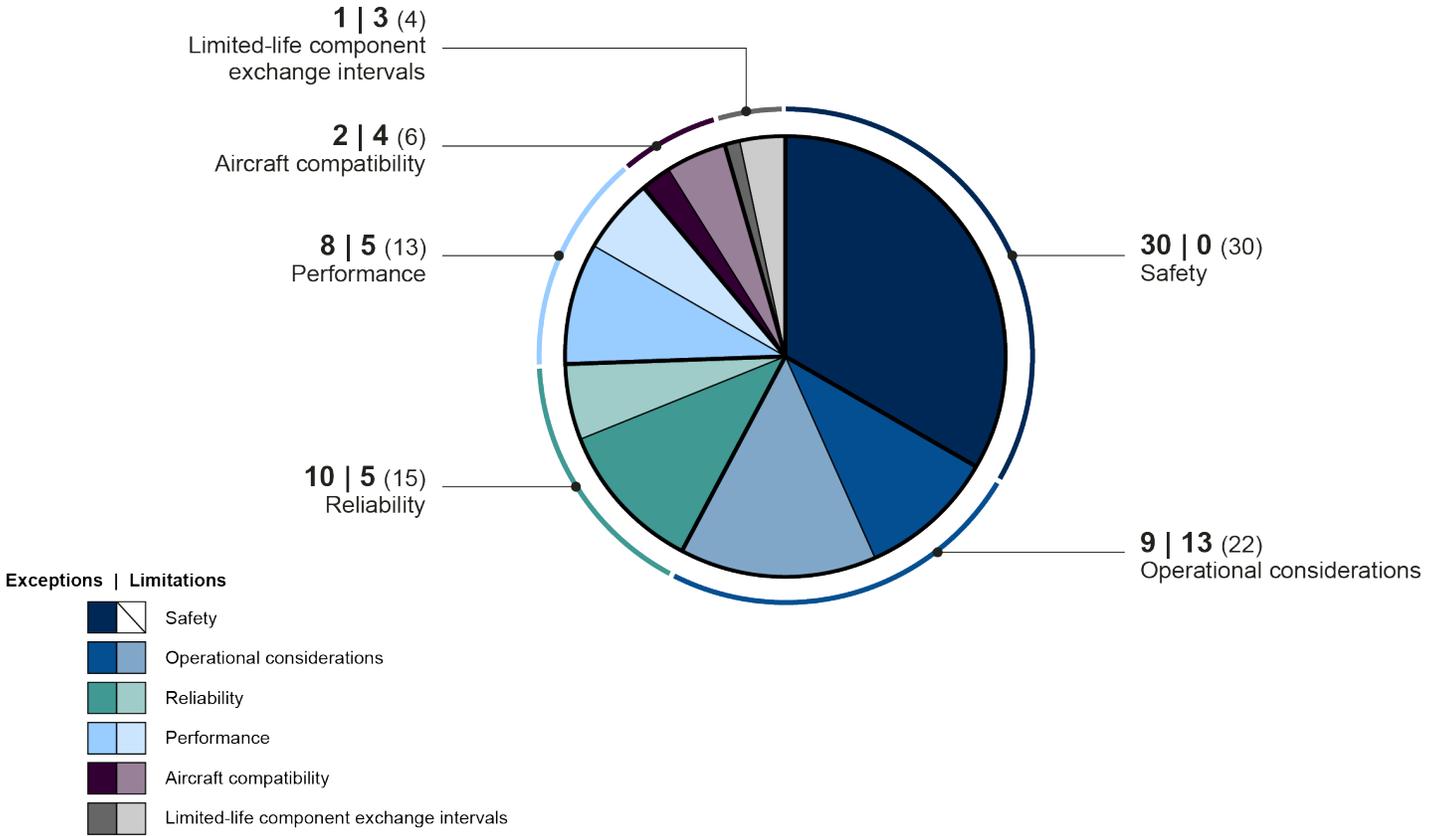
- **Reliability.** According to our review of NNSA's MARs, NNSA identifies 10 exceptions and five limitations affecting reliability across the nuclear stockpile. NNSA defines weapon reliability as the probability of achieving the specified yield, at the target, across the stockpile-to-target sequence of environments.²³ In some cases, reliability exceptions and limitations arise from NNSA's lack of information due to limited testing. Other reliability concerns exist for aging components.
- **Performance.** According to our review of NNSA's MARs, NNSA identifies eight exceptions and five limitations affecting performance across the nuclear stockpile. Performance exceptions indicate that a weapon's assessed yield does not meet defined military characteristics. In contrast, performance limitations refer to a weapon type not meeting yield requirements under certain circumstances or environments.
- **Aircraft compatibility.** According to our review of NNSA's MARs, NNSA identifies two exceptions and four limitations affecting aircraft compatibility across the nuclear stockpile. Aircraft compatibility exceptions and limitations generally indicate that NNSA does not have sufficient information on whether a weapon is compatible with its planned delivery vehicle. Compatibility includes maintaining weapon reliability through environments created by the aircraft.
- **Limited-life component exchange interval.** According to our review of NNSA's MARs, NNSA identifies one exception and three limitations affecting limited-life component exchange intervals across the nuclear stockpile. These indicate that limited-life components must be replaced more frequently than specified in a weapon type's military characteristics to achieve required performance.

NNSA and DOD officials told us that none of the identified exceptions or limitations rise to a level that would require a weapon to be removed from the stockpile. See figure 1 for additional details.

²³National Nuclear Security Administration, *Weapons Reliability Report* (Washington, D.C.: September 2021).

Figure 1: Number of Nuclear Weapon Exceptions and Limitations by Category, as of March 2023

Number of nuclear weapons exceptions | limitations by category (total)



Source: National Nuclear Security Administration. | GAO-23-105671

Data table for Figure 1: Number of Nuclear Weapon Exceptions and Limitations by Category, as of March 2023

Category	Exceptions	Limitations	Total
Safety	30	0	30
Operational considerations	9	13	22
Reliability	10	5	15
Performance	8	5	13
Aircraft compatibility	2	4	6
Limited-life component exchange intervals	1	3	4

Source: National Nuclear Security Administration. | GAO-23-105671

For details on the number of exceptions and limitations for each weapon type, see the separately reported classified annex to this report.²⁴

NNSA and DOD Plan to Address Some Exceptions and Limitations through Weapon Modernization Programs

Officials from NNSA and DOD told us that ongoing and planned modernization programs are expected to address some nuclear weapon exceptions and limitations; addressing as many exceptions and limitations as feasible is a primary focus of the programs. Laboratory representatives we interviewed said that they work with NNSA and DOD, through the project officers groups, to weigh the risks posed by exceptions and limitations against the design costs associated with addressing exceptions and limitations through modernization. Weighing the risks against costs helps NNSA and DOD to determine which exceptions and limitations can be feasibly addressed.

NNSA has addressed or plans to address some existing exceptions and limitations through modernization programs. For example:

- **W76.** Based on our analysis of NNSA's MARs, the recently completed W76-1 and W76-2 life extension programs have addressed some of the W76-0 exceptions. NNSA will continue to report W76-0 exceptions until the weapon is retired.
- **W87.** A minor alt—the Alt 360—is currently underway. NNSA officials told us that when they complete the program in fiscal year 2023, they expect to remove an exception from the MAR.²⁵
- **B61.** According to our analysis of NNSA's MARs, the B61-12 life extension program will address several existing safety, reliability, performance, and operational considerations exceptions and limitations for some of the legacy B61 versions. According to NNSA documentation, NNSA is scheduled to complete the B61-12 modernization program in fiscal year 2026. NNSA will continue to

²⁴GAO-23-106548C.

²⁵Generally, weapon alts are not considered modernization programs but can address exceptions or limitations. For example, according to NNSA officials, the W87 Alt 360 is not considered a modernization program but does address an exception. However, for reporting purposes, we are including this alt as a modernization program.

report all exceptions and limitations for B61 legacy versions until those versions are retired.

- **W88.** NNSA was able to avoid identifying an additional MAR exception for the W88 by expanding the scope of the W88's ongoing Alt 370 modernization program. According to NNSA documentation, NNSA is scheduled to complete the W88 modernization program in fiscal year 2026.
- **W80.** According to NNSA officials, the ongoing W80-4 life extension program is expected to address most, if not all, exceptions and limitations currently reported in the MAR for the W80-1 legacy weapon. According to NNSA documentation, NNSA is scheduled to complete the W80-4 modernization program in fiscal year 2031. NNSA will continue to report all exceptions and limitations for the W80-1 until it is retired.

For additional details on exceptions and limitations addressed through modernization, see the separately reported classified annex to this report.²⁶

Current Nuclear Weapons Exceptions and Limitations Do Not Constrain DOD

According to USSTRATCOM officials and project officers group members, remaining nuclear weapons exceptions and limitations—those not addressed or planned to be addressed through modernization—do not constrain DOD's ability to store, maintain, or operate nuclear weapons. For example, DOD has developed mitigation strategies to reduce risks associated with exceptions and limitations. In other cases, DOD has accepted some exceptions or limitations because they concern scenarios with a low probability of occurrence and would, thus, not merit the design costs of a full modernization effort. USSTRATCOM officials also stated that the current nuclear stockpile's flexibility and diversity has, to date, enabled DOD to develop operational plans that consider some exceptions and limitations. Though the stockpile's future flexibility and diversity may change, officials reported that they are highly confident that their current operational plans meet DOD's objectives.

²⁶GAO-23-106548C.

Mitigation. NNSA and DOD have developed procedural and other mitigation strategies to address some identified exceptions and limitations. Specifically:

- **Maintenance safety protocols.** Project officers group members stated that DOD has developed worker safety protocols—including training, logistical considerations, and missile engineering systems—to help mitigate exceptions that could result in an unintended detonation.²⁷ The mitigations include measures to protect weapons from external forces, such as electrical charges, and protocols for safe handling during routine weapon maintenance. In addition, according to the USSTRATCOM Commander’s fiscal year 2021 weapons assessment report, DOD has developed procedures to help ensure that weapons remain inoperable during accidents.

Secure storage and transport. Air Force project officers group members stated that the Air Force has made some adjustments to weapon storage procedures and configurations on bombers or in launch silos to address safety exceptions. NNSA also developed a specialized adaptor that enables NNSA to transport some weapons in a manner consistent with their safety requirements. In addition, according to the USSTRATCOM Commander’s fiscal year 2021 weapons assessment report, DOD has developed administrative controls to reduce safety risks during handling and transport.

- **Joint testing.** According to NNSA and DOD officials, they conduct joint testing to identify and address uncertainties with regard to weapon behavior in certain environments and delivery modes.
- **Flexible operational plans.** According to USSTRATCOM officials, DOD maintains a robust, flexible operational plan that mitigates weapon exceptions and limitations through advanced analysis capabilities and maintaining an adaptable array of logistical and targeting options that take weapon exceptions and limitations into account.²⁸ Officials reported that the current and projected stockpile enables DOD to develop such flexible operational plans, which enable different systems to support the others in the event of exceptions,

²⁷NNSA and DOD officials told us that safety exceptions were their primary concern. According to our analysis, safety exceptions account for about half of all exceptions and one-third of exceptions and limitations combined.

²⁸We have a separate and ongoing review of nuclear weapons capabilities, force structure requirements, and targeting in response to a provision of the National Defense Authorization Act for Fiscal Year 2022.

limitations, or other problems. Officials stated that they are confident that their operational plans can meet DOD's objectives. In September 2022, officials also said that flexibility may continue to decline because of further stockpile aging. This statement aligns with findings in our February 2012 report, in which we wrote that DOD officials stated that the then-extant stockpile was sufficiently large and flexible to mitigate limitations but that there may be less flexibility in the future as the stockpile ages.²⁹

Acceptance. According to the USSTRATCOM Commander's fiscal year 2021 weapons assessment report, DOD has accepted several exceptions and limitations because they concern scenarios with a low probability of occurrence. USSTRATCOM officials said that they accepted such exceptions or limitations after evaluating both the likelihood and the consequences of these low-probability scenarios. For example, DOD has accepted the risk associated with the common safety exception noted above because of the low probability that those conditions will occur simultaneously.³⁰ NNSA and project officers group members we interviewed also discussed exceptions related to weapons' behavior under other abnormal conditions, such as extreme weather environments. According to the USSTRATCOM Commander's report and USSTRATCOM officials, they have accepted the risk of these low-probability events.

According to the 2022 Nuclear Posture Review, the increasing need for a diverse and flexible nuclear deterrent is one of the primary reasons why sustaining and modernizing the current stockpile is necessary. DOD officials we interviewed for this report said that the future, modernized stockpile may need to be more diverse in terms of warheads, bombs, and delivery systems. Such diversity would provide redundancy in the event

²⁹[GAO-12-188](#).

³⁰As previously stated, the probability of an unintended nuclear detonation must not exceed one in a million under abnormal conditions. In the context of discussing DOD's decision to accept the risk associated with the common safety exception noted above, project officers group officials stated that NNSA's modeling probability represents the likelihood of detonation when certain abnormal conditions are already present but that NNSA does not factor in the likelihood that such conditions occur in the first place, making the likelihood of occurrence even lower.

an exception or limitation required a weapon to be removed from the stockpile.³¹

For additional information on DOD's efforts to mitigate weapons exceptions and limitations, see the separately reported classified annex to this report.³²

Agency Comments

We provided a draft of this report to DOD and NNSA for review and comment. DOD and NNSA provided technical comments, which we incorporated as appropriate.

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

If you or your staff members have any questions about this report, please contact Allison B. Bawden at (202) 512-3841 or bawdena@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 significant contributions to the report are listed in appendix II.



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Director, Natural Resources and Environment

³¹We previously reported on stockpile and delivery platform modernization in May 2021. See GAO, *Nuclear Triad: DOD and DOE Face Challenges Mitigating Risks to U.S. Deterrence Efforts*, [GAO-21-210](#) (Washington, D.C.: May 6, 2021).

³²GAO-23-106548C.

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Appendix I: Crosswalk between Exception and Limitation Categories Reported by the NNSA in 2023 and Limitation Categories Reported by GAO in 2012

In our 2012 report, we identified 10 limitation categories; however, the National Nuclear Security Administration (NNSA) has since changed the way it reports exceptions and limitations. Specifically, NNSA has released a tool describing the format and contents that laboratories should use in each major assembly release (MAR). This tool provides for separately reporting exceptions and limitations and includes the categories that laboratories should use.¹

Our review of MARs found that the joint Lawrence Livermore National Laboratory (Livermore)-Sandia National Laboratories (Sandia) and the joint Los Alamos National Laboratory (Los Alamos)-Sandia MARs have distinct reporting structures. The joint Los Alamos-Sandia MARs report exceptions and limitations separately, divide them among the categories listed in the tool, and include additional categories not listed, depending on the weapon. The joint Livermore-Sandia MARs, on the other hand, do not separate exceptions and limitations and do not report on specific categories. This information is included in the joint Livermore-Sandia MARs, but the document is not structured around these categories.²

¹NNSA released a tool in August 2019 on separately reporting exceptions and limitations and included in the tool four categories of exceptions and limitations that laboratories are to use in their MARs: safety, reliability, performance, and operational considerations. This tool also specifies the minimum content necessary for each MAR, including requirements document citations; performance (yield); weapons' exceptions and limitations; and reasons for MAR issuance or reissuance. The joint MARs produced by Los Alamos and Sandia National Laboratories use two categories to report limitations and exceptions in addition to the four included in the tool: limited-life component exchange intervals and aircraft compatibility.

²We conducted a content analysis to identify and categorize Livermore's exceptions and limitations.

Appendix I: Crosswalk between Exception and Limitation Categories Reported by the NNSA in 2023 and Limitation Categories Reported by GAO in 2012

According to NNSA and Department of Defense (DOD) officials we interviewed, the differences in reporting format did not affect their ability to understand each weapon’s exceptions and limitations.

Table 3: Crosswalk between 2023 NNSA Reported Exceptions and Limitations Categories and 2012 GAO Reported Limitation Categories

NNSA 2023 categories (count)	GAO 2012 categories (count)
Safety (30)	Detonation safety under abnormal conditions (13) Worker safety (6) Transportation (2)
Reliability (15)	Weapon reliability (7) Reliability of use control system components (1)
Performance (13)	Nuclear yield (6)
Operational considerations (22)	Weapon delivery (6) Weight (3) Weapons testing unable to duplicate stockpile-to-target sequence environments (2)
Limited-life component exchange intervals (4)	More frequent replacement of limited-life components (6)
Aircraft compatibility (6)	N/A

Source: National Nuclear Security Administration (NNSA). | GAO-23-105671

According to our analysis and NNSA officials, the total number of exceptions and limitations can change over time. Since our 2012 report, the total number of exceptions and limitations has increased from 52 to 89. NNSA officials told us that the number of exceptions and limitations can change for a variety of reasons, including changes to military characteristic requirements; issuance, revision or cancellations of MARs as modernized weapons enter the stockpile or legacy weapons are retired; and advances in testing and surveillance. For example, according to our review of the current MARs, some military characteristics requirements have changed, resulting in the removal of some exceptions and limitations.

In addition, NNSA has issued new MARs for modernized weapons, which can contain exceptions and limitations carried over from the legacy weapons from which they originated. As a result, certain exceptions and limitations may occur across multiple MARs until the legacy weapon is

Appendix I: Crosswalk between Exception and Limitation Categories Reported by the NNSA in 2023 and Limitation Categories Reported by GAO in 2012

retired and its MAR is cancelled.³ For example, while NNSA has issued new MARs for both the W76-1 and W76-2, the legacy W76-0 remains deployed, and its MAR is still active. Further changes in the count of exceptions and limitations are expected in the future, once the W76-0 is retired from the stockpile and the associated MAR is cancelled.

According to NNSA officials, the number of exceptions and limitations can also change as a result of better testing and surveillance. Officials noted, in such cases, that the exceptions and limitations are often not new, but rather newly identified. That is, conditions that lead to exceptions and limitations may have existed when the weapon was first designed and built but may have only been recently identified through more advanced surveillance and modeling.

According to officials, identifying new exceptions or limitations allows NNSA and DOD to better understand the capabilities of the weapons in the stockpile. NNSA officials said that the stockpile is improving because of NNSA's ongoing modernization efforts. Officials also noted that the exceptions and limitations that were included in our 2012 report and remain in effect today have not materially changed in the intervening years.

³Legacy weapon systems remain in the active stockpile after the laboratory issues a MAR for the modernized weapon to allow for the completion of the modernization program and other logistical considerations. As a result, there may be duplicate exceptions and limitations among the legacy and modernized weapons. Once a legacy weapon is retired from the active stockpile, its MAR is cancelled.

Appendix II: GAO Contacts and Staff Acknowledgments

GAO Contacts

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Staff Acknowledgments

In addition to the contact named above, Jonathan Gill (Assistant Director), John Hocker (Analyst in Charge), David Wishard, David Adams, Antoinette Capaccio, Pamela Davidson, Penney Harwell Caramia, Joseph Kirschbaum, Cynthia Norris, and Sara Sullivan made key contributions to this report.

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