U.S. Nuclear Weapons Capability

Assessing the state of U.S. nuclear weapons capabilities presents several challenges.

First, instead of taking advantage of technological developments to field new warheads that could be designed to be safer and more secure and could give the United States improved options for guaranteeing a credible deterrent, the U.S. has elected to maintain (extend the service life of) nuclear warheads—based on designs from the 1960s, 1970s, and 1980s—that were in the stockpile when the Cold War ended.

Second, the lack of detailed publicly available data about the readiness of nuclear forces, their capabilities, and weapon reliability makes analysis difficult.

Third, the U.S. nuclear enterprise has many components, some of which are also involved in supporting conventional missions. For example, dual-capable bombers do not fly airborne alert with nuclear weapons today, although they did so routinely during the 1960s (and are capable of doing so again should the decision ever be made to resume this practice). Additionally, the national security laboratories do not focus solely on the nuclear weapons mission; as they did during the Cold War, they also perform a variety of functions related to nuclear nonproliferation, medical research, threat reduction, and countering nuclear terrorism, including nuclear detection. The National Command and Control System performs nuclear command and control in addition to supporting ongoing conventional operations.

Thus, assessing the extent to which any one piece of the nuclear enterprise is sufficiently funded, focused, and effective with regard to the nuclear mission is problematic.

In today's rapidly changing world, the U.S. nuclear weapons enterprise must be flexible and resilient to underpin the U.S. nuclear deterrent. If the U.S. detects a game-changing nuclear weapons development in another country or experiences a technical problem with a warhead or delivery system, its nuclear weapons complex must be able to provide a timely response.

The U.S. maintains an inactive stockpile that includes near-term hedge warheads that can be put back into operational status within six to 24 months; extended hedge warheads are said to be ready within 24 to 60 months.[1] The U.S. also preserves significant upload capability on its strategic delivery vehicles so that the nation can increase the number of nuclear warheads on each type of its delivery vehicles if contingencies warrant. For example, the U.S. Minuteman III intercontinental ballistic missile (ICBM) can carry up to three nuclear warheads, although it is currently deployed with only one.[2]

Presidential Decision Directive-15 (PDD-15) requires that the U.S. maintain the ability to conduct a nuclear test within 24 to 36 months of a presidential decision to do so.[3] However, successive government reports have noted the continued deterioration of technical and diagnostics equipment and the inability to fill technical positions that support nuclear testing readiness.[4] A lack of congressional support for improving technical readiness further undermines efforts by the National Nuclear Security Administration (NNSA) to comply with the directive.

The weapons labs face demographic challenges of their own. Most scientists and

engineers with practical nuclear weapon design and testing experience are retired. This means that for the first time since the dawn of the nuclear age, the U.S. will have to rely on the scientific judgment of people who were not directly involved in underground nuclear explosive tests of weapons that they designed, developed, and are certifying.

The shift of focus away from the nuclear mission after the end of the Cold War caused the NNSA laboratories to lose their sense of purpose and to feel compelled to reorient and broaden their mission focus. According to a number of studies, their relationship with the government also evolved in ways that reduce output and increase costs.

Both the lack of resources and the lack of sound, consistent policy guidance have undermined workforce morale. The Congressional Advisory Panel on the Governance of the Nuclear Security Enterprise recommended fundamental changes in the nuclear weapons enterprise's culture, business practices, project management, and organization. Others proposed moving the NNSA to the Department of Defense.[5]

Another important indication of the health of the overall force is the readiness of forces that operate U.S. nuclear systems. In 2006, the Air Force mistakenly shipped non-nuclear warhead components to Taiwan.[6] A year later, it transported nuclear-armed cruise missiles across the U.S. without authorization (or apparently even awareness that it was doing so, mistaking them for conventional cruise missiles).[7] These serious incidents led to the establishment of a Task Force on DOD Nuclear Weapons Management, which found that "there has been an unambiguous, dramatic, and unacceptable decline in the Air Force's commitment to perform the nuclear mission"; that "until very recently, little has been done to reverse it"; and that "the readiness of forces assigned the nuclear mission has seriously eroded."[8]

Following these incidents, the Air Force instituted broad changes to improve oversight and management of the nuclear mission and the inventory of nuclear weapons, including creating the Air Force Global Strike Command to organize, train, and equip intercontinental-range ballistic missile and nuclear-capable bomber crews as well as other personnel to fulfill the nuclear mission and implement a stringent inspection regime. Then, in January 2014, the Air Force discovered widespread cheating on nuclear proficiency exams and charged over 100 officers with misconduct. The Navy had a similar problem, albeit on a smaller scale.[9]

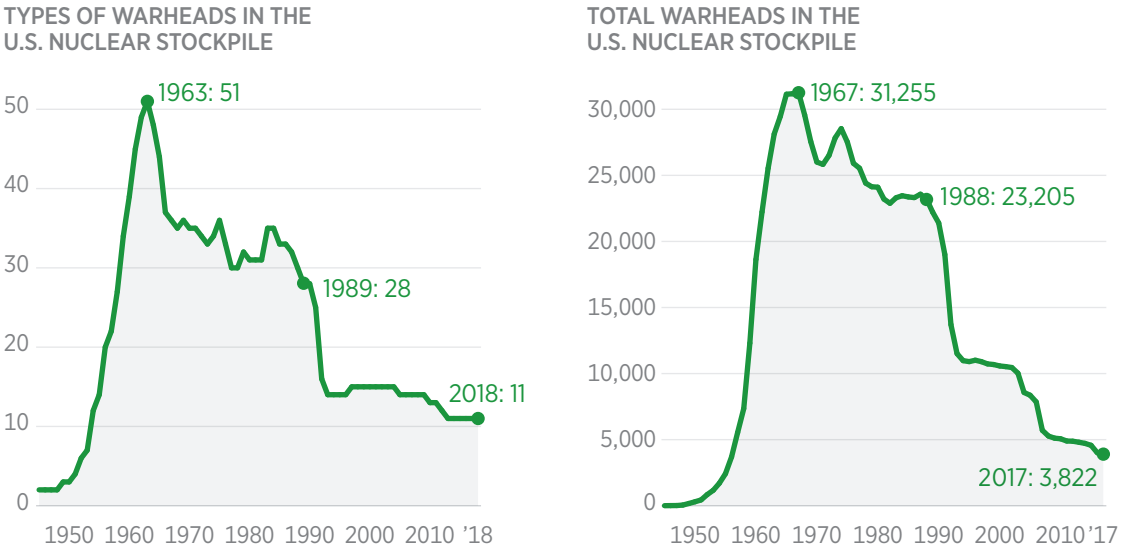
The Department of Defense conducted two nuclear enterprise reviews, one internal and one external. Both reviews identified a lack of leadership attention, a lack of resources to modernize the atrophied infrastructure, and unduly burdensome implementation of the personnel reliability program as some of the core challenges preventing a sole focus on accomplishing the nuclear mission.[10] The Navy and Air Force took steps to address these concerns, but if changes in the nuclear enterprise are to be effective, leaders across the executive and legislative branches will have to continue to provide sufficient resources to mitigate readiness and morale issues within the force.

Fiscal uncertainty and a steady decline in resources for the nuclear weapons enterprise (trends that have begun to reverse in recent years) have negatively affected the nuclear deterrence mission. Under Secretary of Defense for Policy John Rood testified in March 2018 that:

> The U.S. military remains the strongest in the world. However, our advantages are eroding as potential adversaries modernize and build up their conventional and nuclear forces. They now field a broad arsenal of advanced missiles, including variants that can reach the American homeland....
>
> While this picture is unsettling and clearly not what we desire, as Secretary of Defense [James] Mattis has pointed out, "We must look reality in the eye and see the world as it is, not as we wish it to be."[11]

CHART 15

A Smaller and Less Diverse Nuclear Arsenal



SOURCES: Robert S. Norris and Hans M. Kristensen, "U.S. Nuclear Warheads, 1945–2009," *Bulletin of the Atomic Scientists,* 2009, https://www.tandfonline.com/doi/full/10.2968/065004008 (accessed April 20, 2018); U.S. Department of Energy, "Stockpile Stewardship and Management Plan," *Report to Congress*, November 2017, https://www.energy.gov/sites/prod/files/2017/11/f46/fy18ssmp_final_november_ 2017%5B1%5D_0.pdf (accessed April 23, 2018; U.S. Department of Energy, "Restricted Data Declassification Decisions, 1946 to the Present," https://fas.org/sgp/library/rdd-5.html (accessed April 23, 2018); and U.S. Department of Defense, "Stockpile Numbers," http://open.defense.gov/Portals/23/Documents/frddwg/2017_Tables_UNCLASS.pdf (accessed April 23, 2018).

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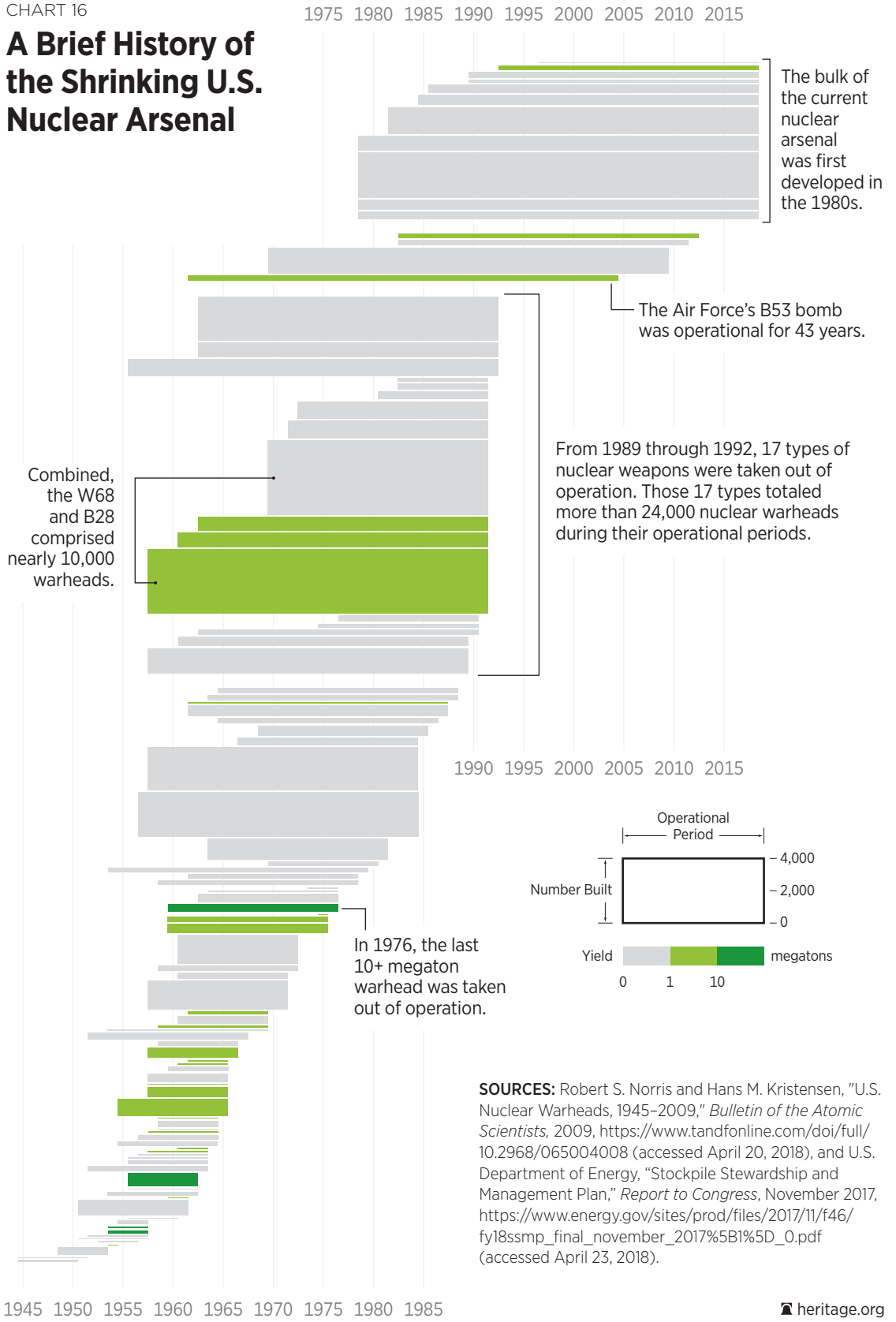
The Trump Administration has inherited a comprehensive modernization program for nuclear forces: warheads, delivery systems, and command and control. The Obama Administration included this program in its budget requests, and Congress to a significant extent has funded it. Because such modernization activities require long-term funding commitments, it is important that this commitment continue.

The Trump Administration's reassessment of the U.S. nuclear force posture has included correcting some of the more questionable elements of the 2010 Nuclear Posture Review (NPR). Most specifically, the 2018 NPR recognizes that Russia's aggressive international policies and both Russia's and China's robust nuclear weapon modernization programs should inform the U.S. nuclear posture.[12] The 2018 NPR calls for tailoring U.S. nuclear deterrence strategies and restores deterring a large-scale attack against the U.S. homeland and its allies as the first priority of U.S. nuclear weapons policy. To that end, the 2018 NPR supports modernization of nuclear weapons and the nuclear weapons complex, as well as the sustainment of a nuclear triad, and proposes two low-yield options: a submarine-launched low-yield warhead in the short term and a nuclear-armed sea-launched cruise missile in the long term.

It is not clear how the additional workload created by these capabilities will affect the NNSA complex. Despite these departures from the 2010 NPR, however, the 2018 NPR is "clearly in the mainstream of U.S. nuclear policy as it has evolved through nearly eight decades of the nuclear age."[13]

CHART 16

A Brief History of the Shrinking U.S. Nuclear Arsenal



SOURCES: Robert S. Norris and Hans M. Kristensen, "U.S. Nuclear Warheads, 1945–2009," *Bulletin of the Atomic Scientists,* 2009, https://www.tandfonline.com/doi/full/10.2968/065004008 (accessed April 20, 2018), and U.S. Department of Energy, "Stockpile Stewardship and Management Plan," *Report to Congress*, November 2017, https://www.energy.gov/sites/prod/files/2017/11/f46/fy18ssmp_final_november_2017%5B1%5D_0.pdf (accessed April 23, 2018).

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Implications for U.S. National Security

U.S. nuclear forces and U.S. military forces in general are not designed to shield the nation from all types of attacks from all adversaries. They are designed to deter large-scale conventional and nuclear attacks that threaten America's sovereignty, forward-deployed troops, and allies.

U.S. nuclear forces play an important role in the global nonproliferation regime by providing U.S. security guarantees and assurances to NATO, Japan, and South Korea that lead these allies either to keep the number of their nuclear weapons lower than might otherwise be the case (France and the United Kingdom) or to forgo their development and deployment altogether. North Korea has proven that a country with very limited intellectual and financial resources can develop a nuclear weapon if it decides to do so. Iran continues on the path to obtaining a nuclear weapon.

This makes U.S. nuclear guarantees and assurances to allies and partners ever more important. Should the credibility of American nuclear forces continue to degrade, countries like South Korea could pursue an independent nuclear option, which would raise several thorny issues including possible additional instability across the region.

Certain negative trends could undermine U.S. nuclear deterrence if problems are not addressed. There is no shortage of challenges on the horizon, from an aging nuclear weapons infrastructure and unchallenged workforce to the need to recapitalize all three legs (land, air, and sea) of the nuclear triad, and from the need to conduct life-extension programs while maintaining a self-imposed nuclear weapons test moratorium to limiting the spread of nuclear know-how and the means to deliver nuclear weapons. Additionally, the United States must take account of adversaries that are modernizing their nuclear forces, particularly Russia and China.

The 2018 NPR observes that the global strategic security environment has become increasingly dangerous. Russia is now engaged in an aggressive nuclear buildup. Concurrently, Moscow is using its capabilities to threaten the sovereignty of U.S. allies in Eastern Europe and the Baltics. China is engaging in a similar nuclear buildup as it projects power into the South China Sea. North Korea and Iran have taken an aggressive posture toward the West as they attempt to shift from being nuclear proliferators to being nuclear-armed states.

Deterrence is an intricate interaction between U.S. conventional and nuclear forces and the psychology of both allies and adversaries that the U.S. uses these forces to defend the interests of the U.S. and its allies. Nuclear deterrence must reflect the mindset of the adversary the U.S. seeks to deter. If an adversary believes that he can fight and win a limited nuclear war, the task for U.S. leaders is to convince that adversary otherwise even if U.S. leaders think it is not possible to control escalation. The U.S. nuclear portfolio must be structured in terms of capacity, capability, variety, flexibility, and readiness to achieve this objective. In addition, military requirements and specifications for nuclear weapons will be different depending on who is being deterred, what he values, and what the U.S. seeks to deter him from doing.

Due to the complex interplay among strategy, policy, actions that states take in international relations, and other actors' perceptions of the world around them, one might never know precisely if and when a nuclear or conventional deterrent provided by U.S. forces loses credibility. Nuclear weapons capabilities take years or decades to develop, as does the infrastructure supporting them—an infrastructure that the U.S. has neglected for decades. We can be reasonably certain that a robust, well-resourced, focused, and modern nuclear enterprise is more likely to sustain its deterrent value than is an outdated one with questionable capabilities.

The U.S. is capable of incredible mobilization when danger materializes. The nuclear threat environment is dynamic and proliferating, with old and new actors developing advanced capabilities while the U.S. enterprise is relatively static, potentially leaving the United

States at a technological disadvantage. This is worrisome because of its implications both for the security of the United States and for the security of its allies and the free world.

Scoring U.S. Nuclear Weapons Capabilities

The U.S. nuclear weapons enterprise is composed of several key elements that include warheads; delivery systems; nuclear command and control; intelligence, surveillance, and reconnaissance; aerial refueling; and the research and development and manufacturing infrastructure that designs, manufactures, and maintains U.S. nuclear weapons. The complex also includes the experienced people, from physicists to engineers, maintainers, and operators, without whom the continuous maintenance of the nuclear infrastructure would not be possible.

The factors selected below are the most important elements of the nuclear weapons complex. They are judged on a five-grade scale, where "very strong" means that a sustainable, viable, and funded plan is in place and "very weak" means that the U.S. is not meeting its security requirements and has no program in place to redress the shortfall, which is very likely to damage vital national interests if the situation is not corrected.

Current U.S. Nuclear Stockpile Score: Strong

U.S. warheads must be safe, secure, effective, and reliable. The Department of Energy (DOE) defines reliability as "the ability of the weapon to perform its intended function at the intended time under environments considered to be normal" and as "the probability of achieving the specified yield, at the target, across the Stockpile-To-Target Sequence of environments, throughout the weapon's lifetime, assuming proper inputs."[14] Since 1993, reliability has been determined through an intensive warhead surveillance program; non-nuclear experiments (that is, without the use of experiments producing nuclear explosive yield); sophisticated calculations using high-performance computing; and related evaluations.

The reliability of nuclear warheads and delivery systems becomes more important as the number and diversity of nuclear weapons in the stockpile decrease, because fewer types of nuclear weapons means a greater risk of a "common mode failure" that could affect one or more of the remaining warhead types, coupled with the absence of sufficient hedge warheads to replace operational warheads until they can be repaired. Americans, allies, and adversaries must be confident that U.S. nuclear warheads will perform as expected.[15]

As warheads age, aging components must be replaced before they begin to degrade warhead reliability. Otherwise, military planning and employment of these warheads become much more complex. Despite creating impressive amounts of knowledge about nuclear weapons physics and materials chemistry, the long-term effect of aging components that comprise a nuclear weapon, including plutonium pits, is uncertain. As General Kevin Chilton (Ret.), former Commander, U.S. Strategic Command, has stated, "We cannot life extend these [nuclear weapons] forever.... [W]e better know how to do it when we get there...and the only way to be assured of that is to exercise that muscle in the near term."[16]

The United States has the world's safest and most secure stockpile, but security of long-term domestic and overseas storage sites, potential problems introduced by improper handling, or unanticipated effects stemming from long-term handling could compromise the integrity of U.S. warheads. The nuclear warheads themselves contain security measures that are designed to make it difficult, if not impossible, to detonate a weapon absent a proper authorization.

Grade: The Department of Energy and Department of Defense are required to assess the reliability of the nuclear stockpile annually.

This assessment does not include delivery systems, although the U.S. Strategic Command assesses overall weapons system reliability, which includes both the warhead and delivery platforms.

Absent nuclear weapons testing, the assessment of weapons reliability becomes more subjective over time, albeit based on experience, non-nuclear experiments, and simulations. While certainly an educated opinion, some argue that it is not a substitute for the type of objective data that is obtained through nuclear testing. Testing was used to diagnose potential problems and to certify the effectiveness of fixes to those problems. A continuous cycle of replacement of aging components with modern versions will inevitably introduce changes that take weapons away from the designs that were tested in the 1960s through 1980s. This risk must be weighed against the downside risks entailed in a U.S. resumption of nuclear testing.

"[I]n the past," according to the late Major General Robert Smolen, some of the nuclear weapon problems that the U.S. now faces "would have [been] resolved with nuclear tests."[17] By 2005, a consensus emerged in the NNSA, informed by the nuclear weapons labs, that it would "be increasingly difficult and risky to attempt to replicate exactly existing warheads without nuclear testing and that creating a reliable replacement warhead should be explored."[18] When the U.S. did conduct nuclear tests, it frequently found that small changes in a weapon's tested configuration had a dramatic impact on weapons performance. In fact, the 1958–1961 testing moratorium resulted in weapons with serious problems being introduced into the U.S. stockpile.[19]

In fiscal year (FY) 2018, the NNSA nuclear weapons lab directors and the Commander of U.S. Strategic Command, advised by his Strategic Advisory Group, assessed that the stockpile "remains safe, secure, and reliable."[20]

The lack of nuclear weapons testing creates some uncertainty concerning the adequacy of fixes to the stockpile when problems are found. This includes updates that are made in order to correct problems found in the weapons or changes in the weapons resulting from life-extension programs. It is simply impossible to duplicate exactly weapons that were designed and built many decades ago. According to former Defense Threat Reduction Agency Director Dr. Stephen Younger, we have had to fix "a number of problems that were never anticipated" by using "similar but not quite identical parts."[21] Political decisions made by successive Administrations have resulted in fewer types of weapons and, consequently, the potential for a greater impact across the inventory if an error is found during the certification process.

"To be blunt," warned Secretary of Defense Robert Gates in October 2008, "there is absolutely no way we can maintain a credible deterrent and reduce the number of weapons in our stockpile without either resorting to testing our stockpile or pursuing a modernization program."[22] The U.S. is pursuing warhead life-extension programs that replace aging components before they can cause reliability problems, but the national commitment to this modernization program, including the necessary long-term funding, continues to be uncertain.

In light of our overall assessment, we grade the U.S. stockpile as "strong." We are concerned that this rating may be revised downward in future years if the nation lags further in providing challenging nuclear weapons design and development opportunities as means to hone the skills of a next generation of weapons scientists and engineers.

Reliability of U.S. Delivery Platforms Score: Marginal

Reliability encompasses not only the warhead, but strategic delivery vehicles as well. In addition to a successful missile launch, this includes the separation of missile boost stages, performance of the missile guidance system, separation of the multiple re-entry vehicle warheads from the missile post-boost vehicle, and accuracy of the final re-entry vehicle in reaching its target.[23]

The U.S. tries to conduct flight tests of ICBMs and submarine-launched ballistic missiles (SLBMs) every year to ensure the

reliability of its systems. Anything from electrical wiring to faulty booster separations could degrade the efficiency and safety of the U.S. strategic deterrent if it were to malfunction. U.S. strategic, long-range bombers regularly conduct intercontinental training and receive upgrades in order to sustain a high level of combat readiness, but potential challenges are on the horizon.

Grade: There was one U.S. ICBM test during the time period covered, and that test was successful. However, another test scheduled for February 2018 was cancelled with no explanation.[24] The ICBM test force has also been struggling with test kit supply. SLBM tests were successful in 2017 and 2018. To the extent that data from these tests are publicly available, they provide objective evidence of the delivery systems' reliability and send a message to U.S. adversaries that the system works. The aged systems, however, occasionally have reliability problems.[25] Overall, this factor earns a grade of "marginal," which is lower than the previous year's score, because of emerging problems with the ICBM test program and a lower number of overall launches. Additional future concerns stem from advanced networked air defense systems and their potential to increase risk to manned bombers.

Nuclear Warhead Modernization Score: Weak

During the Cold War, the United States maintained a strong focus on designing and developing new nuclear warhead designs in order to counter Soviet advances and modernization efforts and to leverage advances in understanding the physics, chemistry, and design of nuclear weapons. Today, the United States is focused on sustaining the existing stockpile, not on developing new warheads, even though all of its nuclear-armed adversaries are developing new nuclear warheads and capabilities and accruing new knowledge in areas in which the U.S. used to lead.

Since the collapse of the Soviet Union, nuclear warheads and delivery vehicles have not been replaced despite being well beyond their designed service lives. This could increase the risk of failure due to aging components and signal to adversaries that the United States is less committed to nuclear deterrence.

New warhead designs could allow American engineers and scientists to improve previous designs and devise more effective means to address existing military requirements (for example, the need to destroy deeply buried and hardened targets) that have emerged in recent years. New warheads could also enhance the safety and security of American weapons.

An ability to work on new warhead designs would also help American experts to remain engaged and knowledgeable, would help to attract the best talent to the nuclear enterprise and retain that talent, and could help the nation to gain additional insights into foreign nations' nuclear weapon programs. As the Panel to Assess the Reliability, Safety, and Security of the United States Nuclear Stockpile noted, "Only through work on advanced designs will it be possible to train the next generation of weapon designers and producers. Such efforts are also needed to exercise the DoD/NNSA weapon development interface."[26]

Other nations maintain their levels of proficiency by having their scientists work on new nuclear warheads and possibly by conducting very low-yield nuclear weapons tests. At the urging of Congress, the NNSA is increasing its focus on programs to exercise skills that are needed to develop and potentially build new nuclear warheads through the Stockpile Responsiveness Program. These efforts ought to be expanded and sustained in the future.

Grade: The lack of plans to modernize nuclear warheads—life-extension programs are not modernization—and restrictions on thinking about new weapon designs that might accomplish the deterrence mission in the 21st century more effectively earn nuclear warhead modernization a grade of "weak."

Nuclear Delivery Systems Modernization Score: Strong

Today, the United States fields a triad of nuclear forces with delivery systems that are

safe and reliable, but as these systems age, there is increased risk of a significantly negative impact on operational capabilities. The older weapons are, the more at risk they are that faulty components, malfunctioning equipment, or technological developments will limit their reliability in the operating environment. Age can degrade reliability by increasing the potential for systems to break down or fail to respond correctly. Corrupted systems, defective electronics, or performance degradation due to long-term storage defects (including for nuclear warheads) can have serious implications for American deterrence and assurance. If it cannot be assumed that a strategic delivery vehicle will operate reliably at all times, that vehicle's deterrence and assurance value is significantly reduced.

The U.S. Air Force and Navy plan to modernize or replace each leg of the nuclear triad in the next several decades, but fiscal constraints are likely to make such efforts difficult. The Navy is fully funding its programs to replace the *Ohio*-class submarine with the *Columbia*-class submarine and to extend the life of and eventually replace the Trident SLBM. Existing ICBMs and SLBMs are expected to remain in service until 2032 and 2042, respectively, and new bombers are not planned to enter into service until 2023 at the earliest. Budgetary shortfalls are leading to uncertainty as to whether the nation will be able to modernize all three legs of the nuclear triad. The U.S. Strategic Command says that a triad is a "requirement."[27] This requirement, validated by all U.S. NPRs since the end of the Cold War, gives U.S. leadership credibility and flexibility, attributes that are necessary for any future deterrence scenarios.

Maintenance issues caused by the aging of American SSBNs and long-range bombers could make it difficult to deploy units overseas for long periods or remain stealthy in enemy hot spots. At present, the United States can send only a limited number of bombers on missions at any one time. Remanufacturing some weapon parts is difficult and expensive either because some of the manufacturers are no longer in business or because the materials that constituted the original weapons are no longer available (for example, due to environmental restrictions). The ability of the U.S. to produce solid-fuel rocket engines and continued U.S. dependence on Russia as a source of such engines are other long-range concerns.[28]

Grade: U.S. nuclear platforms are in dire need of recapitalization. Plans for modernization of the U.S. nuclear triad are in place, and funding for these programs has been sustained so far by Congress and by the services, notwithstanding difficulties caused by sequestration. This demonstration of commitment to nuclear weapons modernization earns this indicator a grade of "strong."

Nuclear Weapons Complex Score: Weak

Maintaining a reliable and effective nuclear stockpile depends in large part on the facilities where U.S. devices and components are developed, tested, and produced. These facilities constitute the foundation of our strategic arsenal and include the:

- Los Alamos National Laboratories,
- Lawrence Livermore National Laboratory,
- Sandia National Laboratory,
- Nevada National Security Site,
- Pantex Plant,
- Kansas City Plant,
- Savannah River Site, and
- Y-12 National Security Complex.

In addition to these government sites, the defense industrial base supports the development and maintenance of American delivery platforms.

These complexes design, develop, test, and produce the weapons in the U.S. nuclear arsenal, and their maintenance is of critical importance. As the 2018 NPR states:

> An effective, responsive, and resilient nuclear weapons infrastructure is essential to the U.S. capacity to adapt flexibly to shifting requirements. Such an infrastructure offers tangible evidence to both allies and potential adversaries of U.S. nuclear weapons capabilities and thus contributes to deterrence, assurance, and hedging against adverse developments. It also discourages adversary interest in arms competition.[29]

A flexible and resilient infrastructure is an essential hedge in the event that components fail or the U.S. is surprised by the nuclear weapon capabilities of potential adversaries. U.S. research and development efforts and the industrial base that supports modernization of delivery systems and warheads are important parts of this indicator.

Maintaining a safe, secure, effective, and reliable nuclear stockpile requires modern facilities, technical expertise, and tools both to repair any malfunctions quickly, safely, and securely and to produce new nuclear weapons if required. The existing nuclear weapons complex, however, is not fully functional. The U.S. cannot produce more than a few new plutonium pits (one of the core components of nuclear warheads) per year; there are limits on the ability to conduct life-extension programs; and Dr. John S. Foster, Jr., former director of the Lawrence Livermore National Laboratory, has reported that the U.S. no longer can "serially produce many crucial components of our nuclear weapons."[30]

If the facilities are not properly funded, the U.S. will gradually lose the ability to conduct high-quality experiments. In addition to demoralizing the workforce and hampering further recruitment, obsolete facilities and poor working environments make maintaining a safe, secure, reliable, and militarily effective nuclear stockpile exceedingly difficult. NNSA facilities are old: In 2016, the agency reported that "[m]ore than 50 percent of its facilities are over 40 years old, nearly 30 percent date to the Manhattan Project era, and 12 percent are currently excess and no longer needed."[31] Deferred maintenance can indicate "aging infrastructure and associated challenges, such as those relating to reliability, mission readiness, and health and safety."[32] The state of the NNSA's infrastructure did not change during the covered period, although the agency did manage to halt growth in deferred maintenance.[33]

Since 1993, the DOE has not had a facility dedicated to production of plutonium pits. The U.S. currently keeps about 5,000 plutonium pits in strategic reserve. There are significant disagreements as to the effect of aging on pits and whether the U.S. will be able to maintain them indefinitely without nuclear weapons testing. Currently, the U.S. can produce no more than about 10 plutonium pits a year at the Los Alamos PF-4 facility. Infrastructure modernization plans for PF-4, if funded, will boost that number to about 30 by the middle of the next decade and to between 50 and 80 by the end of the following decade. Russia reportedly can produce approximately 1,000 pits a year.[34]

Manufacturing non-nuclear components can be extremely challenging either because some materials may no longer exist or because manufacturing processes have been forgotten and must be retrieved. There is a certain element of art to building a nuclear weapon, and such a skill can be acquired and maintained only through hands-on experience.

Grade: On one hand, the U.S. maintains some of the world's most advanced nuclear facilities. On the other, some parts of the complex—most importantly, parts of the plutonium and highly enriched uranium component manufacturing infrastructure—have not been modernized since the 1950s, and plans for long-term infrastructure recapitalization remain uncertain. The infrastructure therefore receives a grade of "weak."

Personnel Challenges Within the National Nuclear Laboratories Score: Marginal[35]

Combined with nuclear facilities, U.S. nuclear weapons scientists and engineers are critical to the health of the complex and the stockpile. The 2018 NPR emphasizes that:

> The nuclear weapons infrastructure depends on a highly skilled, world-class workforce from a broad array of disciplines, including engineering, physical sciences, mathematics, and computer science. Maintaining the necessary critical skills and retaining personnel with the needed expertise requires sufficient opportunities to exercise those skills.[36]

The ability to maintain and attract a high-quality workforce is critical to assuring the future of the American nuclear deterrent. Today's weapons designers and engineers are first-rate, but they also are aging and retiring, and their knowledge must be passed on to the next generation that will take on this mission. This means that young designers need challenging warhead design and development programs to hone their skills, but only a very limited number of such challenging programs are in place today. The next generation must be given opportunities to develop and maintain the skills that the future nuclear enterprise needs. The NNSA and its weapons labs understand this problem and, with the support of Congress and despite significant challenges, including a fiscally constrained environment, are taking initial steps to mentor and train the next generation.

The U.S. currently relies on non-yield-producing laboratory experiments, flight tests, and the judgment of experienced nuclear scientists and engineers to ensure continued confidence in the safety, security, effectiveness, and reliability of its nuclear deterrent. Without their experience, the nuclear weapons complex could not function.

A basic problem is that few scientists or engineers at the NNSA weapons labs have had the experience of taking a warhead from initial concept to a "clean sheet" design, engineering development, and production. The complex must attract and retain the best and brightest. The average age of the NNSA's workforce remained 48.1 years as of August 2017.[37] Even more worrisome is that over a third of the NNSA workforce will be eligible for retirement in the next four years. Given the distribution of workforce by age, these retirements will create a significant knowledge and experience gap.[38]

Grade: In addition to employing world-class experts, the NNSA labs have had recent success in attracting and retaining talent. However, because many scientists and engineers with practical nuclear weapon design and testing experience are retired or retiring very soon, nuclear warhead certifications will rely largely on the judgments of people who have never tested or designed a nuclear warhead. Management challenges and a lack of focus on the nuclear weapon mission contribute to the lowering of morale in the NNSA complex. In light of these issues, which have to do more with policy than with the quality of people, the complex earns a score of "marginal."

Readiness of Forces Score: Marginal

The readiness of forces is a vital component of America's strategic forces. The military personnel operating the three legs of the nuclear triad must be properly trained and equipped. It is also essential that these systems are maintained in a high state of readiness.

During FY 2017, the services have continued to align resources in order to preserve strategic capabilities in the short term, but long-term impacts remain uncertain. Continued decline in U.S. general-purpose forces eventually could affect nuclear forces, especially the bomber leg of the nuclear triad. Changes prompted by the 2014 Navy and Air Force cheating scandals have begun to address some of the morale issues. A sustained attention to the situation in the nuclear enterprise is critical.

Grade: Uncertainty regarding the further potential impacts of budgetary shortfalls, as part of the overall assessment, earns this indicator a grade of "marginal."

Allied Assurance Score: Strong

The number of weapons held by U.S. allies is an important element when speaking about the credibility of America's extended deterrence. Allies that already have nuclear weapons can

coordinate action with other powers or act independently. During the Cold War, the U.S. and the U.K. cooperated to the point where joint targeting was included.[39] France maintains its own independent nuclear arsenal, partly as a hedge against the uncertainty of American credibility. The U.S. also deploys nuclear gravity bombs in Europe as a visible manifestation of its commitment to its NATO allies.

The U.S., however, must also concern itself with its Asian allies. The United States provides nuclear assurances to Japan and South Korea, both of which are technologically advanced industrial economies facing nuclear-armed adversaries and potential adversaries. If they do not perceive U.S. assurances and guarantees as credible, they have the capability and know-how to build their own nuclear weapons and to do so quickly. That would be a major setback for U.S. nonproliferation policies.

The 2018 NPR takes a step in a good direction when it places "[a]ssurance of allies and partners" second on its list of four "critical roles" (immediately following "[d]eterrence of nuclear and non-nuclear attack") that nuclear forces play in America's national security strategy. The 2018 NPR proposes two supplements to existing capabilities—a low-yield SLBM warhead and a new nuclear sea-launched cruise missile—as important initiatives that act to strengthen assurance along with the Obama and Trump Administrations' initiatives to bolster conventional forces in NATO.[40]

Grade: At this time, most U.S. allies are not seriously considering developing their own nuclear weapons. European members of NATO continue to express their commitment to and appreciation of NATO as a nuclear alliance. Doubts about the modernization of dual-capable aircraft and even about the weapons themselves, as well as NATO's lack of attention to the nuclear mission and its intellectual underpinning, preclude assigning a score of "very strong." An unequivocal articulation of U.S. commitment to extended deterrence leads to an improvement in this year's score, raising it to "strong."

Nuclear Test Readiness Score: Weak

In the past, underground nuclear testing was one of the key elements of a safe, secure, effective, and reliable nuclear deterrent. For three decades, however, the U.S. has been under a self-imposed nuclear testing moratorium but with a commitment to return to nuclear testing if required to identify a problem, or confirm the fix to a problem, for a warhead critical to the nation's deterrent. Among other potential reasons to resume nuclear testing, the U.S. might need to test to develop a weapon with new characteristics that can be validated only by testing or to verify render-safe procedures. Nuclear tests and yield-producing experiments can also play an important role if the U.S. needs to react strongly to other nations' nuclear weapons tests and communicate its resolve or to understand other countries' new nuclear weapons.

To ensure a capability to resume testing if required, the U.S. maintains a low level of nuclear test readiness at the Nevada National Security Site (formerly Nevada Test Site). Current law requires that the U.S. be prepared to conduct a nuclear weapons test within a maximum of 36 months after a presidential decision to do so. The current state of test readiness is intended to be between 24 and 36 months, although it is doubtful that NNSA has achieved that goal. In the past, the requirement was 18 months.[41] The U.S. could meet the 18-month requirement only if certain domestic regulations, agreements, and laws were waived.[42] Because the United States is rapidly losing its remaining practical nuclear testing experience, including instrumentation of very sensitive equipment, the process would likely have to be reinvented from scratch.[43]

"Test readiness" seeks to facilitate a single test or a very short series of tests, not a sustained nuclear testing program. Because of a shortage of resources, the NNSA has been unable to achieve the goal of 24 to 36 months. The test readiness program is supported by experimental programs at the Nevada National Security Site, nuclear laboratory experiments, and advanced diagnostics development.[44]

Grade: As noted, the U.S. can meet the readiness requirement mandated by the law only if certain domestic regulations, agreements, and laws are waived. In addition, the U.S. is not prepared to sustain testing activities beyond a few limited experiments, which certain scenarios might require. Thus, testing readiness earns a grade of "weak."

Overall U.S. Nuclear Weapons Capability Score: "Marginal" Trending Toward "Strong"

It should be emphasized that "trending toward strong" assumes that the U.S. maintains its commitment to modernization and allocates needed resources accordingly. Absent this commitment, this overall score will degrade rapidly to "weak." Continued attention to this mission is therefore critical.

Although a bipartisan commitment has led to continued progress on U.S. nuclear forces modernization and warhead sustainment, these programs remain threatened by potential future fiscal uncertainties. The infrastructure that supports nuclear programs is aged, and nuclear test readiness has revealed troubling problems within the forces. Additionally, the United States has conducted fewer test launches than in previous years.

On the plus side, the 2018 NPR articulates nuclear weapons policy grounded in realities of international developments and clearly articulates commitment to extended deterrence. The commitment to warhead life-extension programs, the exercise of skills that are critical for the development of new nuclear warheads, and the modernization of nuclear delivery platforms represent a positive trend that should be maintained. Averaging the subscores across the nuclear enterprise in light of our concerns about the future results in an overall score of "marginal."

U.S. Military Power: Nuclear

	VERY WEAK	WEAK	MARGINAL	STRONG	VERY STRONG
Nuclear Stockpile				✓	
Delivery Platform Reliability			✓		
Warhead Modernization		✓			
Delivery Systems Modernization				✓	
Nuclear Weapons Complex		✓			
National Labs Talent			✓		
Force Readiness			✓		
Allied Assurance				✓	
Nuclear Test Readiness		✓			
OVERALL			✓		

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