U.S. Nuclear Weapons Capability

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Assessing the state of U.S. nuclear weapons capabilities presents at least three serious challenges.

First, the United States is not taking full advantage of technologically available developments to field modern warheads (often incorrectly termed "new" warheads) that could be designed to be safer, more secure, and more effective and could give the United States better options for strengthening a credible deterrent. Instead, the U.S. has largely elected to maintain aging 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 the reliability of their weapons makes analysis difficult.

Third, the U.S. nuclear enterprise has many components, some of which are also involved in supporting other military (e.g., conventional) and extended deterrence missions. For example, dual-capable bombers do not fly airborne alert with nuclear weapons today, although they did so routinely during the 1960s and technically could do so again if necessary.

Additionally, the three key national security laboratories no longer focus solely on the nuclear weapons mission (although this remains their primary mission); they also focus extensively on nuclear nonproliferation and counterproliferation, intelligence, biological/medical research, threat reduction, and countering nuclear terrorism, which includes a variety of nuclear-related detection activities. The Nuclear Command, Control, and Communications System performs five essential functions: "detection, warning, and attack characterization; adaptive nuclear planning; decision-making conferencing; receiving Presidential orders; and enabling the management and direction of forces."[1]

Thus, it is hard to assess whether any one piece of the nuclear enterprise is sufficiently funded, focused, and/or effective with regard to the nuclear mission.

In today's rapidly changing world, the U.S. nuclear weapons enterprise must be, as described in the 2018 Nuclear Posture Review (NPR), *"modern, robust, flexible, resilient, ready and appropriately tailored"* to underpin the U.S. nuclear deterrent.[2] If the U.S. detects a game-changing nuclear weapons development in another country, the U.S. nuclear weapons complex must be able to provide a timely response. However, maintaining a capable U.S. nuclear enterprise presents many challenges.

To provide assurance against unexpected failures in the U.S. stockpile or changes in a geopolitical situation, the U.S. maintains an inactive stockpile that includes near-term hedge warheads that "can serve as active ready warheads within prescribed activation timelines" and reserve warheads that can provide "a long-term response to risk mitigation for technical failures in the stockpile."[3] The U.S. preserves upload capability on its strategic delivery vehicles, which means that, if necessary, the nation could increase the number of nuclear warheads on each type of its delivery

vehicles. 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.[4] While the United States preserves these capabilities, doing so in practice would take time and be both difficult and potentially costly. Certain modernization decisions (e.g., 12 versus 14 *Columbia*-class ballistic missile submarines with 16 versus 24 missile tubes per submarine) will limit upload capacity on the strategic submarine force. U.S. heavy bombers will continue to retain a robust upload capability.

Moreover, the United States has not designed or built a new nuclear warhead since the end of the Cold War. Instead, the National Nuclear Security Administration (NNSA) uses life-extension programs (LEPs) to extend the service life of existing weapons in the stockpile. Not all of the existing inactive stockpile, however, will go through the life-extension program. Hence, our ability to respond to contingencies by uploading weapons kept in an inactive status will decline with the passage of time. In other words, LEPs by themselves cannot be relied upon to sustain needed levels of reliability.

Presidential Decision Directive-15 (PDD-15) requires the U.S. to maintain the ability "to conduct a nuclear test within 24-to-36 months of direction by the President to do so."[5] 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.[6] A lack of congressional support for improvements in technical readiness further undermines efforts by the NNSA to comply with the directive.

The nuclear weapons labs also face demographic challenges. Most scientists and engineers with practical "hands-on" experience in nuclear weapons design and/or testing are retired. This means that the certification of weapons designed and tested more than 30 years ago depends on the scientific judgment of designers and engineers who have never been involved in either the testing or the design and development of nuclear weapons. According to NNSA Administrator Lisa Gordon-Hagerty, more than 40 percent of the NNSA workforce will be eligible for retirement over the next five years, further adding to the loss of legacy nuclear weapons knowledge.[7]

The shift in emphasis away from the nuclear mission after the end of the Cold War led to a diminished ability to conduct key activities at the nuclear laboratories. According to Administrator Gordon-Hagerty:

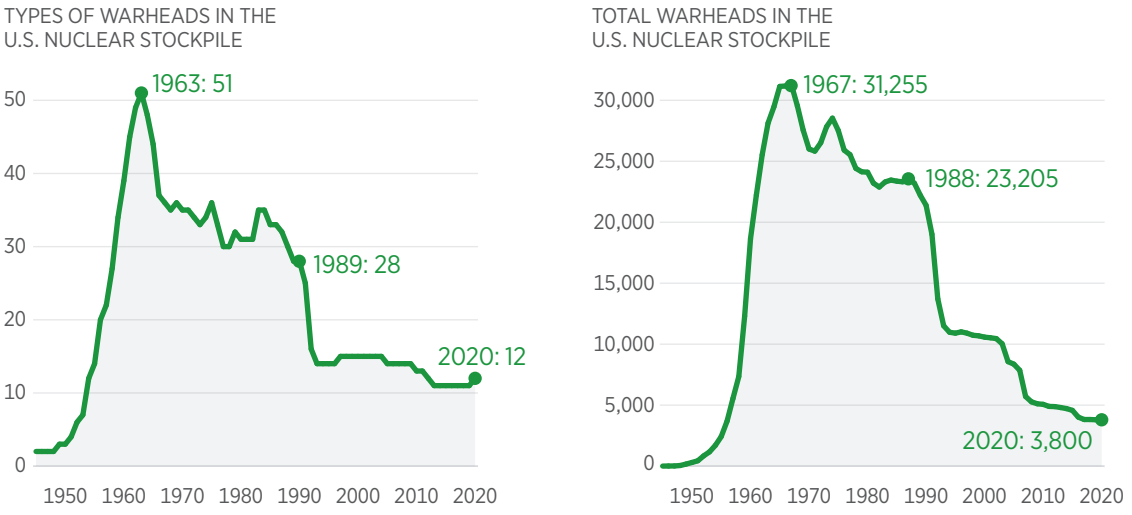
> While the U.S. nuclear weapons stockpile and its supporting infrastructure are safe, secure, effective, and reliable, they are aging. Competing interests over the past thirty years postponed weapon and infrastructure modernization programs, which directly contributed to erosion of our critical capabilities, infrastructure, and capacity to ensure the deterrent's viability into the future. The need to modernize our nuclear weapons stockpile and recapitalize its supporting infrastructure has reached a tipping point.[8]

As a result of this neglect, at the same time the nation faces an urgent need to modernize its aging nuclear warheads, "NNSA is undertaking a risk informed, complex, and time-constrained modernization and recapitalization effort."[9]

Another important indication of the health of the overall force is the readiness of the forces that operate U.S. nuclear systems. Following reports of misconduct in 2014, the Air Force had to make a number of changes to improve the performance, professionalism, and morale of the ICBM force.[10] Today, the COVID-19 pandemic presents another potential obstacle to the readiness of nuclear operators. In April 2020, the Pentagon announced its plans to maintain the readiness of the nuclear enterprise during the pandemic, to include a tiered testing system with forces involved "in critical national capabilities such as strategic deterrence or nuclear deterrence" in the first tier.[11] The Air Force and Navy have also isolated

CHART 10

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*, Vol. 65, No. 4 (2009), https://www.tandfonline.com/doi/pdf/10.2968/065004008 (accessed August 19, 2020); U.S. Department of Energy, Office of Declassification, *Restricted Data Declassification Decisions, 1946 to the Present*, January 1, 1999, https://fas.org/sgp/library/rdd-5.html (accessed August 19, 2020); U.S. Department of Defense, "Stockpile Numbers: End of Fiscal Years 1962–2017," http://open.defense.gov/Portals/23/Documents/frddwg/2017_Tables_UNCLASS.pdf (accessed August 19, 2020); Hans M. Kristensen and Matt Korda, "United States Nuclear Forces, 2020," *Bulletin of the Atomic Scientists*, Vol. 76, No. 1 (2020), https://www.tandfonline.com/doi/full/10.1080/00963402.2019.1701286 (accessed August 19, 2020); Hans M. Kristensen and Matt Korda, "Status of World Nuclear Forces," Federation of American Scientists, current update April 2020, https://fas.org/issues/nuclear-weapons/status-world-nuclear-forces/ (accessed August 19, 2020); and Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020*, Chapter 4, p. 46, https://www.acq.osd.mil/ncbdp/nm/nmhb/chapters/chapter4.htm (accessed August 19, 2020).

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those preparing for deployment to minimize risk to the force.[12]

Over time, fiscal uncertainty and a steady decline in resources for the nuclear weapons enterprise have adversely affected the nuclear deterrence mission. Despite America's continued commitment to nonproliferation and reductions in the number of the world's nuclear weapons, adversaries have increased both their nuclear forces and the role of nuclear weapons in their strategies. As Admiral Charles Richard, Commander, U.S. Strategic Command, testified before the Senate Armed Services Committee in February 2020:

> The contemporary security environment is the most challenging since the Cold War. In the nuclear dimension, we face a range of potential adversaries, each with different interests, objectives, and capabilities. To maintain a credible deterrent in this environment requires us to modernize and recapitalize our strategic forces to ensure our Nation has the capability to deter any actor, at any level. Doing so requires we remain committed to modernizing and recapitalizing our strategic forces and supporting infrastructure, and that we continue to pursue

the supplemental nuclear capabilities intended to address new challenges in the security environment.[13]

In recent years, bipartisan congressional support for the nuclear mission has been strong, and nuclear modernization has received additional funding. Preservation of that bipartisan consensus will be critical as these programs mature and begin to introduce modern nuclear systems to the force.

The Trump Administration has made significant progress in funding a comprehensive modernization program for nuclear forces that includes warheads, delivery systems, and command and control. Despite attempts to pull back from nuclear modernization, Congress has consistently funded the Trump Administration's budget request for these programs. Because such modernization activities require consistent, stable long-term funding commitments, it is essential that Congress continue to invest in this cornerstone of our security.

The Trump Administration's 2018 NPR, recognizing the reality of a worsening security environment that includes the rise of competition with a revisionist and resurgent Russia, an increasingly threatening China, and other growing strategic threats "including major conventional, chemical, biological, nuclear, space, and cyber threats, and violent nonstate actors," called for "tailored deterrence strategies" and reaffirmed that "aggression against the United States, allies, and partners will fail and result in intolerable costs for [the aggressors]."[14] Accordingly, the NPR called for modernization of nuclear weapons and the nuclear weapons complex, as well as significant reinvestments in the nuclear triad.[15]

The NNSA received $16.7 billion in fiscal year (FY) 2020, almost 10 percent more than the $15.2 billion it received in FY 2019, which included full funding for major efforts like modernization of plutonium pit production and five warhead modernization programs.[16] Modernization programs to replace the triad—including the Ground Based Strategic Deterrent (GBSD), Long Range Stand Off Weapon (LRSO), *Columbia*-class nuclear submarine, and B-21 bomber—also continue to progress in 2020. The NPR proposed two supplements to nuclear capabilities: a low-yield warhead for strategic submarine-launched ballistic missiles (SLBMs) in the near term, which was deployed in 2020, and a low-yield nuclear-armed sea-launched cruise missile, for which an analysis of alternatives is currently underway.[17]

Implications for U.S. National Security

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

U.S. nuclear forces play an essential role in underpinning the broad nonproliferation regime by providing U.S. security guaranties that assure allies including NATO, Japan, and South Korea that they can forgo development of nuclear capabilities. In part, U.S. deterrence capabilities also enable the United Kingdom and France to limit their numbers of nuclear weapons to levels they might not otherwise agree to accept.

North Korea has demonstrated that a country with limited intellectual and financial resources can develop a nuclear weapon if it decides to do so. Iran appears to continue on a path that largely retains its ability to develop a nuclear weapon capability, despite U.S. and international pressure to not do so. Such a reality only adds to the importance of U.S. nuclear assurances to allies and partners. Further erosion of the credibility of American nuclear forces could lead countries like Japan or South Korea to pursue an independent nuclear option, encouraging instability across the region.

Several negative trends, if not addressed, could undermine the overall effectiveness of U.S. nuclear deterrence. The United States must account for adversaries that are modernizing their nuclear forces, particularly Russia and China. Additional challenges include increasingly aged nuclear warheads; an aging and crumbling nuclear weapons infrastructure; an

aging workforce; and the need to fully recapitalize all three legs (land, air, and sea) of the nuclear triad including the systems for nuclear command and control while also conducting timely and cost-efficient life-extension programs—all while maintaining the nation's commitment to a testing moratorium under the Comprehensive Test Ban Treaty, which was signed but rejected by the Senate.

The 2018 NPR noted a rapid deterioration of the threat environment since 2010 and identified four enduring roles for U.S. nuclear capabilities:

- Deterrence of nuclear and non-nuclear attack;
- Assurance of allies and partners;
- Achievement of U.S. objectives if deterrence fails; and
- Capacity to hedge against an uncertain future.[18]

Because the capabilities of U.S. adversaries can vary, the 2018 NPR emphasized the need for tailored deterrence strategies. For example, Russia is engaged in an aggressive nuclear buildup, having added several new modern nuclear systems to its arsenal since 2010. In his February 2020 testimony before the Senate Armed Services Committee, Admiral Richard warned that:

> Russia's aggressive and robust military and nuclear modernization campaign across its strategic triad and dual-use systems is close to completion. To date, Russia has recapitalized 76 percent of its strategic nuclear forces with modern weapons and equipment, strengthening its overall combat potential....
>
> Russia's nuclear forces include a range of strategic weapons, some not captured by existing arms control structures, and theater and tactical nuclear weapons entirely outside the arms control framework.... Russia's overall nuclear stockpile is likely to grow significantly over the next decade—growth driven primarily by a projected increase in Russia's non-strategic nuclear weapons. Russia's determined pursuit of "non-strategic" nuclear weapons, together with their recent theory of nuclear rhetoric, indicates a troubling readiness to resort to nuclear weapons early in a crisis.[19]

Concurrently, Russia is using its dual-capable (nuclear/conventional capable) platforms to threaten the sovereignty of U.S. allies in Eastern Europe and the Baltics. It also is developing "novel technologies" such as a nuclear-powered cruise missile and nuclear-capable unmanned underwater vehicle.[20]

China is engaging in a similarly provocative nuclear buildup as it attempts to project power into the South China Sea, partly through illegally created islands on which China has installed offensive capabilities. Defense Intelligence Agency Director Lieutenant General Robert Ashley recently reported that China will likely at least double its nuclear stockpile within the next decade.[21] North Korea "has accelerated its provocative pursuit of nuclear weapons and missile capabilities."[22] And Iran, in addition to being the world's principal state sponsor of terrorism, retains "the technological capability and much of the capacity necessary to develop a nuclear weapon within one year of a decision to do so."[23]

Deterrence is an intricate interaction between U.S. conventional and nuclear forces, and the psychological perceptions of both allies and adversaries with respect to America's willingness to use such forces to defend its interests, as well as its allies and partners, are of the greatest importance. Nuclear deterrence must reflect and be attuned to the mindset of any particular 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. The U.S. nuclear portfolio must be structured

in terms of capacity, capability, variety, flexibility, and readiness to achieve these objectives. In addition, military roles and requirements for nuclear weapons will be inherently 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, and actions that any given state may take, as well as other actors' perceptions of the world around them, one will never know whether or when a nuclear deterrent or conventional forces provided by the U.S. might be perceived as insufficient. Nuclear weapon 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, however, that a robust, well-resourced, focused, and reliable nuclear enterprise is much more likely to sustain the value of the U.S. deterrent than is one that is outdated and/or questionable.

The U.S. has demonstrated that it is capable of incredible mobilization when danger materializes, and today's nuclear threat environment is evolving, dynamic, and proliferating in unpredictable ways, with new and resurgent old actors developing new capabilities. Meanwhile, despite the promise of additional funding, the U.S. nuclear enterprise remains largely static, leaving the United States at what could well be a technological disadvantage. Such a posture puts both the security of the United States and the security of its allies and the entire free world at risk.

Scoring U.S. Nuclear Weapons Capabilities

The U.S. nuclear weapons enterprise is composed of several key elements that include warheads; delivery systems; and the physical infrastructure that designs, manufactures, and maintains U.S. nuclear weapons. The nuclear enterprise also includes and must sustain the talent of our people: the nuclear designers, engineers, manufacturing personnel, planners, maintainers, and operators who help to ensure a nuclear deterrent that is second to none. The nuclear weapons enterprise entails additional elements like nuclear command and control; intelligence, surveillance, and reconnaissance (ISR); and aerial refueling, all of which also play a major role in conventional operations.

The factors selected below are the most important elements of the nuclear weapons complex. They are judged on a five-grade scale that ranges from "very strong," defined as having a sustainable, viable, and funded plan in place, to "very weak," defined as a situation in which the U.S. is not meeting its security requirements and has no program in place to redress the shortfall. The other three possible scores are "strong," "marginal," and "weak."

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 probability that a weapon will perform in accordance with its design intent or military requirements."[24] Since the cessation of nuclear testing in 1992, reliability has been determined through the NNSA's Stockpile Stewardship Program, which consists of an intensive warhead surveillance program; non-nuclear experiments (i.e., experiments that do not produce a nuclear yield); sophisticated calculations using high-performance computing; and related annual assessments and evaluations.

The reliability of nuclear warheads and delivery systems becomes even more important as the number and diversity of nuclear weapons in the stockpile decrease. Fewer types of nuclear weapons means a smaller margin of error if all of one type are affected by a technical problem that might cause a weapon type and/or its delivery system to be decommissioned. Further, with less diversity, the risk that a problem might affect multiple systems

increases. America and its allies must have high confidence that U.S. nuclear warheads will perform as expected.

As warheads age, uncertainty about their ability to perform their mission as expected could increase and significantly complicate military planning. Despite creating impressive amounts of knowledge about nuclear weapons physics and materials chemistry, the U.S. could find itself surprised by unanticipated long-term effects on aging components that comprise a nuclear weapon. "The scientific foundation of assessments of the nuclear performance of US weapons is eroding as a result of the moratorium on nuclear testing," argue John Hopkins, nuclear physicist and a former leader of the Los Alamos National Laboratory's nuclear weapons program, and David Sharp, former Laboratory Fellow and a guest scientist at Los Alamos National Laboratory.[25]

The United States currently has the world's safest and most secure stockpile, but concerns about overseas storage sites, potential problems introduced by improper handling, or unanticipated aging effects could compromise the integrity and/or reliability 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. While some U.S. warheads have modern safety features that provide additional protection against accidental detonation, others do not.

Grade: The Department of Energy and Department of Defense are required to assess the reliability of the nuclear stockpile annually. Each of the three nuclear weapons labs (Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratory) reports its findings with respect to the safety, security, and reliability of the nation's nuclear warheads to the Secretaries of Energy and Defense, who then brief the President. Detailed classified reports are also provided to Congress. While these assessments do not include the nuclear weapons delivery systems, the Commander of U.S. Strategic Command does assess overall nuclear weapons system reliability, including the reliability of both warhead and delivery platforms.

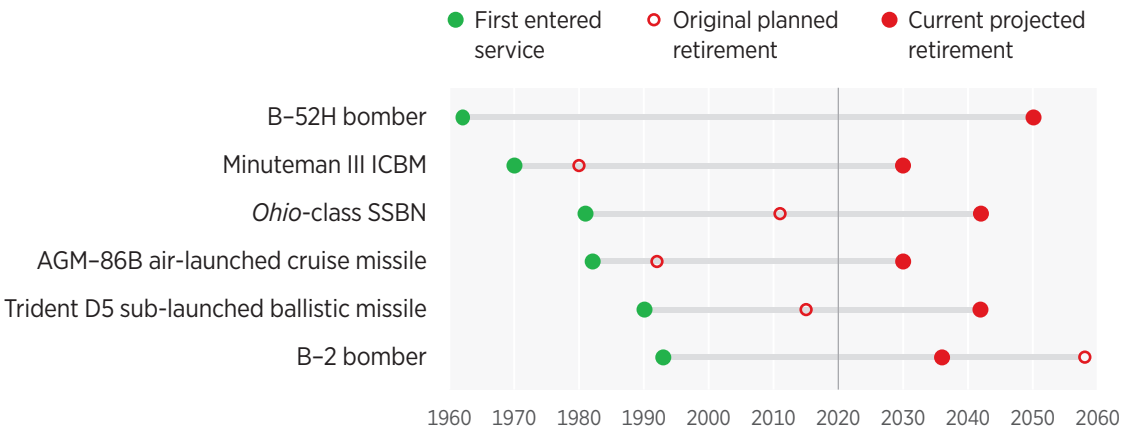
Absent nuclear weapons testing, the national laboratories' assessment of weapons reliability, based on the full range of surveillance, scientific, and technical activities carried out in NNSA's Stockpile Stewardship Program, depends on the expert judgment of the laboratories' directors. This judgment, albeit based on experience, non-nuclear experimentation, and extensive modeling and simulation, is nevertheless inherently subjective and no substitute for objective data obtained through direct nuclear testing. Nuclear testing was used in the past to diagnose potential problems with warheads and to certify the effectiveness of fixes to those problems. It was also used to certify current nuclear warheads, as well as to detect potential problems and confirm the effectiveness of fixes to those problems. Given that modern simulation is based on nuclear tests that were conducted primarily in the 1950s and 1960s with testing equipment of that era, there is a great deal more that today's nuclear testing and detection equipment could teach us about nuclear weapons physics.

By 2005, a consensus emerged in the NNSA, informed by the nuclear weapons labs, that "indefinite refurbishment" of the nuclear stockpile would be "extremely difficult to execute (because many warhead components can not [*sic*] be replicated as originally built), and would result in modifications on top of other modifications that [would] be increasingly difficult to certify without nuclear testing." Two major studies had "concluded that the Reliable Replacement Warhead (RRW) concept, if feasible, would be a preferred alternative to the indefinite refurbishment strategy."[26] 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 caused weapons with serious problems to be introduced into the U.S. stockpile.[27] These problems were discovered only after the resumption of U.S. nuclear weapons testing following the Soviet

FIGURE 5

U.S. Nuclear Delivery Systems Outdated

Current U.S. nuclear delivery systems are between 27 and 58 years old, and some are expected to be retired within a decade.



NOTES: The original retirement date for the B-2 was set at 2058, but in the FY 2019 budget, the Air Force moved up the retirement date by 22 years to 2036. That move could have been caused by projected threats, the cost of sustainment, or both. The original programmed retirement date for the B-52H is not known, but the Air Force has recently stated it plans to continue flying this jet into the 2050s. The average B-52H bomber has logged approximately 20,300 hours, and based on airframe component lifetime estimates and flying 350 hours each year, it could continue flying until 2067.
SOURCES: Heritage Foundation research.

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Union's unannounced breakout from the 1962 agreed moratorium.

The United States is committed to sustaining its nuclear stockpile without nuclear testing, and this creates some inherent uncertainty concerning the adequacy of fixes to the stockpile when problems are found. These growing numbers of additional uncertainties include updates made to correct problems that were 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 Sandia National Laboratories 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."[28]

One of the costs of having to certify weapons without nuclear testing, at least to date, has been fewer types of weapons (i.e., reduced diversity in the stockpile) and, consequently, a greater potential impact across the inventory of warheads should an unknown or misidentified error emerge in the certification process. Loss of diversity in the stockpile also increases the risk of "common-mode" failure that could affect multiple systems simultaneously, making the push for commonality with potential single points of failure in U.S. warheads worrisome. "To be blunt," warned then-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."[29]

The U.S. pursues warhead LEPs that replace aging components before they can cause reliability problems. The number and scope of LEPs being carried out over the next two decades will stress NNSA's warhead design and production complex and remains a concern, particularly given uncertainties regarding the congressional budget process. In spite of these concerns, in FY 2019 and FY 2020, the NNSA continued to assess that the stockpile is "safe, secure, and effective."[30]

In light of our overall assessment, we grade the U.S. stockpile conditionally as "strong" based on the results of the existing method used to certify the stockpile's effectiveness. This grade, however, will depend on whether support for an adequate stockpile, both in Congress and in the Administration, remains strong.

Reliability of U.S. Delivery Platforms Score: Strong

Reliability encompasses not only the warhead, but strategic delivery vehicles as well. For ICBMs and SLBMs, in addition to a successful missile launch, this includes the separation of missile boost stages, performance of the missile guidance system, separation of the reentry vehicles from the missile post-boost vehicle, and accuracy of the final reentry vehicle in reaching its target.[31]

The U.S. conducts flight tests of ICBMs and SLBMs every year to ensure the reliability of its delivery systems with high-fidelity "mock" warheads. Anything from faulty electrical wiring to booster separations could degrade the reliability and safety of the U.S. strategic deterrent. U.S. strategic, long-range bombers also regularly conduct Continental United States and intercontinental exercises and receive upgrades to sustain a demonstrated high level of combat readiness. The Air Force most recently tested the AGM-86B air-launched cruise missile launched from the B52-H bomber in 2017.[32] Platforms have to be modernized and replaced simultaneously, and already diminished capabilities make this even more difficult.

Grade: In July 2018, the Air Force suffered its first unsuccessful ICBM test since 2011,[33] but it has conducted four successful tests since then. These successes include one developmental test in February 2020, the first test hosted by Vandenberg Air Force Base since it became part of the U.S. Space Force.[34] The next ICBM test, scheduled for August 2020, reportedly remained on schedule despite the ongoing COVID-19 pandemic.[35] The SLBM tests were successful in 2019 and 2020.[36]

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. allies and adversaries alike that the U.S. system works and the U.S. nuclear deterrent is ready if needed. The aged systems, however, occasionally have reliability problems, as evidenced by the July 2018 failed Minuteman III launch. Moreover, because of its obsolescence against Russian air defense systems, the B52H bomber can no longer officially carry gravity bombs.[37]Aging will continue to affect delivery platform reliability until platforms are replaced, but two years of successful missile tests and bomber flights indicate that, at least for now, delivery platforms will likely continue to perform reliably.

Until significant evidence tells us otherwise, this factor receives a grade of "strong."

Nuclear Warhead Modernization Score: Marginal

During the Cold War, the United States focused 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 its aging stockpile rather than on fielding new nuclear warheads, but it also seeks to retain the skills and capabilities required to design, develop, and produce new warheads.

Relying only on sustaining our aging stockpile could increase the risk of failure caused by aging components and signal to adversaries that the United States is less committed to nuclear deterrence. In FY 2016, the United States established the Stockpile Responsiveness Program (SRP) "to exercise all capabilities to conceptualize, study, design, develop, engineer, certify, produce, and deploy nuclear weapons."[38] Congress doubled funding for the SRP from $34 million in FY 2019 to $70 million in FY 2020. The Administration requested $70 million for the program in FY 2021.[39]

Modern or new weapon designs could allow American engineers and scientists to improve previous designs and devise more effective means by which to address existing military requirements (e.g., the need to destroy deeply buried and hardened targets) that have emerged in recent years. Future warheads could improve reliability (i.e., remedying some ongoing aging concerns such as replacement of aged nuclear components) while also enhancing the safety and security of American weapons.

The ability to work on future/new weapon design options would help to ensure that today's American experts and those of the next-generation remain engaged and knowledgeable, would help to attract the best talent to the nuclear enterprise, and would help the nation to gain additional insights into foreign nations' (i.e., adversaries) 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."[40]

Meanwhile, potential U.S. adversaries and current and future proliferants are not limited to updating only Cold War designs and can seek designs outside U.S. experiences. Other nations maintain their levels of proficiency by having their scientists work on new nuclear warheads.[41] As recently reported by the Department of State, "Russia has conducted nuclear weapons experiments that have created nuclear yield and are not consistent with the U.S. 'zero-yield' standard," and evidence points to China's possibly having done so as well.[42]

Grade: The nuclear enterprise was able to display improved flexibility when it produced a low-yield version of the W76 warhead, which was designed to counter Russia's perception of an exploitable gap in the U.S. nuclear force posture, within a year despite continued nuclear policy restrictions and a preference for life-extension programs. Such efforts to produce the W76-2 in 2019 warranted an improvement in this score last year.

The NNSA continues to improve in this category in 2020. As part of the SRP, the NNSA plans to conduct feasibility studies of the next Navy warhead, dubbed the W93 in the budget request for FY 2021.[43] Also, as part of its effort to restore the ability to produce plutonium pits, the NNSA produced five pits in 2019.[44] This continued effort in 2020 will help the NNSA to regain the capabilities needed to produce new warheads. The score for this category remains at "marginal," but it will improve when the NNSA, through the SRP in particular, begins to produce tangible advancements in pit production and W93 development.

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 significantly negative impact on operational capabilities. Any margins allowing delay of platform replacement have been significantly diminished. The older weapons systems are, the more likely it is that faulty components, malfunctioning equipment, or technological developments will limit their reliability in the operating environment.

Age degrades reliability by increasing the potential for systems to break down or fail to respond correctly. Corrupted systems, defective electronics, or performance degradation caused by long-term storage defects (including

for nuclear warheads) can have serious implications for American deterrence and assurance. Because it cannot be assumed (especially for systems approaching end of life) that a strategic delivery vehicle will operate in a reliable manner indefinitely, that vehicle's deterrence and assurance value may be significantly reduced with consequent effects on perceptions of deterrence among both allies and adversaries.

The U.S. Air Force and Navy plan to modernize or replace each leg of the nuclear triad in the next few decades, but fiscal constraints and inconsistent funding levels (including issues related to "continuing resolutions") will make such efforts difficult at best. Sustained leadership focus is imperative if the modernization program is to succeed.

The Navy is fully funding its programs to replace the *Ohio*-class submarine with the *Columbia*-class submarine, but issues involving cost estimates and potential industrial base impacts caused by the COVID-19 pandemic could make it harder to achieve the goal of deploying the first submarine in 2031.[45] The Air Force is funding the B-21 Raider Long-Range bomber, which will replace conventionally armed bombers before they become nuclear certified, and the Long Range Standoff Weapon, which will replace the aging air-launched cruise missile. Existing Minuteman III ICBMs are expected to remain in service until 2032, 50 years after their intended lifetime, when they will be replaced by the GBSD missiles. Existing Trident II D5 SLBMs have been life-extended to remain in service until 2042 through the end of the last *Ohio*-class submarine's lifetime.[46]

Remanufacturing some weapon parts is difficult and expensive either because the manufacturers are no longer in business or because the materials that constituted the original weapons are no longer available (e.g., because of environmental restrictions). U.S. triad modernization is a requirement validated by all four of the NPRs since the end of the Cold War and remains a "must" in all future deterrence scenarios. U.S. nuclear weapon modernization plans benefited from predictability associated with the FY 2018–FY 2019 budget deal, but the economic downturn caused by the COVID-19 pandemic and the prospect of future defense budget cuts threaten such progress.

Grade: U.S. nuclear platforms are in dire need of recapitalization. Plans for modernization of the nuclear triad are in place, and Congress and the services have largely sustained funding for these programs. Moreover, some aspects of these programs have progressed in 2020. For instance, the Air Force awarded sole source contracts for both the LRSO and GBSD programs.[47] It is also setting up a joint developmental and operational test force to support the GBSD program.[48] In FY 2020, the Administration's budget request for nuclear modernization received full funding from Congress, despite an initial House-passed spending bill that included significant cuts in these programs. Potential modernization delays and congressional funding cuts could cause this score to be downgraded in the future, but this year, both Congress and the Administration have demonstrated a commitment to nuclear weapons modernization that again earns this indicator a grade of "strong."

Nuclear Weapons Complex
Score: Marginal

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 Laboratories,
- 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 stated:

> 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.[49]

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 the nuclear components needed to replace nuclear weapons in the stockpile.[50] For instance, the United States has not had a substantial plutonium pit production capability since 1993. A plutonium pit is the heart of a nuclear weapon that contains the nuclear material. The NNSA currently plans to produce no fewer than 80 plutonium pits a year by the 2030 time frame—a challenging timeline by the agency's own admission.[51]

If the facilities are not properly funded, the U.S. will gradually lose the ability to conduct the high-quality experiments that are needed to ensure the reliability of the stockpile without nuclear testing. In addition to demoralizing the workforce and hampering recruitment, old and/or obsolete facilities and poor working environments make maintaining a safe, secure, reliable, and militarily effective nuclear stockpile difficult. The NNSA's facilities are old: Nearly 60 percent are more than 40 years old, nearly 30 percent date to the Manhattan Project of the 1940s, and 10 percent are considered excess or no longer needed.[52] As a consequence, the NNSA had accumulated about $4.8 billion in deferred maintenance as of March 2020.[53] Aging facilities have also become a safety hazard: In some buildings, for example, chunks of concrete have fallen from the ceiling.[54]

The U.S. currently retains more than 5,000 old plutonium pits in strategic reserve in addition to pits for use in future LEPs. There are disagreements as to the effect of aging on plutonium pits and how long the U.S. will be able to depend on them before replacement. Because our laboratories estimated the life span of warhead plutonium to be between 45 and 60 years in 2006, it may not be long before the United States has to start replacing core components of its nuclear warheads.[55] Current capacities to do so are insufficient because the U.S. has only demonstrated an ability to produce about 10 plutonium pits a year at the Los Alamos PF-4 facility. If executed as planned, infrastructure modernization of PF-4, as mandated by the 2018 NPR, will boost that number to about 30 by 2026.

A second plutonium pit production facility is being planned to exploit the Mixed Oxide Fuel (MOX) facility that until last year was under construction at the Savannah River Site in South Carolina. The MOX building is being repurposed for plutonium pit production with production of no fewer than 50 pits per year to be achieved by 2030 for an overall requirement of no fewer than 80 plutonium pits a year. Achievement of this timeline is made more difficult by the fact that the NNSA is embarking on the most ambitious warhead sustainment program since the end of the Cold War, overhauling some five warhead types and stressing the demands on both workforce and facilities.

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—importantly, the plutonium and highly enriched uranium component manufacturing infrastructure—have not been modernized since the 1950s. Plans for long-term infrastructure recapitalization remain essential even as the NNSA is embarking on an aggressive warhead life-extension effort. Sustaining and/or increasing critically essential but always decaying tritium gas is likewise essential; delays only increase production needs because the more tritium decays because of our inability to replenish it, the more tritium gas we will need to cover our baseline needs.[56]

Significant progress has been made over the past year, however, in recapitalizing uranium infrastructure and in getting funded plans in place to recapitalize plutonium pit production capacity. With these projects only beginning and still at risk of major funding cuts or cancellations, the infrastructure's grade will likely remain at "marginal" until demonstrable progress has been made.

Personnel Challenges Within the National Nuclear Laboratories Score: Marginal

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. Should a technical or geopolitical development demand a new nuclear weapon, it is crucial that the nuclear weapons workforce possess the skills and the knowledge needed to design, develop, and manufacture warheads of different design in a timely manner.[57]

The ability to maintain and attract a high-quality workforce is critical to assuring the future of the American nuclear deterrent, especially when a strong employment atmosphere adds to the challenge of hiring the best and brightest. 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 of experts. This means that young designers need meaningful and challenging warhead design and development programs to hone their skills, and the SRP offers one visible means by which to address such concerns. The NNSA and its weapons labs understand this problem and with the support of Congress are beginning to take the necessary steps through SRP and foreign weapon assessment to mentor the next generation. To continue this progress, SRP funding should be maintained at least at its current rate of about $70 million per year.

The U.S. currently relies on non-yield-producing laboratory experiments, flight tests, and the judgment of experienced nuclear scientists and engineers, using robust modeling and simulation, 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. Few of today's remaining 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, production, and fielding. The SRP is remedying some of these shortfalls by having its workforce exercise most of the nuclear weapons design and engineering skills that are needed.

The average age of the NNSA's workforce decreased slightly to 46.9 years as of July 2019.[58] Still worrisome, however, is that NNSA sites are reporting rates of retirement eligibility from 15 percent to 44 percent, which will likely increase over the next five years.[59] Given the distribution of workforce by age, these retirements will create a significant knowledge and experience gap.

Grade: In addition to employing world-class experts, the NNSA labs have had some success in attracting and retaining talent (e.g., through improved college graduate recruitment efforts). As many scientists and engineers with practical nuclear weapon design and testing experience are retired, continued nuclear warhead annual assessments and certifications will rely increasingly on the judgments of people who have never tested or designed a nuclear weapon. In light of these issues, the NNSA workforce earns a score of "marginal," albeit with signs of improvement.

Readiness of Forces Score: Strong

The readiness of forces that operate U.S. delivery platforms 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 the crews responsible for the nuclear mission are maintained in an appropriate state of readiness.

During FY 2020, the services have continued to align resources in order to preserve strategic capabilities in the short term. Nevertheless, the long-term possible effects of a continued flat defense budget could have major negative implications for the timely execution of programs. The economic downturn caused by the COVID-19 pandemic could also lead to programmatic delays or further defense budget cuts.

U.S. general-purpose forces are critical to ensuring the overall effectiveness of our nuclear forces (e.g., by providing a pool of qualified candidates to operate nuclear weapon delivery systems). Changes prompted in part by the 2014 Navy and Air Force cheating scandals have addressed most morale issues and have recast the role of forces supporting the nuclear deterrent by, for example, providing additional funding for equipment purchases, creating more mid-career billets to help career-field continuity, focusing leadership attention, and changing training to focus on mission in the field rather than on a theoretical ideal.[60] Sustained attention to the situation in the nuclear enterprise is critical.

Grade: Despite uncertainties regarding the future impacts of budgetary shortfalls, the young men and women who secure, maintain, plan for, and operate U.S. nuclear forces are of an extremely high caliber. Nuclear force commanders have provided assurance that the COVID-19 pandemic has had no impact on force readiness and the ability to launch nuclear weapons.[61] Force readiness thus receives a grade of "strong."

Allied Assurance Score: Strong

The credibility of U.S. nuclear deterrence is one of the most important components of allied assurances. U.S. allies that already have nuclear weapons can coordinate actions with the United States or act independently. During the Cold War, the U.S. and the U.K. cooperated to the point where joint targeting was included. France maintains its own independent nuclear arsenal. The U.S. also deploys nuclear gravity bombs in Europe as a visible manifestation of its commitment to its NATO allies.

The U.S. also has an enduring extended deterrence role with its Asian allies. The United States provides nuclear assurances to Japan and South Korea, both of which are technologically advanced industrial economies facing aggressive nuclear-armed regional adversaries (i.e., China, Russia, and North Korea). Continued U.S. nuclear deterrence assurances and guarantees are critical and must be perceived as credible. Both Japan and South Korea have the capability and basic know-how to build their own nuclear weapons quickly should they chose to do so. That would be a major setback for U.S. nonproliferation policies.

The 2018 NPR took a positive step when it placed "[a]ssurance of allies and partners" second on its list of four "critical roles" that nuclear forces play in America's national security strategy. The 2018 NPR proposed two supplements to existing capabilities—a low-yield SLBM warhead and a new nuclear sea-launched cruise missile—as important initiatives to strengthen assurance along with the Obama and Trump Administrations' initiatives to bolster conventional forces in NATO.[62] The recent successful deployment of the W76-2 low-yield warhead will be an important component of America's ability to deter aggression against its Asian and NATO allies.

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 even as they worry about the impact of Russia's intermediate-range ground-launched missile capabilities and the fate of the New Strategic Arms Reduction Treaty, set to expire in February 2021. Uncertainties surround the purchase and modernization of NATO's dual-capable aircraft and the replacement of existing U.S. nuclear weapons with the B61-12, which is now facing a delay of one to two years.[63] Recent controversy within the German government over continuing to deploy U.S. gravity bombs in Germany adds to this uncertainty. Nevertheless, both Germany and NATO Secretary General Jens Stoltenberg have recently affirmed their commitment to NATO's nuclear sharing.[64] The score for allied assurance therefore remains "strong."

Nuclear Test Readiness Score: Weak

In the past, nuclear testing was one of the key elements of a safe, secure, effective, and reliable nuclear deterrent. While the U.S. is currently under a self-imposed nuclear testing moratorium, it is still required to maintain a low level of nuclear test readiness at the Nevada National Security Site (formerly Nevada Test Site).

"Test readiness" refers to a single test or a very short series of tests, not a sustained nuclear testing program, reestablishment of which would require significant additional resources. Specifically, under the 1993 PDD-15, "DOE [now NNSA] will maintain the readiness and capability to conduct nuclear tests within 2 to 3 years."[65] Because of a shortage of resources, the NNSA has been unable to achieve this goal. Test readiness has not been funded as a separate program since FY 2010 and is instead supported by the Stockpile Stewardship Program that exercises testing elements at the Nevada National Security Site and conducts subcritical nuclear laboratory experiments.[66]

However, whether this approach can assure that the U.S. has the timely ability to conduct yield-producing experiments to correct a flaw in one or more types of its nuclear weapons is open to question. The U.S. might need to test to assure certain weapon characteristics that could possibly be validated only by nuclear testing and to verify render-safe procedures. The ability to conduct yield-producing experiments rapidly is likewise important, especially if the U.S. needs to react strongly to another nation's nuclear weapons tests and/or communicate its unquestioned resolve.

Current law requires that the U.S. must maintain a capability to conduct a nuclear test within 24 to 36 months of a presidential decision to do so.[67] However, the FY 2020 Stockpile Stewardship and Management Plan (SSMP) states that fully complying with domestic regulations, agreements, and laws would "significantly extend the time required for execution of a nuclear test."[68] The time needed to conduct not just a test to address a need within the existing stockpile, but a test to develop a new capability was most recently reported in the FY 2018 SSMP as 60 months.[69] 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.[70]

Grade: The Trump Administration has recently discussed whether to conduct a nuclear test as a demonstration for U.S. adversaries that allegedly have been conducting nuclear

explosive tests of their own.[71] As noted, however, the U.S. through NNSA can meet the legally required readiness requirement 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 because it no longer retains the deep drilling technology in Nevada and has only a few "holes" that are able to contain a nuclear test. 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 of the entire nuclear enterprise—from warheads to platforms to personnel to infrastructure—and allocates needed resources accordingly. Without 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 seriously threatened by potential future fiscal uncertainties. The infrastructure that supports nuclear programs is very aged, and nuclear test readiness has revealed troubling problems within the forces.

On the positive side, the 2018 NPR strongly articulates a core nuclear weapons policy solidly grounded in the realities of today's threats and growing international concerns. The 2018 NPR clearly and strongly articulates a continued 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 (under the SRP), and the just-in-time modernization of nuclear delivery platforms represent a positive trend that must 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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59. Ibid., p. 7-5.
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