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NUCLEAR NOTEBOOK

United States nuclear forces, 2019

Hans M. Kristensen and Matt Korda

ABSTRACT
The Nuclear Notebook is researched and written by Hans M. Kristensen, director of the Nuclear Information Project with the Federation of American Scientists, and Matt Korda, a research associate with the project. The Nuclear Notebook column has been published in the *Bulletin of the Atomic Scientists* since 1987. This issue's column examines the US nuclear arsenal, which remained roughly unchanged in the last year, with the Department of Defense maintaining an estimated stockpile of nearly 3,800 warheads. Most of these warheads are not deployed; approximately 2,050 warheads are held in reserve and approximately 2,385 retired warheads are awaiting dismantlement, giving a total inventory of approximately 6,185 nuclear warheads. Of the approximately 1,750 warheads that are deployed, roughly 1,300 are on ballistic missiles, 300 at strategic bomber bases in the United States, with another 150 tactical bombs deployed at European bases.

KEYWORDS
Ballistic missiles; cruise missiles; Nuclear Posture Review; nuclear weapons; nuclear arsenal; United States

At the beginning of 2019, the US Department of Defense maintained an estimated stockpile of 3,800 nuclear warheads for delivery by more than 800 ballistic missiles and aircraft. Most of the warheads in the stockpile are not deployed, but rather stored for potential upload onto missiles and aircraft as necessary. Many are destined for retirement. We estimate that approximately 1,750 warheads are currently deployed, of which roughly 1,300 strategic warheads are deployed on ballistic missiles, 300 at strategic bomber bases in the United States, while another 150 tactical bombs are deployed at air bases in Europe. The remaining warheads – approximately 2,050 – are in storage as a so-called hedge against technical or geopolitical surprises. Several hundred of those warheads are scheduled to be retired before 2030. (See Table 1.)

Through 2018, the Trump administration followed the Obama administration's practice of declassifying the size of the stockpile and number of dismantled warheads. In April 2019, however, the Defense Department – presumably under guidance from the White House – rejected declassifying the numbers. The decision reverses US nuclear transparency policy and will, if not reversed, create uncertainty and mistrust about the size of the US nuclear arsenal (Kristensen 2019). In addition to the warheads in the Department of Defense stockpile, approximately 2,385 retired – but still intact – warheads are stored under custody of the Department of Energy and are awaiting dismantlement, giving a total US inventory of an estimated 6,185 warheads.

The nuclear weapons are thought to be stored at an estimated 24 geographical locations in 11 US states and five European countries. The location with the most nuclear weapons is the large Kirtland Underground Munitions and Maintenance Storage Complex (KUMMSC) south of Albuquerque, NM (see Table 2). Most of the estimated 2,475 weapons in this location (and estimated 1,785) are retired weapons awaiting shipment for dismantlement at the Pantex Plant in Texas. The state with the second-largest inventory (1,620) is Washington, which is home to the Strategic Weapons Facility Pacific (SWFPAC) and the ballistic missile submarine at Naval Submarine Base Kitsap. (Washington is the state with most nuclear weapons (1,120) if counting only stockpiled weapons.) In addition to stockpiled weapons, the two ballistic missile submarine bases are thought to store retired Navy warheads awaiting dismantlement. With the completion of the W76-1 life-extension program production, these excess warheads are scheduled to be dismantled during the 2020s. Of the five nuclear weapons storage locations in Europe, Incirlik Air Base in Turkey stores the most – about 50 or one-third of the weapons in Europe, although there are unconfirmed rumors that the weapons may have been withdrawn.

Implementing New START

The United States was in compliance with the final New START treaty limits by the specified deadline of February 5, 2018, at which point it was counted as deploying 660 strategic launchers with 1,393 attributed warheads (State Department 2018). In its most recent data exchange on March 1, 2018, the United States counted 656 strategic launchers with 1,365 attributed warheads (State Department 2019). These numbers

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Table 1. US nuclear forces, 2019.

Type/Designation	No.	Year deployed	Warheads x yield (kilotons)	Warheads (total available)[a]
ICBMs				
LGM-30G Minuteman III				
Mk-12A	200	1979	1–3 W78 x 335 (MIRV)	600[b]
Mk-21/SERV	200	2006[c]	1 W87 x 300	200[d]
Total	**400**[e]			**800**[f]
SLBMs				
UGM-133A Trident II D5	240[g]			
Mk-4		1992	1–8 W76-0 x 100 (MIRV)	46[h]
Mk-4A		2008	1–8 W76-1 x 90 (MIRV)	1,490
Mk-4A		(2019)	1–2 W76-2 x low (MIRV)[i]	n.a.
Mk-5		1990	1–8 W88 x 455 (MIRV)	384
Total	**240**			**1,920**[j]
Bombers				
B-52H Stratofortress	87/44[k]	1961	ALCM/W80-1 x 5–150	528
B-2A Spirit	20/16	1994	B61-7/-11, B83-1	322
Total	**107/60**[l]			**850**[m]
Total strategic forces				**3,570**
Nonstrategic forces				
F-15E, F-16 DCA	n/a	1979	1–5 B61-3/-4 bombs x 0.3–170[n]	230
Total				**230**[o]
Total stockpile				**3,800**
Deployed				1,750[p]
Reserve (hedge and spares)				2,050
Retired, awaiting dismantlement				**2,385**
Total Inventory				**6,185**

ALCM: air-launched cruise missile; DCA: dual-capable aircraft; ICBM: intercontinental ballistic missile; LGM: silo-launched ground-attack missile; MIRV: multiple independently targetable re-entry vehicle; SERV: security-enhanced re-entry vehicle; SLBM: submarine-launched ballistic missile.

[a]Lists total warheads available. Only a portion of these are deployed with launchers. See individual endnotes for details.

[b]Roughly 200 of these are deployed on 200 Minuteman IIIs equipped with the Mk-12A re-entry vehicle. The rest are in central storage.

[c]The W87 was initially deployed on the MX/Peacekeeper in 1986 but first transferred to the Minuteman in 2006.

[d]Of 567 W87s produced, 540 remain. The 200 Mk21-equipped ICBMs can each carry one W87. The remaining 340 W87s are in storage. Excess W87 pits are planned for use in the W78 Replacement Program previously designated IW-1 but now called W87-1.

[e]Another 50 ICBMs are in storage for potential deployment in 50 empty silos.

[f]Of these ICBM warheads, 400 are deployed on operational missiles and the rest are in long-term storage.

[g]Only counts 240 SLBMs for deployable ballistic missile submarines. Two other ballistic missile submarines are in refueling overhaul, for a total of 280 launchers. There are a total of 427 SLBMs in the inventory, of which about half are for spares and flight tests.

[h]All W76-0 warheads are thought to have been replaced on ballistic missile submarines by W76-1 warheads, but several hundred are still in storage, and more have been retired and are awaiting dismantlement. After the W76-1 life-extension program production is completed in FY2019, the remaining W76-0 warheads will be scrapped.

[i]The W76-2 is a single-stage low-yield modification of the W76-1 with an estimated yield of 5–7 kilotons.

[j]Of these SLBM warheads, approximately 890 are deployed on missiles loaded in ballistic missile submarine launchers.

[k]Of the 87 B-52s, 76 are in the active inventory. Of those, 46 are nuclear-capable.

[l]The first figure is the total aircraft inventory, including those used for training, testing, and back-up; the second is the portion of the primary-mission aircraft inventory estimated to be tasked with nuclear missions. The United States has a total of 66 nuclear-capable bombers (46 B-52s and 20 B-2s).

[m]Of these bomber weapons, only about 300 are deployed at bomber bases. These include an estimated 200 ALCMs at Minot Air Force Base and approximately 100 bombs at Whiteman Air Force Base. The remaining 550 weapons are in long-term storage. B-52s are no longer tasked with delivering gravity bombs.

[n]The F-15E can carry up to 5 B61s. Some tactical B61s in Europe are available for NATO DCAs (F-16, PA-200).

[o]Roughly 150 B61-3 and −4 bombs are deployed in Europe, of which about 80 are earmarked for use by NATO aircraft. The remaining 80 bombs are in central storage in the United States.

[p]Deployed warheads include approximately 1,300 on ballistic missiles (400 on ICBMs and 900 on SLBMs), 300 weapons at heavy bomber bases, and 150 nonstrategic bombs deployed in Europe.

differ from the estimates presented in this Nuclear Notebook, because the New START counting rules attribute exactly one warhead to each deployed bomber, even though US bombers do not carry nuclear weapons under normal circumstances.

Since the treaty entered into force in February 2011, the United States has reported cutting a total of 226 deployed launchers and 435 deployed strategic warheads. The Department of Defense has also completed the destruction of non-deployed launchers and conversion of 97 launchers to non-nuclear status, with a total of 800 deployed and non-deployed launchers remaining.

The 2018 Nuclear Posture Review states that the United States "will continue to implement the New START Treaty" while it remains in effect (Department of Defense 2018, 73). The treaty will remain in effect until February 2021, at

Table 2. US nuclear weapons by location.

Rank	State/Country	Warheads	Remarks
United States			
1	New Mexico	2,485[a]	Kirtland Underground Munitions and Maintenance Storage Complex (KUMMSC) Occasionally at Los Alamos National Laboratory Occasionally at Sandia National Laboratories
2	Washington	1,620[b]	Strategic Weapons Facility Pacific (SWFPAC) Naval Submarine Base Kitsap (SSBNs)
3	Georgia	1,100[c]	Strategic Weapons Facility Atlantic (SWFLANT) Naval Submarine Base Kings Bay (SSBNs)
4	North Dakota	350	91st Missile Wing silos for Minuteman III ICBMs Minot AFB weapons storage area (ICBMs/B-52s)
5	Montana	150	341st Missile Wing silos for Minuteman III ICBMs Malmstrom AFB weapons storage area
6	Missouri	100	Whiteman AFB weapons storage area
7	Texas	80	Pantex Plant (warhead assembly and dismantlement)[d]
8	Nebraska	72	90th Missile Wing silos for Minuteman III ICBMs
9	Colorado	44	90th Missile Wing silos for Minuteman III ICBMs
10	Wyoming	34	90th Missile Wing silos for Minuteman III ICBMs F.E. Warren AFB weapons storage area
11	California	few	Occasionally at Lawrence Livermore National Laboratory
Europe			
1	Turkey	50	Incirlik AB weapons storage vaults[e]
2	Italy	40	Aviano AB weapons storage vaults Ghedi AB weapon storage vaults
3	Belgium	20	Kleine Brogel AB weapon storage vaults
	Germany	20	
	Holland	20	Büchel AB weapon storage vaults Volkel AB weapon storage vaults

[a] This number includes 900 reserve warheads that are part of the Defense Department stockpile and 1,585 retired warheads awaiting dismantlement at the Pantex Plant. Of the retired warheads, roughly 1,070 were retired before 2009 and scheduled to be dismantled by 2022.
[b] This number includes an estimated 1,120 stockpiled warheads and 500 retired warheads awaiting shipment to Pantex for dismantlement.
[c] This number includes an estimated 800 stockpiled warheads and 300 retired warheads awaiting shipment to Pantex for dismantlement.
[d] Warheads are shipped to Pantex for maintenance, life-extension production, or disassembly and retirement. Although some 20,000 pits (plutonium cores) from previously retired weapons are stored at the plant, the number of intact warheads present at any given time is thought to be limited.
[e] There are unconfirmed rumors that the weapons have been withdrawn from Incirlik AB.

which point it may be extended for up to five years with mutual agreement. The Trump Administration has not yet indicated whether it will seek to extend the treaty; however, given National Security Advisor John Bolton's open disdain for arms control agreements, prospects for extension seem somewhat grim.

The Nuclear Posture Review

New START's entry into effect coincided with the completion, after a year of preparation, of the Trump administration's Nuclear Posture Review (NPR). The review was the first opportunity for the Trump administration to make its mark on US nuclear policy. It includes several important changes compared with the Obama administration's 2010 review.

The most significant change is what appears to be a renewed emphasis on increasing the types and role of US nuclear weapons. The Trump NPR takes a confrontational tone, presenting an assertive posture that embraces "Great Power competition" and including plans to develop new nuclear weapons and to modify others. The report backs away from the goal of seeking to limit the role of nuclear weapons to the sole purpose of deterring nuclear attacks and instead emphasizes "expanding" US nuclear options to deter, and, if deterrence fails, to prevail against both nuclear and "non-nuclear strategic attacks." To be clear, any use of a nuclear weapon to respond to a non-nuclear attack would constitute nuclear first-use.

The NPR explains that "non-nuclear strategic attacks include, but are not limited to, attacks on the US, allied, or partner civilian population or infrastructure, and attacks on US or allied nuclear forces, their command and control, or warning and attack assessment capabilities." (Department of Defense 2018, 21). US nuclear capabilities will be postured to "hedge against the potential rapid growth or emergence of nuclear and non-nuclear strategic threats, including chemical, biological, cyber, and large-scale conventional aggression." (Department of Defense 2018, 38).

To achieve these goals, the NPR states that "the United States will enhance the flexibility and range of its tailored deterrence options. . . . Expanding flexible US nuclear options now, to include low-yield options, is important for the preservation of credible deterrence against regional aggression," the report claims (Department of Defense 2018, 34).

The new tailored capabilities include modifying "a small number" of the existing W76-1 two-stage thermonuclear warheads to single-stage warheads by "turning off" the secondary to limit the yield to what the primary can produce (an estimated five to seven kilotons). This new capability, the NPR claims, is necessary to "help counter any mistaken perception of an exploitable 'gap' in US regional deterrence capabilities."

In the longer term, the NPR declares that the United States will "pursue a nuclear-armed" submarine-launched cruise missile to "provide a needed nonstrategic regional presence, an assured response capability, and [in view of] Russia's continuing. . . violation" of the Intermediate-Range

Nuclear Forces Treaty (INF Treaty), a response that itself is compliant with the treaty. In pursuit of this new missile, the review says "we will immediately begin efforts to restore this capability by initiating a requirements study leading to an Analysis of Alternatives … for the rapid development of a modern [submarine-launched cruise missile]." The report's authors believe that "US pursuit of a submarine-launched cruise missile may provide the necessary incentive for Russia to negotiate seriously a reduction of its nonstrategic nuclear weapons, just as the prior Western deployment of intermediate-range nuclear forces in Europe led to the 1987 [Intermediate-Range Nuclear Forces] Treaty." Despite these efforts to respond to Russia's INF treaty violation in a treaty-compliant manner, the Trump Administration in February 2019 announced its decision to withdraw from the INF Treaty. So far, though, all of the land-based weapons proposed to counter Russia are conventional (Sonne 2019).

The new nuclear "supplements" proposed by the NPR are needed, the authors say, to "provide a more diverse set of characteristics greatly enhancing our ability to tailor deterrence and assurance; expand the range of credible US options for responding to nuclear or non-nuclear strategic attack; and, enhance deterrence by signaling to potential adversaries that their concepts of coercive, limited nuclear escalation offer no exploitable advantage" (Department of Defense 2018, 35).

Yet the US arsenal already includes around 1,000 gravity bombs and air-launched cruise missiles with low-yield warhead options (Kristensen 2017a). The NPR provides no evidence that existing capabilities are insufficient, nor does it document that the yield of US nuclear weapons is a factor in whether Russia would decide to use nuclear weapons. The NPR authors simply claim that the new capabilities are needed. The US Navy used to have a nuclear submarine-launched cruise missile (the TLAM/N) but retired it in 2011 because it was redundant and no longer needed. All other nonstrategic nuclear weapons – with the exception of gravity bombs for fighter-bombers – have also been retired because there is no longer any military need for them, despite Russia's larger nonstrategic nuclear weapons arsenal. The idea that a US submarine-launched cruise missile could now motivate Russia to return to compliance with the Intermediate-Range Nuclear Forces (INF) Treaty is flawed. Russia embarked upon its current violation of the treaty at a time when the TLAM/N was still in the US arsenal, so it remains somewhat of a mystery why Russia would suddenly change its mind if the United States reintroduced a nuclear sea-launched cruise missile (SLCM) into its arsenal. Moreover, US Strategic Command has already strengthened strategic bombers' support of NATO in response to Russia's more provocative and aggressive behavior; 46 B-52 bombers currently are equipped with the air-launched cruise missile (ALCM), and both the B-52 and the new B-21 bomber will receive the new long-range standoff (LRSO) weapon, which will have essentially the same capabilities as the SLCM proposed in the NPR.

Russia's decisions about the size and composition of its nonstrategic arsenal appear to be driven by Washington's superiority in conventional forces, not by the US nonstrategic nuclear arsenal or by the yield of a particular weapon. Instead, pursuit of a new SLCM to "provide a needed nonstrategic regional presence" in Europe and Asia could – especially when combined with the parallel expansion of US long-range conventional strike capabilities – strengthen Russia's reliance on nonstrategic nuclear weapons and potentially trigger Chinese interest in such a capability.

Moreover, a new submarine-launched cruise missile would require installation of nuclear-certified storage and launch control equipment on the attack submarines that are assigned the new mission. Sea- and land-based personnel would need to be trained and certified to maintain and handle the weapons. These are complex and expensive logistical requirements that would further strain financial and operational resources in the Navy. Additionally, nuclear-capable vessels triggered frequent and serious political disputes during the Cold War when they visited foreign ports in countries that did not allow nuclear weapons on their territory; in the case of New Zealand, diplomatic relations have only recently – 30 years later – recovered from those disputes. Reconstitution of a nuclear SLCM would reintroduce this foreign relations irritant and needlessly complicate relations with key allied countries in Europe and Northeast Asia. These additional costs should be weighed against the benefits that the NPR's authors claim that a new submarine-launched cruise missile would provide.

Apart from these new "supplements" to the arsenal, the core focus of the NPR remains the same as in the 2010 review: to continue the massive modernization program – initiated under the Obama administration and known as "the program of record" – to replace or upgrade *(a)* all nuclear delivery systems (specifically: a new class of nuclear-powered ballistic missile submarines (SSBN), a new nuclear-capable strategic bomber, a new long-range air-launched cruise missile (LRSO), a new intercontinental ballistic missile (GBSD), and a new nuclear-capable tactical fighter-bomber aircraft (F-35A); (*b*) the command and control systems at the US Department of Defense; and (*c*) the nuclear warheads and their supporting infrastructure at the US Department of Energy's National Nuclear Security Administration. According to an estimate published in January 2019 by the US Congressional Budget Office (CBO), modernizing and operating the US nuclear arsenal and the facilities that support it will cost around

$494 billion for the period 2019–2028 (Congressional Budget Office 2019, 1). This is $94 billion more than CBO's 2017 estimate for the 2017–2026 period, in part because modernization programs continue to ramp up and cost estimates are increasing, and as a result of the NPR's call for new nuclear weapons.

The nuclear modernization (and maintenance) program will continue well beyond 2028 and, based on the CBO's estimate, will cost $1.2 trillion over the next three decades. Notably, although the CBO estimate accounts for inflation (Congressional Budget Office 2017), other estimates forecast that the total cost will be closer to $1.7 trillion (Arms Control Association 2017). Whatever the actual price tag will be, it is likely to increase. The NPR does not acknowledge the US is facing affordability issues in the modernization program but instead labels it "an affordable priority" and points out the total cost is only a small portion of the overall defense budget (Department of Defense 2018, XI). There is little doubt, however, that limited resources, competing nuclear and conventional modernization programs, tax cuts, and the rapidly growing deficit will present significant challenges for the nuclear modernization program.

Nuclear planning, nuclear exercises

So far, the changes in the Trump administration's Nuclear Posture Review do not appear significant enough to have required new guidance from the White House on nuclear weapons employment. The previous guidance, issued in 2013, also reaffirmed the importance of nuclear weapons and modernization and emphasized a strong counterforce strategy – planning principles that have already been incorporated into a host of highly flexible strategic and regional nuclear strike plans (Kristensen 2013a).

These strike plans are incorporated into a "family" of plans organized under the strategic "Operations Plan (OPLAN) 8010–12," and also into various regional plans. The OPLAN, which first entered into effect in July 2012, is flexible enough to absorb normal changes to the posture as they emerge, including those flowing from the NPR. In addition to nuclear forces, the strike plans also include conventional cruise missiles such as the Tactical Tomahawk submarine-launched cruise missile and the extended-range Joint Air-to-Surface Standoff Missile (JASSM-ER). The operational plan includes strike plans against Russia, China, North Korea, and Iran.

Gen. John Hyten – commander of Strategic Command – was asked in March 2017 whether he saw a need to expand nuclear options and deploy low-yield warheads on ballistic missiles. He appeared to respond in the negative (Hyten 2017a), telling Congress: "I can tell you that our force structure now actually has a number of capabilities that provide the president of the United States a variety of options to respond to any numbers of threats… ." In a lengthy interview with military reporters three weeks later, Hyten further explained:

> "I'll just say that the plans that we have right now, one of the things that surprised me most when I took command on November 3 was the *flexible options that are in all the plans today* (emphasis added). So we actually have very flexible options in our plans. So if something bad happens in the world and there's a response and I'm on the phone with the secretary of defense and the president and the entire staff, which is the attorney general, secretary of state, and everybody, *I actually have a series of very flexible options from conventional all the way up to large-scale nuke* that I can advise the president on to give him options on what he would want to do (emphasis added).
>
> So *I'm very comfortable today with the flexibility of our response options* (emphasis added). Whether the president of the United States and his team believes that that gives him enough flexibility is his call. So we'll look at that in the Nuclear Posture Review. But I've said publicly in the past that *our plans now are very flexible* (emphasis added).
>
> And the reason I was surprised when I got to [Strategic Command] about the flexibility, is because the last time I executed or was involved in the execution of the nuclear plan was about 20 years ago, and there was no flexibility in the plan. It was big, it was huge, it was massively destructive, and that's all there. *We now have conventional responses all the way up to the nuclear responses*, and I think that's a very healthy thing (emphasis added)" (Hyten 2017b).

To practice and fine-tune these plans – which, to accommodate a new low-yield SLBM warhead and a new submarine-launched cruise missile, would have to be updated – the armed forces conducted several nuclear strike exercises in 2018. These included Strategic Command's Global Thunder 19 exercise in October-November 2018, which practiced command and control of offensive nuclear strike operations across the globe, as well as Strategic Command's other mission areas across the United States. The exercise involved forces from Denmark, Canada, the United Kingdom, Australia, and South Korea (US Strategic Command Public Affairs 2018).

In 2018 and early 2019, US strategic bombers engaged in a variety of forward deployments, including B-52s, B-2s, and non-nuclear B-1s to Guam in January 2018 (Lamothe 2018); B-52s to Australia in November-December 2018 (Pacific Air Forces Public Affairs 2018); and B-2s to Hawaii in January 2019 (509th Bomb Wing Public Affairs 2019).

In March 2019, the Air Force deployed an unprecedented (in post-Cold War times) six B-52 bombers to the United Kingdom from where they flew missions over Europe from Norway, to the Baltic States, to Romania, to Greece, and to Morocco. Four of the six B-52s were nuclear-capable. The operations included a five-bomber operation over Norway (US Air Force Europe 2019a) and a four-bomber mission over the Baltic Sea (US Air Force Europe 2019b).

In noticeable contrast to other trends, annual large-scale US-South Korean military exercises – Foal Eagle and Key Resolve––were significantly scaled back in 2018 due to ongoing diplomacy efforts between the United States, South Korea, and North Korea. In a stark departure from previous years, the 2018 exercises did not include US nuclear-powered submarines, nuclear-powered aircraft carriers, or strategic bombers (Gady 2018). In March 2019, immediately following the Hanoi Summit, the United States and South Korea announced that these two annual strategic exercises will be cancelled and reorganized into a series of smaller exercises (Starr and Crawford 2019).

Land-based ballistic missiles

The US Air Force operates a force of 400 silo-based Minuteman III ICBMs split across three wings: the 90th Missile Wing at F.E. Warren Air Force Base in Colorado, Nebraska, and Wyoming; the 91st Missile Wing at Minot Air Force Base in North Dakota; and the 341st Missile Wing at Malmstrom Air Force Base in Montana. In addition to the 400 silos with missiles, another 50 silos are kept "warm" to load stored missiles if necessary. Each wing has three squadrons, each with 50 Minuteman III silos. They are collectively controlled by five launch control centers.

The 400 ICBMs carry one warhead each – either a 300-kiloton W87/Mk21 or a 335-kiloton W78/Mk12A. ICBMs equipped with the W78/Mk12A can be uploaded to carry three independently targetable warheads each, for a total of 800 warheads available for the ICBM force if necessary. The ICBMs completed a multibillion-dollar, decade-long modernization program in 2015 to extend the service life of the Minuteman III to 2030. Although the United States did not officially deploy a new ICBM, the upgraded Minuteman IIIs "are basically new missiles except for the shell," according to Air Force personnel (Pampe 2012).

An ongoing Air Force modernization program involves upgrades to the arming, fuzing, and firing component of the Mk21 re-entry vehicle, at a cost of slightly over a billion dollars in total. The publicly stated purpose of this refurbishment is to extend the vehicles' service life, but the effort appears to also involve adding a "burst height compensation" to enhance the targeting effectiveness of the warheads (Postol 2014). Priority is on replacement of the Mk21 fuze. A total of 693 fuze replacements were initially planned; however, the new fuzes will also reportedly be deployed on the Minuteman replacement missile – the GBSD – which means that the fuze modernization program is likely to expand significantly to accommodate those new missiles (Woolf 2018, 17). The effort complements a similar fuze upgrade underway to the Navy's W76-1/Mk4A warhead. The enhanced targeting capability might also allow for lowering the yield on future warhead designs.

In August 2017, the Air Force awarded $678 million worth of contracts to Boeing and Northrop Grumman to develop trade studies for the next-generation ICBM that is currently known as the Ground-Based Strategic Deterrent (GBSD). The Air Force will use these studies to specify GBSD requirements and release a final "request for proposals" in 2019–2020, following which it will select a missile design and award the development contract to the winner (Erwin 2018). The new missile is scheduled to begin replacing Minuteman IIIs in 2029 or 2030. The plan is to buy 666 missiles – of which 400 would be deployed, with the remainder used for test launches and as spares – at an estimated cost of $100 billion (Reif 2017). The Air Force says the GBSD will meet existing user requirements but have the adaptability and flexibility to be upgraded through 2075 (US Air Force 2016). The new missile is expected to have a greater range than the Minuteman III, making it possible to target not just Russia from the continental United States but also potentially China, North Korea, and Iran.

The payload section of the new GBSD "will use the existing Mk12A and Mk21 re-entry vehicles … in the single and multiple [re-entry vehicle] configurations," but with new fuzes for enhanced targeting capability (US Air Force 2015a). An estimated $3 billion contract is expected to be awarded in September 2019 to either Boeing, Lockheed Martin, Northrop Grumman, Raytheon, or Orbital ATK (which Northrup Grumman now owns) to integrate the Mk21 re-entry vehicle into the GBSD (Cohen 2018). To arm the GBSD, the Air Force and NNSA previously planned to life-extend the W78 as part of a controversial Interoperable Warhead (IW) program that would have combined ICBM and Navy warheads. Instead, the W78 Replacement Program is now called the W87-1 to reflect plans to "replacing the W78 with an IHE-based W87-1, using a well-tested IHE [Insensitive High Explosive] primary design" (Energy Department 2018b).

In 2018, the Minuteman III flight-testing program conducted five live launches, the first of which took

place on April 25th after a planned February test was postponed. A Minuteman III picked from F. E. Warren Air Force Base was launched from Vandenberg Air Force Base to deliver unarmed "test re-entry vehicles" some 6,759 kilometers (4,200 miles) to the Kwajalein Test Range in the Western Pacific (Scully 2018a).

The second test launch took place on May 14th, when a Minuteman III picked from Minot Air Force Base was launched from Vandenberg to the Kwajalein Test Range (Kelly 2018).

The third test launch took place on July 31st, when a Minuteman III picked from Malmstrom Air Force Base was launched from Vandenberg to the Kwajalein Test Range. However, the Mission Flight Control Officers terminated the flight as the missile was over the Pacific Ocean, due to an unknown malfunction (Scully 2018b).

The fourth test launch took place on August 2nd, when a Minuteman III picked from F.E. Warren Air Force Base was launched from Vandenberg to the Kwajalein Test Range (Air Force Global Strike Command 2018).

The final test launch of 2018 took place on November 6th at Vandenberg, followed by another on February 5th, 2019, when a Minuteman III picked from Minot Air Force Base was launched from Vandenberg to the Kwajalein Test Range (Scully 2019).

Nuclear-powered ballistic missile submarines

The US Navy operates a fleet of 14 Ohio-class ballistic missile submarines, of which eight operate in the Pacific from their base near Bangor, Washington and six operate in the Atlantic from their base at Kings Bay, Georgia. Normally, 12 of them are considered operational, with the remaining two boats in a refueling overhaul at any given time. But because operational submarines undergo minor repairs at times, the actual number at sea at any given time is closer to eight or 10. Four or five of those are thought to be on "hard alert" in their designated patrol areas, while another four or five boats could be brought to alert status in hours or days.

During 2017, the Navy completed a program to reduce the number of launch tubes on each submarine from 24 to 20. The reduction was part of the US implementation of the New START treaty limit on strategic launchers. The New START data for February 2018 counted a total of 280 SLBM launchers, or 14 submarines with 20 launchers each. Of these launchers, 203 were counted as deployed with a loaded SLBM, corresponding to 10 fully loaded boats, with one or two partially loaded (State Department 2018).

In 2017, the Navy also started loading the upgraded Trident II D5LE (LE stands for "life-extended") SLBM, which is equipped with the new Mk6 guidance system designed to "provide flexibility to support new missions" and make the missile "more accurate," according to the Navy and Draper Laboratory (Naval Surface Warfare Center 2008; Draper Laboratory 2006). The first missiles were loaded onto a boat in February 2017 and will gradually replace all existing Trident SLBMs on US and British ballistic missile submarines. The D5LE will also arm the new US Columbia-class and British Dreadnought-class ballistic missile submarines when they enter service, but will eventually be replaced with a new SLBM.

Each Trident SLBM can carry up to eight nuclear warheads, but normally carry an average of four or five warheads, for an average load-out of approximately 90 warheads per submarine. The payload of the different missiles on a submarine are thought to vary significantly to provide maximum targeting flexibility, but all deployed submarines are thought carry the same combination to maximize flexibility. Normally, 900 to 950 warheads are deployed on the operational ballistic missile submarines, although the number can be lower due to maintenance of individual submarines. The New START data from September 2018 showed there were 945 SLBM warheads deployed.

Three versions of two basic warhead types are deployed on SLBMs: 100-kiloton W76-0 (which is being retired), the enhanced W76-1 that appears to have a lower yield (possibly 90 kilotons) than the W76-0, and the 455-kiloton W88. The W76-1 is a refurbished version of the W76-0, apparently with slightly lower yield but with enhanced safety features added. The National Nuclear Security Administration announced in January 2019 that it has completed production of the W76-1 (Energy Department 2019a). The Mk4A reentry body that carries the W76-1 is equipped with a new arming, fuzing, and firing unit, with better targeting efficiency than the old Mk4/W76 system (Kristensen, McKinzie, and Postol 2017). Production has begun of a low-yield version of the W76-1 known as W76-2, which only uses the warhead fission primary to produce a yield of 5–7 kilotons. The First Production Unit of the W76-2 was completed at the Pantex Plant on February 22, 2019, and the full complement of warheads are scheduled for delivery to the Navy by the end of Fiscal Year 2019 (NNSA 2019). It is unknown how many W76-2 will be produced, but the NPR says it's a "small number" (Department of Defense 2018, 54), probably less than 50.

The Mk4A/W76-1 combination reportedly is also being supplied to the United Kingdom for use on its nuclear-powered ballistic missile submarines (Kristensen 2011b), although the warhead on the British subs is thought to be a slightly modified version of the W76.

Since 1960, US ballistic missile submarines have conducted approximately 4,100 deterrent patrols at sea. During the past 15 years, operations have changed significantly, with the annual number of deterrent patrols having declined by more than half, from 64 patrols in 1999 to approximately 26 patrols in 2015. Most submarines now conduct what are called "modified alerts," which mix deterrent patrol with exercises and occasional port visits (Kristensen 2013b).

While most ballistic missile submarine patrols last around 77 days, they can be shorter – or, occasionally, can last significantly longer. In June 2014, for example, the *Pennsylvania* (SSBN-735) returned to its Kitsap Naval Submarine Base in Washington after a 140-day deterrent patrol – the longest patrol ever by an Ohio-class ballistic missile submarine.

In contrast to the Cold War years, when the overwhelming majority of deterrent patrols took place in the Atlantic Ocean, today more than 60 percent of deterrent patrols normally take place in the Pacific, reflecting increased nuclear war planning against China and North Korea (Kristensen 2013b).

SSBNs normally do not visit foreign ports, but there are exceptions. Over a four-year period in the late 1970s and early 1980s, US SSBNs routinely conducted port visits to South Korea (Kristensen 2011a). Occasional visits to Europe, the Caribbean, and Pacific ports continued during the 1980s and 1990s. After Russia's invasion of Ukraine in 2014, the Navy has started to conduct one or two foreign port visits per year. A visit to Scotland in 2015 appeared to be a warning to Russia and was described as a US Navy plan to make ballistic missile submarines more visible (Melia 2015). A highly publicized visit to Guam in 2016 – the first visit to the island by a ballistic missile submarine since 1988 – was a clear warning to North Korea. Visits continued in 2017 and 2018 to Hawaii and Alaska.

Design of the next generation of ballistic missile submarines, known as the Columbia class, is well under way. This new class is scheduled to begin replacing the current Ohio-class ballistic missile submarines in the late 2020s. The Columbia class will be 2,000 tons heavier than the Ohio class and will be equipped with 16 missile tubes rather than 20. The Columbia program, which is expected to account for approximately one-fifth of the Navy's entire shipbuilding program during the mid-2020s to mid-2030s, is projected to cost $103 billion (Congressional Research Service 2018) – or an average of $8.1 billion to $8.6 billion per submarine. Navy officials said in late 2017 that they had managed to bring the average boat cost down to $7.21 billion (Eckstein 2017), although it remains to be seen if the projection will hold. A $5.1 billion development contract was awarded to General Dynamics Electric Boat in September 2017, with construction of the first boat scheduled for 2021 (US Navy 2017). General Dynamics expects to receive $75 billion in revenue over the life span of the Columbia-class project (Medici 2017).

The most recent tests of the Trident IID5 SLBM took place on March 26, 2018, when the Navy launched two missiles from the USS Nebraska (SSBN-739) in the Pacific Test Range, off the coast of Southern California. These launches marked the 166th and 167th successful test flights of the Trident II D5 SLBM since its introduction into the US arsenal in 1989 (Gutridge 2018).

Strategic bombers

The US Air Force currently operates a fleet of 20 B-2A bombers (all of which are nuclear-capable) and 87 B-52H bombers (46 of which are nuclear-capable). A third strategic bomber, the B-1, is not nuclear-capable. Of these bombers, we estimate that approximately 60 (18 B-2As and 42 B52Hs) are assigned nuclear missions under US nuclear war plans on a day-to-day basis. The New START data from February 2018 counted 49 deployed nuclear bombers (13 B-2As and 36 B-52Hs) (State Department 2018). The bombers are organized into nine bomb squadrons in five bomb wings at three bases: Minot Air Force Base in North Dakota, Barksdale Air Force Base in Louisiana, and Whiteman Air Force Base in Missouri.

Each B-2 can carry up to 16 nuclear bombs (the B61-7, B61-11, and B83-1 gravity bombs), and each B-52H can carry up to 20 air-launched cruise missiles (the AGM-86B). B-52H bombers are no longer assigned gravity bombs (Kristensen 2017b). An estimated 850 nuclear weapons, including 528 air-launched cruise missiles, are assigned to the bombers, but only about 300 weapons are thought to be deployed at bomber bases. The remaining 550 bomber weapons are thought to be in central storage at the large Kirtland Underground Munitions Maintenance and Storage Complex (KUMMSC) outside Albuquerque, New Mexico.

The United States is modernizing its nuclear bomber force by upgrading nuclear command and control capabilities on existing bombers; developing improved nuclear weapons (the B61-12 and the long-range standoff missile, or LRSO); and designing a new heavy bomber, the B-21 Raider.

Upgrades to the nuclear command and control systems that the bombers use to plan and conduct nuclear strikes include the Global Aircrew Strategic Network Terminal (Global ASNT) – a new high-altitude electromagnetic pulse–hardened network of fixed and mobile nuclear command and control terminals that provides wing command posts, task forces, munitions support

squadrons, and mobile support teams with survivable ground-based communications to receive launch orders and disseminate them to bomber, tanker, and reconnaissance air crews. Full operational capability for the Global Aircrew Strategic Network Terminal is expected in 2019.

Another command and control upgrade involves a program known as Family of Advanced Beyond Line-of-Sight Terminals (FAB-T), which replaces existing terminals designed to communicate with the MILSTAR satellite constellation. These new, extremely high frequency terminals are designed to communicate with several satellite constellations, including Advanced Extremely High Frequency satellites. FAB-T will provide protected high–data-rate communication for nuclear and conventional forces, to include what is officially called Presidential National Voice Conferencing. According to the Air Force (US Air Force 2015b), "FAB-T will provide this new, highly secure, state-of-the-art capability for [Department of Defense] platforms to include strategic platforms and airborne/ground command posts via MILSTAR, [Advanced Extremely High Frequency], and Enhanced Polar System (EPS) satellites. FAB-T terminals will also support the critical command and control … of the MILSTAR, [Advanced Extremely High Frequency], and EPS satellite constellations."

The heavy bombers are also being upgraded with improved nuclear weapons. This effort includes development of the first guided, standoff nuclear gravity bomb – known as the B61-12 – which is intended to replace all existing gravity bombs. The bomb will use a modified version of the warhead used in the current B61-4 gravity bomb. B61-12 integration drop tests have already been conducted from the B-2 bomber (and several tactical fighter jets). Approximately 480 B61-12 bombs, which appear to have earth-penetration capability (Kristensen and Matthew 2016), are expected to cost a total of roughly $10 billion, with the first production unit scheduled for March 2020 (Mehta 2018). The capability to launch B61-12s will be integrated into the F-35A's Block 4 software, which will be patched into existing F-35As in six month increments, concluding in 2023 (Roblin 2019).

The Air Force is also designing a new nuclear air-launched cruise missile known as the long-range standoff (LRSO) missile. It will replace the AGM-86B air-launched cruise missile in 2030 and carry the W80-4 warhead, a modified version of the W80-1 used in the current air-launched cruise missile. In February 2019, the Nuclear Weapons Council authorized Development Engineering (Phase 6.3) for the W80-4 (Energy Department 2019b). A solicitation invitation to defense contractors in 2015 listed three potential options for the LRSO engine: First, a derivative subsonic engine that improves on current engine technology by up to 5 percent; second, an advanced subsonic engine that improves on current technology by 15 percent to 20 percent; and third, a supersonic engine (US Air Force). In August 2017, the Air Force awarded 5-year contracts of $900 million each to Lockheed Martin and Raytheon to develop design options for the missile. In March 2019, the Air Force awarded Boeing a $250 million contract to integrate the future LRSO capability onto the B-52Hs, which is expected to be completed by the beginning of 2025 (Hughes 2019). Development and production are projected to reach at least $4.6 billion for the missile (US Air Force 2019) with another $10 billion for the warhead (Energy Department 2018a).

The missile itself is entirely new, with significantly improved military capabilities compared with the air-launched cruise missile, including longer range, greater accuracy, and enhanced stealth (Young 2016). This violates the White House pledge from 2010 (White House 2010) that the "United States will not … pursue … new capabilities for nuclear weapons" – but the Trump review appears to do away with such constraints.

Supporters of the LRSO argue that a nuclear cruise missile is needed to enable bombers to strike targets from well outside the range of the modern and future air-defense systems of potential adversaries and to provide US leaders with flexible strike options in limited regional scenarios. However, critics argue that conventional cruise missiles, such as the extended-range version of the Joint Air-to-Surface Standoff Missile (JASSM-ER), can currently provide standoff strike capability, and that other nuclear weapons would be sufficient to hold the targets at risk.

Unlike the current air-launched cruise missile, which is only carried by the B-52H bomber, the long-range standoff missile will be integrated on the B-52H and new B-21 bombers (Kristensen 2013c). Warhead production is scheduled from 2025 through 2031. The Air Force plans to buy 1,000 missiles (Reif 2015), but there will only be enough warheads for about half of those. The excess missiles are intended to be used as spares and for test flights over the course of the weapon's 30-year service life. Moreover, several hundred of the existing air-launched cruise missiles were converted to conventional missiles (AFM-86C/D), and US Air Force Global Strike Command has stated that "we fully intend to develop a conventional version of the [long-range standoff missile] as a future spiral to the nuclear variant" (Wilson 2015).

But given the deployment of several new long-range conventional cruise missiles and the development of even more advanced versions, it remains to be seen if the Air Force can persuade Congress to also pay for a conventional version of the LRSO. Indeed, the Air

Force has already decided to retire the existing conventional air-launched cruise missile and replace it with the extended-range conventional joint air-to-surface standoff missile (JASSM-ER). If Congress will not pay for conventional LRSOs, it can probably be assumed that the plan to buy 1,000 missiles can be reduced by several hundred.

Development of the new B-21 Raider next-generation heavy bomber continues at Northrop Grumman, with the preliminary design review receiving approval in early 2017. The B-21 is expected to enter service in the mid-2020s to gradually replace the B-1B and B-2 bombers during the 2030s and 2040s.

In early 2018, the Air Force Chief of Staff reportedly assessed that 175 B-21s would be necessary (Seligman 2018), and it was announced in May that the bombers would be hosted at Dyess Air Force Base (Texas), Ellsworth Air Force Base (South Dakota), and Whiteman Air Force Base (Missouri) (Secretary of the Air Force Public Affairs 2018). At an estimated $550 million per plane, 175 B-21s would cost a total of $96.25 billion; however, details about the B-21 program, including the cost estimate, are still shrouded in secrecy. Like all previous bomber programs, the cost estimate will most likely increase.

The B-21 is very similar in design to the B-2 but is expected to be slightly smaller and have a reduced weapons capability. Nuclear weapons will include the B61-12 guided nuclear bomb and the LRSO. The B-21 will also be capable of delivering a wide range of non-nuclear weapons, including the JASSM-ER cruise missile.

Nonstrategic nuclear weapons

The United States has one type of nonstrategic nuclear weapon in its stockpile – the B61 gravity bomb. The weapon exists in two modifications: the B61-3 and the B61-4. A third version, the B61-10, was retired in September 2016. Approximately 230 tactical B61 bombs of all versions remain in the stockpile. About 150 of these (versions –3 and –4) are through to be deployed at six bases in five European countries: Aviano and Ghedi in Italy; Büchel in Germany; Incirlik in Turkey; Kleine Brogel in Belgium; and Volkel in the Netherlands. This number has declined since 2009 partly due to reduction of operational storage capacity at Aviano and Incirlik (Kristensen 2015).

The Belgian and Dutch air forces (with F-16 aircraft), as well as the German and Italian air forces (with PA-200 Tornado aircraft), are assigned nuclear strike missions with US nuclear weapons. At least until 2010, Turkey was still using F-16s for the nuclear mission, although it is possible that the mission has since been mothballed. NATO states that do not host nuclear weapons can still participate in the nuclear mission as part of conventional supporting operations, known as SNOWCAT (Support Nuclear Operations With Conventional Air Tactics). Under normal circumstances, the nuclear weapons are kept under the control of US Air Force personnel; their use in war must be authorized by the US president. Concerns were raised about the security of the nuclear weapons at the Incirlik base during the failed coup attempt in Turkey in July 2016, and reports emerged in late 2017 suggesting that the weapons might have been "quietly removed" (Hammond 2017). These reports have not been confirmed, however, and Incirlik is still included in scheduled nuclear storage base upgrades. The remaining 80 B61s stored in the United States are for potential use by US fighter-bombers in support of allies outside Europe, including Northeast Asia.

NATO is working on a broad modernization of the nuclear posture in Europe that involves upgrading bombs, aircraft, and the weapons storage system. The B61-12 will be deployed to Europe beginning in 2022–2024, at which point the older B61-3 and B61-4 bombs will be returned to the United States. The B61-12 will use the nuclear explosive package of the B61-4, which has a maximum yield of approximately 50 kilotons, but it will be equipped with a guided tail kit to increase accuracy and standoff capability, which will allow strike planners to select lower yields for existing targets to reduce collateral damage. The increased accuracy will give the tactical bombs in Europe the same military capability as strategic bombs in the United States. The B61-12 also appears to have some earth-penetration capability, which increases its ability to hold at risk underground targets (Kristensen and Matthew 2016).

Work intended to integrate the B61-12 on F-15E, F-16, and PA-200 aircraft is well under way and the F-35A – with its incoming Block 4 software patch – is expected to become nuclear-certified with the B61-12 in 2024–2026.

Several of the NATO allies that currently have a nuclear strike mission plan to upgrade their fighter-bombers to the more capable and stealthy US-built F-35A. The Netherlands has already received its first F-35A training aircraft and the first Italian F-35A flew initially in September 2015. Belgium and Turkey are also acquiring the F-35A, although the Trump administration has now halted delivery of F-35As to Turkey because of its plans to acquire the Russian S-400 air-defense system. Germany officially rejected the F-35A in early 2019, in favor of purchasing either an upgraded Eurofighter Typhoon or the Boeing F/A-18E/F Super Hornet (Sprenger 2019).

NATO is also preparing a life extension of the Weapons Storage Security System over the next four years. The work will upgrade command and control and security at six active bases (Aviano, Büchel, Ghedi, Kleine Brogel, Incirlik, and Volkel) and one training base (Ramstein).

The Trump Nuclear Posture Review has recommended rapid development of a nuclear non-strategic submarine-launched cruise missile to recreate a capability to deploy such a weapon in support of NATO (and Pacific) allies. A previous cruise missile was retired in 2011. The new weapon would likely be intended for deployment on attack submarines. It remains to be seen if Congress will agree to fund the project.

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