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NUCLEAR NOTEBOOK

United States nuclear forces, 2018

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ABSTRACT
The US nuclear arsenal remained roughly unchanged in the last year, with the Defense Department maintaining an estimated stockpile of some 4,000 warheads to be delivered via ballistic missiles and aircraft. Most of these warheads are not deployed but stored, and many are destined to be retired. Of the approximately 1,800 warheads that are deployed, roughly 1,650 are on ballistic missiles or at 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 2018, the US Defense Department maintained an estimated stockpile of 4,000 nuclear warheads for delivery by more than 800 ballistic missiles and aircraft. Since September 2009, when the United States announced that the nuclear arsenal contained 5,113 warheads, the stockpile has decreased by 1,113. The most recent cut was announced in January 2017 by Joe Biden, then the vice president, who said the stockpile as of September 2016 had included 4,018 warheads (Kristensen 2017). Since January 2017, a small number of additional warheads has probably been retired, leaving a stockpile of approximately 4,000 warheads.

Most of the warheads in the stockpile are not deployed, but rather stored for potential upload onto missiles and aircraft if so decided. Many are destined for retirement. We estimate that approximately 1,800 warheads are currently deployed, of which roughly 1,650 strategic warheads are deployed on ballistic missiles and at bomber bases in the United States. Another 150 tactical bombs are deployed in Europe. The remaining warheads – approximately 2,200, or 55 percent of the total – 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.

In addition to the warheads in the Defense Department stockpile, approximately 2,550 retired but still intact warheads are stored under custody of the Energy Department and are awaiting dismantlement, for a total US inventory of roughly 6,550 warheads (see Table 1).

Implementing the New START treaty

After nearly seven years of implementation, the New START treaty entered into effect on 5 February 2018 – that is, the United States and Russia had been required by that date to meet the treaty's limits on strategic arms. But the United States reached the treaty's limits several months early. As of February 5, 2018, the United States reported that its nuclear arsenal included 1,350 deployed strategic warheads distributed among 652 deployed missiles and bombers – compared with March 2017, a decrease of 61 deployed strategic warheads and a decrease of 21 launchers. The changes reflect the removal of excess intercontinental ballistic missiles (ICBMs) from their silos, deactivation of excess launch tubes on several nuclear-powered ballistic missile submarines, and denuclearization of several excess B-52H bombers. Since the treaty entered into force in February 2011, the United States has reported cutting a total of 230 deployed launchers and 450 deployed strategic warheads. The Defense Department has also completed the destruction and denuclearization of non-deployed launchers, with a total of 800 deployed and non-deployed launchers remaining.

There are now 450 ICBM silos, in which 400 ICBMs and as many warheads are deployed. The 50 empty silos are "kept warm" so missiles can be reloaded if necessary. Several hundred additional warheads are also in storage for potential upload.

The US Navy has now reduced the number of missile tubes on each nuclear missile submarine to 20 from 24. New START data as of September 2017 showed a total of 280 launch tubes, of which 40 tubes on two subs were in overhaul and not part of the deployable force. The treaty data showed 212 deployed submarine-launched ballistic missiles (SLBMs), corresponding to 10 ballistic missile submarines fully loaded and two others in various stages of missile loading or offloading. Combined,

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Table 1. US nuclear forces, 2018.

Type/Designation	No.	Year deployed	Warheads x yield (kilotons)	Warheads (total available)[1]
ICBMs				
LGM-30G Minuteman III				
Mk-12A	200	1979	1–3 W78 x 335 (MIRV)	600[2]
Mk-21/SERV	200	2006[3]	1 W87 x 300	200[4]
Total	**400**[5]			**800**[6]
SLBMs				
UGM-133A Trident II D5/D5LE	240[7]			
Mk-4		1992	1–8 W76-0 x 100 (MIRV)	216[8]
Mk-4A		2008	1–8 W76-1 x 100 (MIRV)	1,320
Mk-5		1990	1–8 W88 x 455 (MIRV)	384
Total	**240**			**1,920**[9]
Bombers				
B-52H Stratofortress	87/44	1961	ALCM/W80-1 x 5–150	528
B-2A Spirit	20/16	1994	B61-7/-11, B83-1	452
Total	**107/60**[10]			**980**[11]
Total strategic forces				**3,700**
Nonstrategic forces				
F-15E, F-16 DCA	n/a	1979	1–5 B61-3, –4 bombs x 0.3–170[12]	300
Total				**300**[13]
Total stockpile				**4,000**
Deployed				1,800[14]
Reserve (hedge and spares)				2,200
Retired, awaiting dismantlement				**2,550**
Total Inventory				**6,550**

[1] Lists all warheads available for each weapon type. The DOD stockpile includes two warhead categories: active and inactive. Only a portion of the active are deployed.
[2] Roughly 200 of these are deployed on 200 Minuteman IIIs equipped with the Mk-12A re-entry vehicle. The rest are in central storage.
[3] The W87 was initially deployed on the MX/Peacekeeper in 1986 but first transferred to the Minuteman in 2006.
[4] There are a total of 540 W87s in the stockpile. The 200 Mk21-equipped ICBMs can each carry one W87. The remaining 320 W87s are in storage.
[5] Another 50 ICBMs are in storage for potential deployment in 50 empty silos.
[6] Of these ICBM warheads, 400 are deployed on operational missiles and the rest are in long-term storage.
[7] 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.
[8] 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.
[9] Of these SLBM warheads, approximately 890 are deployed on missiles loaded in ballistic missile submarine launchers.
[10] 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).
[11] 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 680 weapons are in long-term storage. B-52s are no longer tasked with delivering gravity bombs.
[12] The F-15E can carry up to 5 B61s. Some tactical B61s are available for NATO DCAs (F-16, PA-200).
[13] Roughly 150 B61-3 and -4 bombs are deployed in Europe, of which about 80 are earmarked for use by NATO aircraft. The remaining 150 bombs are in central storage in the United States.
[14] Deployed warheads include approximately 1,345 on ballistic missiles (400 on ICBMs and 945 on SLBMs), 300 weapons at heavy bomber bases, and 150 nonstrategic bombs deployed in Europe.

the submarines carried 945 warheads – an average of four to five warheads per missile, or nearly 90 warheads on each boat.

There are now 66 nuclear-capable bombers left, of which 60 are considered deployable (18 B-2s and 42 B-52s). The New START treaty data from September 2017 showed that only 49 (11 B-2s and 38 B-52s) were deployed at that time, with the remaining aircraft down for maintenance. A total of 41 B-52s have been converted to non-nuclear configurations to meet the goal of reducing deployed nuclear bombers to no more than 60 by 2018. Denuclearized B-52 bombers are being re-equipped with new long-range conventional cruise missiles. They are now participating in exercises alongside their nuclear-capable counterparts, and sometimes deploy on entirely non-nuclear bomber operations.

The new 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. The review is 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.[1]

The most significant change is what appears to be a shift away from seeking to reduce the number of US nuclear weapons and their role in US military strategy. Instead, the Trump review takes a more confrontational tone and presents an assertive posture that seeks to increase reliance on nuclear weapons. This shift entails plans to develop new nuclear weapons and modify others. The report backs away from the goal of establishing nuclear weapons' sole purpose as deterring nuclear attacks, and more forcefully emphasizes a role for nuclear weapons in deterring "non-nuclear strategic attacks" – even cyber attacks. To achieve that, the review declares (Defense Department 2018, 34) 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 new tailored capabilities include, if approved by Congress, in the short term, modifying "a small number" of W76-1 warheads on the Trident II D5LE SLBM to "ensure a prompt response option that is able to penetrate adversary defenses." This new capability, the report claims, is necessary to "help counter any mistaken perception of an exploitable 'gap' in US regional deterrence capabilities." The report's authors appear to be under the mistaken impression that Russia believes the United States would not use nuclear weapons if Russia did.

In the longer term, the review 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."

Combined, these "supplements" to the nuclear arsenal will, according to the authors of the review (Defense Department 2018, 35), "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."

Yet the review provides no evidence that existing capabilities are insufficient. It simply claims that the new capabilities are needed. The strategic situation in Europe today is very different than in 1987, as are the capabilities of the US military. 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, except gravity bombs for fighter-bombers, have also been retired. There was no longer any military need for them in regional scenarios. The idea that a US submarine-launched cruise missile could now motivate Russia to return to compliance with the Intermediate-Range Nuclear Forces 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, and why Russia would suddenly change its mind if the United States reintroduced a nuclear submarine-launched cruise missile is unclear. Moreover, US Strategic Command has already strengthened strategic bombers' support of NATO in response to Russia's more provocative and aggressive behavior; the bombers currently carry the air-launched cruise missile and will receive the new long-range standoff weapon, which will have essentially the same capabilities as the submarine-launched cruise missile. 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 weapons yield. Instead, pursuit of a new submarine-launched cruise missile to "provide a needed nonstrategic regional presence" in Europe and Asia could strengthen Russia's reliance on nonstrategic nuclear weapons and potentially even 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 battles. Reconstitution of a nuclear submarine-launched cruise missile would reintroduce this foreign relations irritant and needlessly complicate relations with key allied countries in Europe and Northeast Asia. These additional costs need to be weighed against the benefits that the review's authors claim a new submarine-launched cruise missile would provide.

Above and beyond these "supplements" to the arsenal, the overwhelming focus of the review 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 every weapon in the nuclear arsenal. Over the next decade, this program envisions spending $400 billion (a 15-percent increase over the previous estimate, from 2015) on modernizing and maintaining the nuclear arsenal and the facilities that support it (Congressional Budget Office 2017a). Costs required for maintaining and modernizing the nuclear forces would continue well beyond the next decade, requiring more than $1.5 trillion over the next 30 years. Modernization represents a substantial portion of this cost. The Congressional Budget Office estimates that the planned modernization would boost the total costs of US nuclear forces over 30 years by roughly 50 percent – compared to the costs of operating and sustaining only the forces that are already fielded (Congressional Budget Office 2017b). The scope of the modernization effort, which includes all aspects of the nuclear arsenal and the production complex that supports it, is extraordinary. Despite numerous warnings about the modernization program being unaffordable as currently structured, the NPR offers no ideas for resolving this serious challenge.

Whether Congress agrees to fund these expensive programs instead of building simpler and cheaper life-extended versions of existing designs remains to be seen. Moreover, significantly redesigning warheads to make them interoperable would challenge the pledge in the 2010 US Nuclear Posture Review Report (Defense Department 2010) that the United States "will not develop new nuclear warheads" but instead consider the "full range" of life-extension program options, including "refurbishment of existing warheads, reuse of nuclear components from different warheads, and replacement of nuclear components." This pledge was intended to prevent resumption of nuclear explosive testing and adhere to the 1996 Comprehensive Nuclear Test Ban Treaty. The report also stated that any life-extension programs "will use only nuclear components based on previously tested designs, and will not support … new military capabilities". Of course, compliance depends on how "new" military capabilities are defined, since the addition of new or improved features outside the nuclear explosive package may increase a weapon's military capabilities. It is anticipated that the United States will generally seek to increase the accuracy of its nuclear weapons to lower the yield of modified warheads, with improved performance margins.

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. 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 (Hyten 2017b):

> "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)."

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 2017. These included Strategic Command's Global Lightning 17 in February, a nuclear command and control exercise designed to ensure the resilience, redundancy, and survivability of US strategic deterrent forces, with a focus on Strategic Command's support of geographic combatant commanders during a crisis or contingency. The exercise scenarios were directed against a number of strategic threats across Strategic Command's mission areas and coincided with Austere Challenge 17, a computer-assisted, command-post exercise conducted by US European Command and designed to train multi-combatant command coordination in scenarios focused on European security. Hyten stated (US Strategic Command Public Affairs 2017) that Global Lightning 17 validated Strategic Command's "ability to rapidly respond together with decisive and overwhelming success in Europe, or to enable other combatant commands."

2017 was a very busy year for US strategic bombers; they engaged in a variety of forward deployments and long-range strike exercises to Northern Europe, the Western Pacific, and Australia. B-2 bombers conducted long-range strike sorties into the Mediterranean and Pacific in January, followed by a long-range B-52 strike exercise toward the Mediterranean in May. Non-nuclear B-1 bombers, recently equipped with the JASSM-ER conventional long-range cruise missile, conducted 15 integrated missions with nuclear B-52s near Australia and the South China Sea in January and February. This was followed by high-profile overflights of South Korea in March and August in response to North Korean missile test flights over Japan. In June 2017 – as part of the BALTOPS and Saber Strike exercises – all three types of heavy bombers deployed to the United Kingdom for regional deterrence operations over the Baltic Sea and Eastern Europe – the first time that all three heavy bomber types have been deployed to Europe at the same time. Some B-52s were intercepted by Russian fighters. The operations also included dual-capable F-16 fighter-bombers.

Finally, Strategic Command's Global Thunder exercise in October and November practiced command and control of offensive nuclear strike operations, as well as Strategic Command's other mission areas across the United States. Around the same time, B-52s deployed to Europe and B-2 bombers apparently simulated strikes against North Korea.

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).

A planned Air Force modernization program involves upgrades to the arming, fuzing, and firing component of the Mk12A and Mk21 re-entry vehicles. 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 are planned, at a cost of nearly $830 million. 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.

The Air Force is also upgrading the ICBM nuclear command and control system as part of a transition from the MILSTAR satellite constellation to new Advanced Extremely High Frequency satellites. This project involves upgrading launch control terminals at the launch control centers used to receive emergency action messages from the National Command Authority. The upgrade will provide "expansion in capability, enhanced operator control, and a state-of-the-art security architecture." It will significantly increase the speed of emergency-action-message transfer and enable the ICBM crews to communicate with both MILSTAR and Advanced Extremely High Frequency satellites. Initial operational capability apparently was reached in 2016 (Oakes 2015).

In August 2017, the Air Force awarded $678 million worth of contracts to Boeing and Northrop Grumman – contracts that represent a stage in the competition for the final contract to develop the next-generation ICBM currently known as the Ground-Based Strategic Deterrent. The new missile is scheduled to begin replacing Minuteman IIIs in 2029 or 2030. With the approval of Program Milestone A in August 2016, the Ground-Based Strategic Deterrent program officially moved into the "technology maturation and risk reduction" phase. 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 Ground-Based Strategic Deterrent 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 China, North Korea, and Iran.

The payload section of the new Ground-Based Strategic Deterrent "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 2015b). The Ground-Based Strategic Deterrent was previously scheduled to carry the first so-called interoperable warhead, which could also be used on the Navy's Trident SLBM, but the Trump Nuclear Posture Review does not explicitly mention the interoperable warhead or the complex "3 + 2" warhead plan it was part of, and instead lists a more generic-sounding "W78 warhead replacement," with an option to "investigate the feasibility of fielding the nuclear explosive package in a Navy flight vehicle" (Defense Department 2018, 39).

In 2017, the Minuteman III flight-testing program conducted three live launches and several simulated launches. During Strategic Command's Global Lightning 17 exercise, on February 8, a Minuteman III picked from Minot 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.

A second flight test took place on April 26, when a Minuteman III picked from F.E. Warren Air Force Base launched a single re-entry vehicle from Vandenberg Air Force Base approximately 6,759 kilometers (4,200 miles) to Kwajalein. The launch order was executed from the Airborne Launch Control System on board a Navy E-6B Mercury aircraft.

The third flight occurred on May 3, when a Navy E-6B Mercury jet launched a Minuteman III from Vandenberg Air Force Base. The missile, which was picked from an operational silo at F.E. Warren Air Force Base, delivered a single unarmed warhead approximately 6,759 kilometers (4,200 miles) to Kwajalein.

The fourth and final test took place on August 2, with a Minuteman III picked from F.E. Warren Air Force Base. The single re-entry vehicle apparently broke apart when it impacted the water in the Kwajalein lagoon some 6,759 kilometers (4,200 miles) away.

During the year, several simulated ICBM launches were also conducted. One of these involved six missiles "launched" from F.E. Warren Air Force Base by a Navy E-6B Mercury jet.

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 the 14 submarines are considered operational, with the remaining two boats in a refuelling 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 September 2017 counted a total of 280 SLBM launchers, or 14 submarines with 20 launchers each. Of these launchers, 212 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 may vary significantly to provide maximum targeting flexibility, but all deployed submarines are thought carry the same number and types of warheads. Normally, a total of around 900 to 1,000 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 2017 showed there were 945 SLBM warheads deployed.

Three versions of two basic warhead types exist for the SLBMs: the 100-kiloton W76-0, which is being phased out, the new 100-kiloton enhanced W76-1, and the 455-kiloton W88. The W76-1 is a refurbished version of the W76-0, with the same yield but with enhanced safety features added. Moreover, the Mk4A re-entry 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). Full-scale production of approximately 1,600 W76-1s is under way at the Pantex Plant in Texas, with roughly 85 percent already completed and with a scheduled finish date of 2019. We estimate that all W76 warheads deployed on ballistic missile submarines are now of the W76-1 design, and that all remaining W76-0s serve as hedge warheads and feedstock for W76-1 production. Once W76-1 production is complete, all remaining W76-0s will be retired and the W76 warhead stockpile will be reduced by a factor of two. The Trump review has proposed converting a "small number" of W76-1 warheads to low-yield capability, probably with a yield of around 5 kilotons, intended for limited strikes.

The Mk4A/W76-1 combination 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 the first deterrent patrol in 1960, US ballistic missile submarines have conducted some 4,070 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 take place in the Pacific, reflecting increased nuclear war planning against China and North Korea (Kristensen 2013b).

Over a four-year period in the late 1970s and early 1980s, US nuclear submarines routinely conducted port visits to South Korea (Kristensen 2011a). Occasional visits to Europe, the Caribbean, and Pacific ports continued during the 1980s and 1990s. These days, US ballistic missile submarines normally do not visit foreign ports, but since 2015, the Navy has started to conduct one or two public visits per year. A 2015 visit to Scotland was the first time since 2003 that a US ballistic missile submarine had visited a foreign port. The visits to Scotland, part of a US Navy plan to make ballistic missile submarines more visible (Melia 2015), began after Russia's invasion of Ukraine. They are intended to remind the Russian leadership and other adversaries about the nuclear security guarantee that US nuclear submarines provide to NATO and Pacific allies. 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 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.[2] 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 between $97 billion (Government Accountability Office 2016) and $103 billion (Congressional Budget Office 2015a) – 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 US Navy test-launched Four Trident II (D5) SLBMs from one ballistic missile submarine in 2017. As part of Follow-On Commander Evaluation Test number 53, the missiles were launched in the Pacific from the USS Kentucky (SSBN-737) over the course of three days. The event marked the final test launches of the original Trident II D5; from now on, all launches will test the new Trident II D5LE.

Strategic bombers

The US Air Force currently operates a fleet of 20 B-2 bombers (all of which are nuclear-capable) and 89 B-52H bombers (66 of which are nuclear-capable). A third strategic bomber, the B-1, is not nuclear-capable. Of these bombers, we estimate that approximately 60 (16 B-2s and 44 B-52Hs) are assigned nuclear missions under US nuclear war plans on a day-to-day basis. The New START data from September 2017 counted 49 deployed nuclear bombers. 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. An estimated 980 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 680 weapons are 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); and designing a new heavy bomber.

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 – 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 2015c), "FAB-T will provide this new, highly secure, state-of-the-art capability for [Defense Department] 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 begin replacing all existing gravity bombs beginning in the mid-2020s. 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.

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.[3] 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 2015a). In August 2017, the Air Force awarded contracts of $900 million each to Lockheed Martin and Raytheon to develop design options for the missile.

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 new long-range standoff missile 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.[4] Critics argue that conventional cruise missiles today can provide bomber 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, B-2, and new B-21 bombers (Kristensen 2013c). The cost of developing and producing the missile is on the order of $20 billion, with the first missiles scheduled for deployment in the late 2020s. 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 (Wilson 2015) that "we fully intend to develop a conventional version of the [long-range standoff missile] as a future spiral to the nuclear variant."

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 new long-range standoff missile.[5] 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 long-range standoff missiles, 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-2A bombers. The B-52H will be retained through 2050.

The Air Force in 2016 suggested it needed 175 to 200 B-21s. In early 2017, the military told Congress that it needed around 165, and in early 2018 the Air Force chief of staff reportedly assessed that the necessary number of B-21s was 175 (Seligman 2018). At an estimated $550 million per plane, 175 B-21s would cost $96.25 billion. 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 a little smaller and have slightly less weapons capability. Nuclear weapons will include the B61-12 guided nuclear bomb and the long-range standoff missile. 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 500 tactical B61 bombs of all versions remain in the stockpile. About 150 of these (versions −3 and −4) are 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 represents a unilateral reduction of 30 bombs since 2009.

The Belgian, Dutch, and possibly Turkish 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. Under normal circumstances, the weapons are kept

under the control of US Air Force personnel; their use in war must be authorized by the US president. The weapons 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 in the early 2020s, 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.[6] 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 will continue through at least 2018 (Kristensen 2014b). The F-35A is expected to become nuclear-certified with the B61-12 in 2024.

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 for the first time in September 2015. Turkey is also acquiring the F-35A, and Belgium is formally considering which replacement aircraft to get. The choice is between the F-35A, the Eurofighter, and the FA-18; the F-35A is a strong favorite. Germany does not currently have a plan to replace the PA-200 Tornado in the nuclear role, and although the German air force appears to favor the F-35A, the German parliament has not decided.

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).

NATO's annual nuclear strike exercise for dual-capable fighters was held at Kleine Brogel Air Base in Belgium and Büchel Air Base in Germany in October 2017. The exercise, known as Steadfast Noon, included aircraft from Belgium, the Czech Republic, Germany, Italy, the Netherlands, Poland, Turkey, and the United States. The Czech and Polish aircraft participated in a non-nuclear supporting role known as SNOWCAT.

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.

Notes

1. For a copy of the Trump administration's Nuclear Posture Review, as well as previous reviews and other related materials, see Federation of American Scientists (2018).
2. For overviews of the Columbia-class ballistic missile submarine program, see Brougham (2012) and O'Rourke (2016).
3. For background on the W80-4 and the long-range standoff program, see Kristensen (2014a).
4. For a review of official statements on the long-range standoff mission, see Kristensen (2015a).
5. For a comparison of the capabilities of the long-range standoff missile with advanced conventional cruise missiles, see Kristensen (2015b).
6. For analyses of the military implications of the enhanced B61-12, see Kristensen and Matthew (2016) and Kristensen (2011c).

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References

Brougham, W. J. 2012. "Ohio Replacement Program." Presentation to the 2012 Navy Submarine League, October 18. http://news.usni.org/news-analysis/documents/ohio-replacement-program

Congressional Budget Office. 2015a. "An Analysis of the Navy's Fiscal Year 2016 Shipbuilding Plan." October. 25. https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/50926-Shipbuilding-2.pdf

Congressional Budget Office. 2017a. "Projected Costs of US Nuclear Forces, 2017 to 2026." February. 1. https://www.cbo.gov/sites/default/files/115th-congress-2017-2018/reports/52401-nuclearcosts.pdf

Congressional Budget Office. 2017b. "Approaches for Managing the Costs of US Nuclear Forces, 2017 to 2046." October. 1. https://www.cbo.gov/system/files/115th-congress-2017-2018/reports/53211-nuclearforces.pdf

Defense Department. 2010. "Increasing Transparency in the US Nuclear Weapons Stockpile." Fact sheet, May 3. http://www.defense.gov/Portals/1/features/defenseReviews/NPR/10-05-03_Fact_Sheet_US_Nuclear_Transparency__FINAL_w_Date.pdf

Defense Department. 2018. "Nuclear Posture Review." February. https://fas.org/wp-content/uploads/media/2018-Nuclear-Posture-Review-Version-2.pdf

Draper Laboratory. 2006. "Keeping Trident Ever Ready." In *Explorations*, 8. Spring.

Eckstein, M. 2017. "Columbia Class Ballistic Missile Sub on Schedule, down to $7.2 Billion Apiece." *US Naval Institute News*, November 6. https://news.usni.org/2017/11/06/columbia-class-ballistic-missile-sub-schedule-7-2-billion-apiece

Federation of American Scientists. 2018. "2018 Nuclear Posture Review: FAS 2018 Nuclear Posture Review Resource," January. https://fas.org/issues/nuclear-weapons/nuclear-posture-review/

Government Accountability Office. 2016. "Defense Acquisitions: Assessment of Selected Weapon Programs." GAO-16-329SP. March. 124. http://www.gao.gov/assets/680/676281.pdf

Hyten, J. 2017a. "Testimony before the House Armed Services Committee on Military Assessment of Nuclear Requirements." March 8. https://www.youtube.com/watch?v=mRwWM6X5vNk&feature=youtu.be&t=5621

Hyten, J. 2017b. "Military Reporters and Editors Association Conference, Keynote Speech, US Strategic Command." March 31. http://www.stratcom.mil/Media/Speeches/Article/1153029/military-reporters-and-editors-association-conference-keynote-speech/

Kristensen, H. M. 2011a. "When the Boomers Went to South Korea." *FAS Strategic Security Blog*, October 4. https://fas.org/blogs/security/2011/10/ssbnrok/

Kristensen, H. M. 2011b. "British Submarines to Receive Upgraded US Nuclear Warhead." *FAS Strategic Security Blog*, April 1. http://fas.org/blog/security/2011/04/britishw76-1/

Kristensen, H. M. 2011c. "B61 LEP: Increasing NATO Nuclear Capability and Precision Low-yield Strikes." *FAS Strategic Security Blog*, June 15. http://fas.org/blogs/security/2011/06/b61-12/

Kristensen, H. M. 2013a. "New Nuclear Weapons Employment Guidance Puts Obama's Fingerprint on Nuclear Weapons Policy and Strategy." *FAS Strategic Security Blog*, June 30, 2013. http://fas.org/blogs/security/2013/06/nukeguidance/

Kristensen, H. M. 2013b. "Declining Deterrent Patrols Indicate Too Many SSBNs." *FAS Strategic Security Blog*, April 30. https://fas.org/blogs/security/2013/04/ssbnpatrols/

Kristensen, H. M. 2013c. "B-2 Stealth Bomber to Carry New Nuclear Cruise Missile." *FAS Strategic Security Blog*, April 22. https://fas.org/blogs/security/2013/04/b-2bomber/

Kristensen, H. M. 2014a. "W80-1 Warhead Selected for New Nuclear Cruise Missile." *FAS Strategic Security Blog*, October 10. http://fas.org/blogs/security/2014/10/w80-1_lrso/

Kristensen, H. M. 2014b. "B61-12 Nuclear Bomb Integration on NATO Aircraft to Start in 2015." *FAS Strategic Security Blog*, March 13. http://fas.org/blogs/security/2014/03/b61-12integration/

Kristensen, H. M. 2015a. "LRSO: The Nuclear Cruise Missile Mission." *FAS Strategic Security Blog*, October 20. https://fas.org/blogs/security/2015/10/lrso-mission/

Kristensen, H. M. 2015b. "Forget LRSO; JASSM-ER Can Do the Job." *FAS Strategic Security Blog*, December 16. https://fas.org/blogs/security/2015/12/lrso-jassm/

Kristensen, H. M. 2017. "Obama Administration Announces Unilateral Weapon Cuts." *FAS Strategic Security Blog*, January 11. https://fas.org/blogs/security/2017/01/obama-cuts/

Kristensen, H. M., and M. Matthew 2016. "Video Shows Earth-Penetrating Capability of B61-12 Nuclear Bomb." *FAS Strategic Security Blog*, January 14. https://fas.org/blogs/security/2016/01/b61-12_earth-penetration/

Kristensen, H. M., M. McKinzie, and T. A. Postol. 2017. "How US Nuclear Force Modernization Is Undermining Strategic Stability: The Burst-Height Compensating Super-Fuze." *Bulletin of the Atomic Scientists*, March 1. https://thebulletin.org/how-us-nuclear-force-modernization-undermining-strategic-stability-burst-height-compensating-super10578

Medici, A. 2017. "General Dynamics Sees $75B in Possible Revenue with Columbia Submarine Construction." *Washington Business Journal*, August 9. https://www.bizjournals.com/washington/news/2017/08/09/general-dynamics-sees-75b-in-possible-revenue-with.html

Melia, M. 2015. "Nuclear Subs Returning to Ports." *Associated Press*, December 21. http://www.usnews.com/news/us/articles/2015-12-21/apnewsbreak-port-visits-resume-for-nuclear-armed-navy-subs

Naval Surface Warfare Center. 2008. In *Underwater Wonder, Submarines: A Powerful Deterrent*, Warfighter Solutions, 14. Crane (Indiana): Crane Division of the Naval Surface Warfare Center.

Oakes, J. 2015."Nuclear Satellite Terminal Upgrade to Begin Operational Testing." *66th Air Base Group Public Affairs*,

January 14. http://www.af.mil/News/ArticleDisplay/tabid/223/Article/560193/nuclear-satellite-terminal-upgrade-to-begin-operational-testing.aspx

O'Rourke, R. 2016. "Navy Columbia Class (Ohio Replacement) Ballistic Missile Submarine (SSBN[X]) Program: Background and Issues for Congress." *US Congressional Research Service*, October 25. https://digital.library.unt.edu/ark:/67531/metadc958660/

Pampe, C. 2012. "Life Extension Programs Send Missiles into the Future." *US Air Force Global Strike Command*, October 26. http://www.afgsc.af.mil/news/story.asp?id=123323606

Postol, T. A. 2014. "How the Obama Administration Learned to Stop Worrying and Love the Bomb." *The Nation*, December 10. http://www.thenation.com/print/article/192633/how-obama-administration-learned-stop-worrying-and-love-bomb

Reif, K. 2015. "Air Force Wants 1,000 New Cruise Missiles." *Arms Control Today*, May 7. https://www.armscontrol.org/ACT/2015_05/News/Air-Force-Wants-Thousand-New-Cruise-Missiles

Reif, K. 2017. "New ICBM Replacement Cost Revealed." *Arms Control Today*, March. https://www.armscontrol.org/act/2017-03/news/new-icbm-replacement-cost-revealed

Seligman, L. 2018. Tweet dated January 18, 7:29 AM. https://twitter.com/laraseligman/status/954012855518617601

State Department. 2018. "New START Treaty Aggregate Numbers of Strategic Offensive Arms." Fact sheet, January 12 (effective date: September 1, 2017). https://www.state.gov/documents/organization/277683.pdf

US Air Force. 2015a. "Request for Information: Long Range Stand off (LRSO) Program." February 27, 2. https://www.fbo.gov/utils/view?id=3a2ff30fd5d499e00b94185aabc52c40

US Air Force. 2015b. "Request for Information (RFI) #1: Ground Based Strategic Deterrent." *Air Force Material Command, Solicitation Number FA8219-15-R-GBSD-RFI1*, January 23, 1. https://www.fbo.gov/?s=opportunity&mode=form&id=fd2b08860cc35f177778509964590ba4&tab=core&_cview=1

US Air Force. 2015c. Department of Defense Fiscal Year (FY) 2016 President's Budget Submission, Air Force Justification Book Volume 3b, Research, Development, Test & Evaluation, Air Force, Volume III, Part 2, February. 3b–27. http://www.saffm.hq.af.mil/Portals/84/documents/FY16/AFD-150309-012.pdf?ver=2016-08-24-100326-097

US Air Force. 2016. "AF Reaches First Milestone in Acquisition of New ICBM." *Air Force Nuclear Weapons Council Public Affairs Office*, September 1. http://www.kirtland.af.mil/News/Article-Display/Article/933565/af-reaches-first-milestone-in-acquisition-of-new-icbm

US Navy. 2017. "Navy Awards Contract for Columbia Class Submarine Development." September 21. http://www.navy.mil/submit/display.asp?story_id=102534

US Strategic Command Public Affairs. 2017. "USSTRATCOM, Allies, and Partners Conclude Global Lightning 17." February 17. http://www.stratcom.mil/Media/News/News-Article-View/Article/1088036/usstratcom-allies-and-partners-conclude-global-lightning-17/

White House. 2010. "Statement by President Barack Obama on the Release of Nuclear Posture Review." Office of the Press Secretary, April 6. https://obamawhitehouse.archives.gov/the-press-office/statement-president-barack-obama-release-nuclear-posture-review

Wilson, S. W. 2015. "Prepared Testimony before the Senate Armed Services Committee Strategic Forces Subcommittee." April 22. 13. http://www.armed-services.senate.gov/imo/media/doc/Wilson_04-22-15.pdf

Young, S. 2016. "Just How New Is the New, Nuclear-Armed Cruise Missile?" *Union of Concerned Scientists*, January 13. http://allthingsnuclear.org/syoung/the-new-cruise-missile