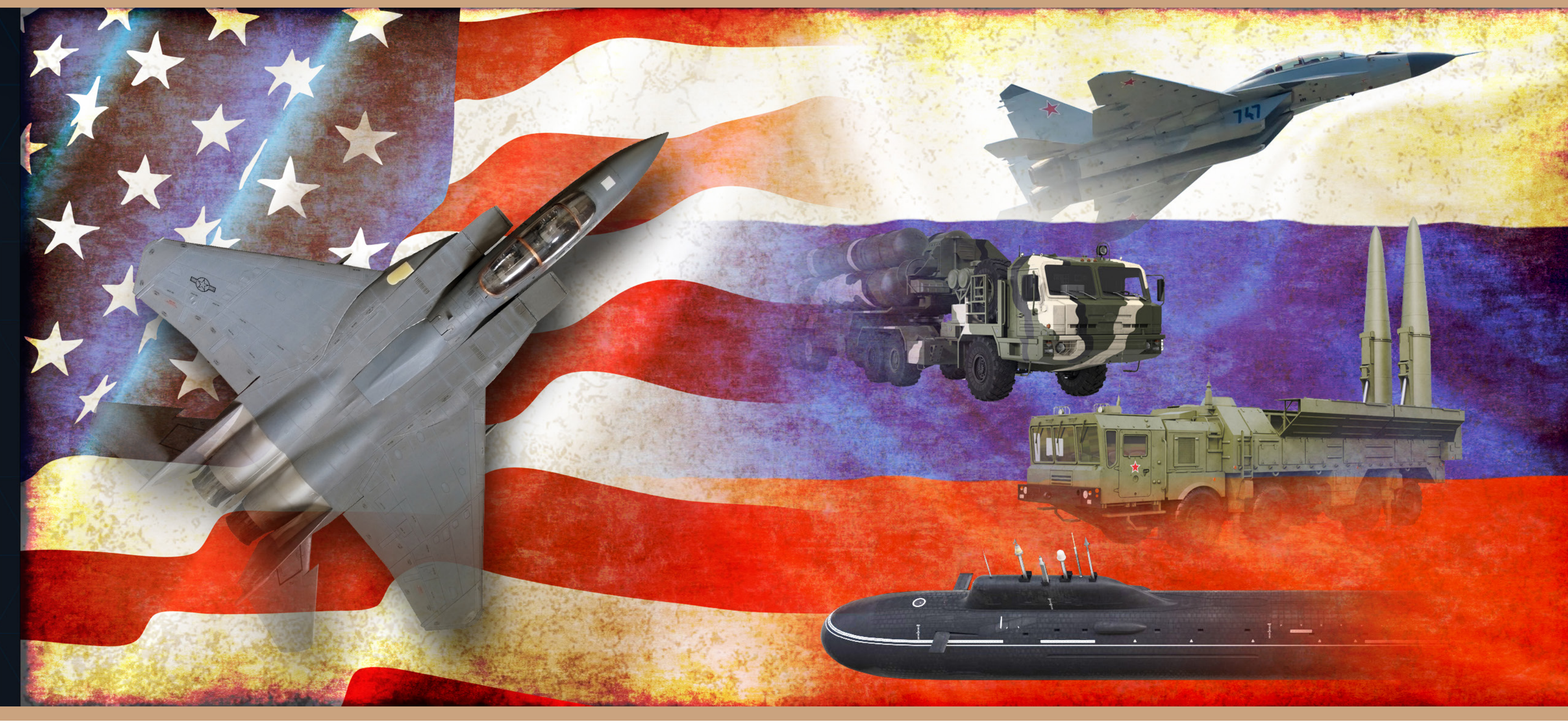
NONSTRATEGIC NUCLEAR FORCES

Moving beyond the 2018 Nuclear Posture Review

National Security Perspective



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The authors have performed classified analyses on many of the topics covered in this report. To request classified briefings, contact Dennis Evans (dennis.evans@jhuapl.edu or 240-228-6916), Jonathan Schwalbe (jonathan.schwalbe@jhuapl.edu or 240-228-6439), or Barry Hannah (barry.hannah@jhuapl.edu or 240-228-1024). These classified analyses included studying a wide variety of real, planned, and possible US weapons, and various foreign weapons, against a wide variety of real and notional targets. These classified analyses influenced the opinions and recommendations of the authors, but they do not lend themselves to simple, unambiguous conclusions or recommendations, apart from a clear need to *deter* enemy first use of nuclear weapons instead of *responding* to such usage.

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Table 1. Modified from George Ullrich, "US-Russian Nonstrategic Nuclear Weapons—A Troubling Numerical and Technological Asymmetry" (briefing, May 15, 2014; presented at the Potomac Foundation, July 2015).

Summary

The United States has had a triad of strategic nuclear weapons—land-based intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs) on ballistic missile submarines (SSBNs), and long-range bombers—since the early 1960s. These systems have been the subject of many arms-control treaties between the United States and the Soviet Union/Russia. In their current configuration, US strategic nuclear weapons serve primarily to deter Russia and China from initiating major nuclear wars against the United States and its allies.

Additionally, at one time, the United States and the Soviet Union each had many thousands of nonstrategic nuclear weapons (NSNWs)—of many types—that were not covered by any treaties until the Intermediate Nuclear Forces (INF) Treaty banned several types of US and Soviet weapons in 1987. These US weapons were intended to provide a fallback option against extremely powerful conventional aggression and to deter enemy use of nuclear weapons in a previously conventional war. The number and variety of US NSNWs has declined by more than 90 percent since the 1980s because of the INF Treaty and various unilateral decisions (such as the Presidential Nuclear Initiatives, or PNI, of 1991). By contrast, Russia still has a large force of NSNWs and is modernizing these weapons.

In addition to the imbalance in NSNW arsenal size, there are significant performance deficiencies in US NSNWs, which are limited to unguided bombs carried by non-stealthy short-range fighters at bases in NATO countries. In particular, the bases are vulnerable to preemptive attacks (large conventional attacks, small nuclear attacks, or both). Moreover, the aircraft have questionable survivability against modern air defenses and provide limited geographic coverage without aerial refueling, which is infeasible in contested airspace. Finally, unguided bombs have an uncertain ability to achieve high lethality against hard targets without causing major collateral damage.

Strategic bombers based in the continental United States can augment NSNWs in a regional war (in addition to playing a key role in conventional war), but they suffer from their own drawbacks in the nuclear role. Perhaps most worrisome, use of these bombers could invite a nuclear attack against their bases in the United States. In addition, bombers based in the United States provide a slow response (tens of hours). Moreover, for the nuclear mission, the B-2 is armed only with unguided bombs in the nuclear role (questionable ratio of lethality to collateral damage). Finally, the non-stealthy B-52 relies on the AGM-86 Air-Launched Cruise Missile (ALCM), which is nearing the end of its life and was not designed to penetrate state-of-the-art air defenses of the sort that modern adversaries will have in the 2020s.

Modernization efforts are under way to address some of the deficiencies in both strategic bombers and NSNWs on fighters. The Long-Range Standoff (LRSO) cruise missile is in the early stages of development as a replacement for the ALCM, and it will be carried by strategic bombers (the B-52 and the future B-21) starting in the 2030s. Thus, LRSO will likely bring some performance advantages over the AGM-86, but not in the near future. The B61-12 guided bomb is under development for use by the B-2, the F-35A, and the future B-21. The B61-12 will be more accurate than unguided bombs, and the F-35 will be more survivable than current nuclear-capable fighters, but the F-35 and the B-2 may have survivability issues against advanced air defenses in the future.

The situation is far different with Russia. Open-source estimates suggest that Russia has 1,000 to 6,000 NSNWs of many types, including a ground-launched cruise missile (GLCM) that violates the INF Treaty. Russia is modernizing its NSNWs, focusing on accurate, low-yield weapons. Moreover, many of these Russian systems

have improved survivability against a preemptive attack and improved in-flight survivability. Finally, Russia's nuclear doctrine has become more aggressive since Vladimir Putin became prime minister in 1999 and president in 2000. Hence, the United States is at a serious numerical and technological disadvantage in NSNWs relative to Russia, and Russia's doctrine is crafted to exploit this imbalance.

In addition, the United States has no NSNWs deployed in eastern Asia, whereas China has NSNWs (ballistic missiles), albeit in much smaller numbers and at a lower level of technical sophistication than Russian NSNWs. North Korea may also have a small number of primitive NSNWs. These additional imbalances are further cause for concern.

NSNWs received little US attention for decades, despite major Russian interest, until the 2018 Nuclear Posture Review (NPR). The 2018 NPR recommended that the United States develop a low-yield option for the Trident D5 SLBM and pursue a new nuclear sea-launched cruise missile (SLCM). The D5 would still be a strategic weapon that counts against treaty limits on strategic weapons, but the lower yield would make it more suitable for use in a regional war. In addition, the 2018 National Defense Authorization Act (NDAA) directed early development work on a new GLCM.

Given these developments, it is a good time to reexamine NSNWs and regional nuclear war at a level of detail beyond that of the 2018 NPR. Hence, in this report we address nuclear weapons that would be useful in limited regional nuclear war, even if they are nominally strategic or they would violate the INF Treaty. We compare capabilities of US and foreign NSNWs and evaluate various salient characteristics of potential US weapons. Additionally, we recommend that the United States consider various questions on NSNWs, including:

- Are there any conceivable circumstances under which the United States and NATO could "fight through" limited use of low-yield NSNWs and still win a war with conventional weapons? If so, would this lead to success or only to larger-scale foreign use of nuclear weapons?
    - While an assessment can and should be made regarding our ability to "fight through" limited use of low-yield NSNWs, it is the second question that is most significant for future conflicts. That question cannot be definitively answered, due in part to the inability to predict the political and psychological repercussions from even the most limited use of nuclear weapons. Hence, it is highly desirable, if not imperative, to *deter* first use of NSNWs by any plausible nuclear-armed adversary.
- Does Russia derive significant advantages from its superiority in NSNWs? If the answer is yes, should the United States improve its offensive capabilities in NSNWs, take steps to reduce vulnerabilities to small-scale nuclear attacks, or both?
    - Again, no definitive answers are possible, for the same reasons stated above. We believe that the answer to the first question is yes, and discussions in the 2018 NPR report suggest the same.
    - We also believe that the United States should improve its offensive capabilities for limited nuclear war (as endorsed in the NPR) and take steps to reduce vulnerabilities to small nuclear attacks (especially attacks employing cruise missiles, due to Russia's emphasis on these weapons), while continuing to examine the myriad aspects of improved NSNWs (utility, cost, technical difficulty, offense–defense synergy, political issues, etc.).[1]

[1] The NPR did not consider improved defenses against small nuclear attacks, even though such defenses could be highly synergistic with improvements in US nuclear capabilities.

Any decision to develop improved weapons should be preceded by analysis on how they might contribute to deterrence, whether allies would agree to basing rights (where relevant), and how they might be used in a war if the United States had them. Further, although there is nothing unreasonable about the two new capabilities recommended in the NPR report (a low-yield warhead for the Trident D5 and a new nuclear SLCM), more thorough analyses could refine the path forward and possibly identify alternative or additional nuclear (and defensive) capabilities to pursue.

While we believe these additional analyses are important to defining the best path forward, a few considerations for future NSNWs seem clear. For example, weapons at sea would avoid the need for foreign bases; because sea basing would be more survivable than basing on land close to a powerful adversary, we see them as the preferred approach. However, the United States should also consider measures to increase the effectiveness of nuclear-capable fighters at existing bases, such as standoff weapons and better base defenses for fighters in Europe, along with higher readiness for nuclear-capable fighters, more realistic exercises, and dispersal plans for these fighters. Improved weapons for strategic bombers—such as an accurate, low-yield penetrator bomb—could also be valuable.

Table S-1 summarizes strong and weak points for several possible new types of weapons, three of which were endorsed in either the 2018 NPR or the 2018 NDAA. The table also includes three other weapons that we believe are worthy of consideration. The main body of this report discusses additional types of weapons.

The discussions above deal mainly with delivery systems. We assumed that suitable warheads would be available, but this may not be the case, especially before 2030 and/or without production capability and capacity improvements for the National Nuclear Security Administration (NNSA). It is not clear whether NNSA can meet the schedule for planned warhead life extensions and dismantlements. If the requirement were expanded to provide warheads for new, more, or different delivery systems, the production challenges would likely be overwhelming.[2] Hence, improvements in nuclear weapons need to be coupled with upgrades to NNSA's capability and capacity.

In conclusion, we do not know the answers to all the questions posed in this report, but we believe that NSNWs are important and are likely to remain important in the 2030s. Thus, it is time to think seriously about NSNWs again, and about the health of the US nuclear warhead infrastructure. The 2018 NPR called attention to these issues, but we need to do more analysis on both policy considerations and technical issues (in particular, the most desirable offensive and defensive capability enhancements to pursue).

2 NNSA, *Fiscal Year 2017 Stockpile Stewardship and Management Plan—Biennial Plan Summary*; and NNSA, *Fiscal Year 2018 Stockpile Stewardship and Management Plan—Report to Congress.*

Table S-1. Military Benefits and Other Factors for Potential New Weapons

Parameter[a]	Cruise Missile on		GLCM in Europe	Heavy Penetrator Bomb on B-2	B61-12 Nuclear Bomb on F-35C	Low-Yield Reentry Vehicle on Trident D5
	Attack Submarine	F-35A				
Earliest availability (approximate)	2030	2030	2030	2027	2027	2023
Less need for vulnerable bases	Yes	Maybe	Maybe[b]	Same as the B-2 with the B61-12	Yes	Yes
Less need for foreign approval	Yes	No	No		Yes	Yes
Faster response	Yes	No	Maybe[b]		In Asia	Yes
Improved prelaunch survivability	Yes	No	Maybe[b]		Yes	Yes
Improved in-flight survivability	Yes	Yes	Yes		Maybe[c]	Yes
Improved target coverage	Yes	Yes	Maybe[d]		Yes	Yes
Improved lethality	Maybe[d]	Maybe[d]	Maybe[d]	Yes, major	No	No
Reduced collateral damage	Maybe[d]	Maybe[d]	Maybe[d]	Yes, major	No	Doubtful
Technical challenges	Medium–low	Medium–low	Medium–low	Medium–high	Low	Low
INF violation	No	No	Yes	No	No	No
New START violation	No	If range > 600 km	No	No	No	No
PNI violation	Yes	No	No	No	Yes	No
Political controversy	Medium	Medium	Very high	Medium	Medium	Medium–high
Overall desirability	High	Medium	Low	Medium	Medium	Medium

[a] Improvements are measured relative to the program of record in about 2025 (the AGM-86 ALCM on the B-52 plus the B61-12 bomb on fighters and the B-2). Improvements are *not* measured relative to current ICBMs or SLBMs.

[b] If deployed in the field at the start of a war.

[c] Depends on the enemy.

[d] Depends on the technical characteristics achieved for the weapon (yield, accuracy, range, etc.). Target coverage for a GLCM would also depend on the available bases and launch sites.

The United States has had a strategic triad of land-based intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs) on ballistic missile submarines (SSBNs), and long-range nuclear-capable bombers since the early 1960s. These systems have received considerable attention and have been the subject of many arms-control treaties between the United States and Russia (or the Soviet Union). In their current configuration, US strategic nuclear weapons serve primarily to deter Russia and China from initiating major nuclear wars against the United States and its allies.

Additionally, at one time, the United States and the Soviet Union each had many thousands of nonstrategic nuclear weapons (NSNWs)—of many types—that were not covered by any treaties until the Intermediate Nuclear Forces (INF) Treaty banned several types of US and Soviet weapons in December 1987. From the United States' standpoint, these weapons were intended to provide a fallback option against extremely powerful conventional aggression and to deter enemy use of nuclear weapons in a previously conventional war. Types of US and Soviet NSNWs in the 1980s included:

- Mobile intermediate-range ballistic missiles (IRBMs) with ranges shorter than those of ICBMs
- Cruise missiles launched from ground vehicles, surface ships, and attack submarines (SSNs)
- Surface-to-air missiles, both land-based and sea-based, and land-based ballistic missile defense (BMD) interceptors
- Air-to-air missiles
- Various types of air-to-ground weapons on tactical aircraft
- Torpedoes, depth charges, anti-ship missiles, and other naval weapons
- Battlefield nuclear weapons (such as artillery, short-range rockets, and land mines)

Land-based intermediate-range nuclear weapons were a topic of great controversy and attention in the 1980s. The Soviet Union deployed SS-20 IRBMs and, despite major European demonstrations against US nuclear weapons, the United States deployed the BGM-109G Gryphon ground-launched cruise missile (GLCM) and the Pershing II IRBM in Europe in 1983. These developments led to the INF Treaty, which banned ground-launched IRBMs and GLCMs (both conventional and nuclear). Figure 1 shows the three most advanced and, possibly, most controversial weapons banned by the INF Treaty.

The number and variety of US NSNWs has declined drastically since the 1980s, and US NSNWs now consist only of unguided B61 bombs carried by non-stealthy short-range fighters deployed at several bases in NATO countries. The United States does not have any NSNWs that could be used on short notice in eastern Asia, and certain US strategic weapons may be of limited use throughout most of Asia because of their need to fly over Russia, China, or both and the large number of casualties they would cause in most cases.

Russia, by contrast, continues to emphasize NSNWs. Various sources estimate that Russia has 1,000 to 6,000 NSNWs of many types and is modernizing them.[1] In addition, in the 1990s, Russia abandoned the Soviet pledge of "no first use of nuclear weapons." It has since adopted a more aggressive doctrine with ambiguous conditions for its use of nuclear weapons. Russia might be increasing its emphasis on NSNWs in an effort to compensate for weaknesses in its conventional military.

Meanwhile, India, Pakistan, and China have deployed NSNWs and are increasing the size of their nuclear arsenals. North Korea will almost certainly have NSNWs by 2020, and it may have a few already.

[1] Kristensen and Norris (in "Russian Nuclear Forces, 2016") estimate the number at 2,000. See also Woolf, *Nonstrategic Nuclear Weapons*.

US BGM-109G Gryphon GLCM (top left), Soviet SS-20 Saber IRBM (bottom left), and US Pershing II IRBM (right).

Figure 1. The Three Most Advanced and, Possibly, Most Controversial Weapons Banned by the INF Treaty

Hence, it is a good time to examine this entire family of weapons. NSNWs had received little US attention in decades until the last year or so. Although the 2002 Nuclear Posture Review (NPR) did not lead to an unclassified report, a significant amount of public discussion followed it, with almost no mention of NSNWs.[2] The 2010 NPR report contains minimal references to NSNWs. The 2018 NPR, by contrast, discusses NSNWs at length and highlights regional imbalances of the sort discussed in this report. The following direction is in the report's executive summary:[3]

> In the near-term, the United States will modify a small number of existing SLBM warheads to provide a low-yield option, and in the longer term, pursue a modern nuclear-armed sea-launched cruise missile (SLCM). Unlike DCA,[4] a low-yield SLBM warhead and SLCM will not require or rely on host nation support to provide deterrent effect. They will provide additional diversity in platforms, range, and survivability, and a valuable hedge against future nuclear "break out" scenarios.

The 2018 NPR does not discuss the full range of possible new NSNWs and other nuclear enhancements that the United States could pursue, nor does it explain why these two weapons were assessed to be the most desirable, nor does it discuss how improved defenses might enhance the effectiveness of US NSNWs. This report, on the other hand, discusses a

[2] A concept known as the new triad played a major role in the 2001–2002 NPR. See Frankel, Scouras, and Ullrich, *New Triad*.

[3] US Department of Defense, *Nuclear Posture Review February 2018*, XII. The main body of the NPR devotes several pages to NSNWs, but this excerpt from the executive summary identifies the two weapons chosen for development. It is clear from the overall discussion that the low-yield SLBM refers to a low-yield warhead in an existing ballistic (no terminal guidance) reentry vehicle for the Trident D5 SLBM. The 2018 NPR also discusses nuclear command, control, and communications in more detail than did the 2010 document.

[4] [DCA stands for dual-capable aircraft and refers to US and NATO fighters that can carry nuclear bombs. The term should also apply to bombers but is seldom used in that context.]

wide range of possible US nuclear enhancements and their relative strengths and weaknesses, and recommends future analyses on offense–defense synergies.

A 2017 report by Frankel, Scouras, and Ullrich discusses NSNWs in considerable detail.[5] This current report would best be read in conjunction with that earlier report. Frankel, Scouras, and Ullrich focus heavily on the impact of Russian NSNWs on the situation in Europe, and they consider topics including the following:

- Doctrinal and modernization-related developments during the time between the breakup of the Soviet Union and the 2010 NPR
- The US mind-set at the time of the 2010 NPR
- Adverse developments since 2010, including Russia's aggression in Ukraine and its continuing modernization of NSNWs
- Considerations for the then-upcoming 2017–2018 NPR
- Options to compensate for asymmetries in NSNWs in Europe

The current report covers technical issues regarding NSNWs—including discussion on which NSNWs would be most advantageous to procure, if the nation decides to increase its capabilities in this mission—as well as issues pertaining to NSNWs in the Pacific. This report is organized as follows:

- Arms control and the definition of NSNWs used in the report
- Desirable characteristics of NSNWs
- Current nuclear arsenals and the imbalances in Europe and eastern Asia
- Candidate US weapons for use in limited regional nuclear war
- Issues pertaining to the availability of suitable warheads for new weapons
- Conclusions and observations

Arms-Control Treaties and the Definition of Nonstrategic Nuclear Weapons

The United States and Russia are governed by two treaties limiting the size and nature of their nuclear arsenals: the New Strategic Arms Reduction Treaty (START) and the INF Treaty. No other country faces any restrictions on the size or nature of its nuclear arsenal, apart from prohibitions against nuclear proliferation,[6] and no other country needs to distinguish between strategic nuclear weapons and NSNWs.[7]

The New START Treaty, which may expire in 2021, uses the following definitions:

- *Ballistic missile* means a weapon-delivery missile that follows a ballistic trajectory over most of its flight path.
- *Cruise missile* means an unmanned, self-propelled aerial weapon-delivery vehicle that uses aerodynamic lift to sustain flight over most of its one-way flight path.
- *ICBM* means a land-based ballistic missile, even if purely conventional, with a maximum range exceeding 5,500 kilometers.
  - Ambiguities could arise if a missile can carry more than one reentry vehicle and it has a range of more than 5,500 kilometers with one

[5] Frankel, Scouras, and Ullrich, *Nonstrategic Nuclear Weapons at an Inflection Point*. Also see Ullrich, Scouras, and Frankel, "Nonstrategic Nuclear Weapons: The Neglected Stepchild."

[6] Many countries have forsaken the acquisition of nuclear weapons per the Nuclear Non-Proliferation Treaty. Under this treaty, the original five nuclear powers have agreed not to assist other countries to develop or otherwise acquire nuclear weapons.

[7] Because nominally strategic weapons might be used in limited regional nuclear war, especially if they provide high accuracy combined with low-yield options, it is important to understand limitations imposed by New START.

reentry vehicle but less than 5,500 kilometers with multiple vehicles or a heavier vehicle.

- *SLBM* means a submarine-launched ballistic missile, even if purely conventional, with a range exceeding 600 kilometers.
  - A nuclear ballistic missile on a surface ship would not be banned by any treaty and would not count against New START limits unless the relevant type of missile had also been carried by a submarine. The earlier START Treaty had no such loophole.
- *Heavy bomber* means a nuclear-capable aircraft with a one-way range exceeding 8,000 kilometers or any aircraft (regardless of range or weapons load) that carries a nuclear cruise missile with a range exceeding 600 kilometers.
  - An aircraft can carry conventional cruise missiles of any range without counting against New START limits.

New START limits the United States and Russia to 700 "deployed strategic delivery vehicles," 800 "total strategic delivery vehicles," and 1,550 "deployed strategic nuclear warheads." Each operational heavy bomber, ICBM, or SLBM counts as one deployed strategic delivery vehicle. Each usable, but empty, ICBM silo counts as one total strategic delivery vehicle. Each empty SLBM tube on an SSBN in long-term overhaul also counts as one total strategic delivery vehicle. Each heavy bomber in long-term maintenance counts as one total strategic delivery vehicle. Each operational heavy bomber counts as one deployed strategic nuclear warhead. New START places no limits on the number or nature of weapons carried by heavy bombers or on land-based or sea-based nuclear cruise missiles. An operational ICBM or SLBM with *N* warheads counts as *N* operationally deployed nuclear warheads, even if all the warheads are conventional.

The INF Treaty uses the same definitions as New START, and it bans the United States and Russia from having ground-launched IRBMs or GLCMs, even if conventional, with a maximum range between 500 and 5,500 kilometers. When the INF Treaty was signed in 1987, the United States and the Soviet Union had a near monopoly on intermediate-range ground-launched missiles, and all missiles of the sort banned by the treaty were, in fact, nuclear. Unfortunately, technology has marched on since 1987, and this treaty has had unintended consequences: China, Iran, and North Korea all possess sizable arsenals of conventional missiles of the sort that this treaty denied to the United States and Russia, with the Chinese arsenal being by far the largest and most advanced. China, India, Pakistan, and, possibly, North Korea have small numbers of intermediate-range nuclear missiles.

After the 1987 INF Treaty banned a wide range of land-based missiles, the United States went on to unilaterally eliminate all nuclear weapons at sea (except SLBMs) as part of the 1991 Presidential Nuclear Initiatives (PNI). In particular, the United States withdrew its nuclear SLCMs from service and eventually dismantled them during the Obama administration. Soviet President Mikhail Gorbachev pledged to take similar actions, but there was no treaty to this effect. Russia has retained and modernized NSNWs at sea, including SLCMs.

There is no simple, universally accepted definition for the term *nonstrategic nuclear weapon*. This report addresses nuclear weapons (some of which would violate the INF Treaty) that could be deployed by the United States without having to be counted against New START limits. This is essentially the "definition by exclusion" Woolf describes in a recent Congressional Research Service report on NSNWs.[8]

The current report also examines weapons—even nominally "strategic" weapons—that would be useful against geographically small adversaries (either for deterrence or for responding to first use of nuclear weapons) and weapons that would be useful for

[8] Woolf, *Nonstrategic Nuclear Weapons.*

deterring or responding to small-scale regional use of low-yield nuclear weapons. Hence, the scope of this report is broader than might be implied by its title and includes the future Long-Range Standoff (LRSO) nuclear cruise missile for bombers and modern Russian cruise missiles on bombers.[9] Examples of weapons of these types include the following:

- Weapons for heavy bombers[10]
- Air-launched weapons, with a range of less than 600 kilometers, for fighters[11]
- Nuclear-capable aircraft with a one-way range less than 8,000 kilometers and that do not carry any nuclear weapon with a range exceeding 600 kilometers[12]
- Land-based ballistic missiles with a range less than 5,500 kilometers
- GLCMs
- Nuclear SLCMs
- Surface-to-air missiles, BMD interceptors, and air-to-air missiles
- Short-range battlefield or naval weapons

This report presents analyses relevant to deciding whether the United States should maintain, expand, or improve its NSNWs (and nominally strategic weapons that might be useful in a regional role). In case the United States decides to expand its NSNWs, the report also examines which elements the United States should emphasize for any new NSNWs—more force structure, more survivable basing, or better technical characteristics of the weapons themselves.

Desirable Characteristics of Nonstrategic Nuclear Weapons

After much discussion, subject matter experts in the National Security Analysis Department and the Force Projection Sector of the Johns Hopkins University Applied Physics Laboratory suggest that desirable characteristics for NSNWs include the following:

- The ability to respond rapidly when and where needed
- Sufficient range to reach the vast majority of plausible targets, preferably in a manner that has little risk of being misconstrued as an attack on a great power that is not the object of the attack
- Good prelaunch survivability against an enemy attack
- Good in-flight survivability
- High lethality against the intended target, preferably combined with low collateral damage
  - This combination of factors renders the weapon more usable in a manner that might be politically acceptable, which might increase the weapon's deterrent value by convincing adversaries that it might be used in a crisis. Conversely, such weapons could be regarded as undesirable because they might lower the nuclear threshold.
  - Achieving these factors requires high accuracy combined with the lowest yield that can accomplish the objective. For underground targets, penetration into the ground before detonation also helps.

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[9] If LRSO missiles were deployed only on bombers that already count as delivery vehicles under New START, there would be no limits on how many the United States could deploy. If deployed on aircraft that would not otherwise count against New START, LRSO missiles would cause these aircraft to count against New START (if LRSO has a range exceeding 600 kilometers, which seems likely).

[10] Each such bomber counts as one warhead regardless of the number of nuclear weapons that it carries, so fielding new weapons on such bombers would have no arms-control implications.

[11] A fighter might be able to carry a nuclear weapon with a range exceeding 600 kilometers, without counting against treaty limits, if that weapon is not a cruise missile.

[12] Except for fighters, the only example of such an aircraft is the Russian Backfire medium bomber.

- Tactical suitability, which involves factors such as good safety features against accidental or unauthorized detonation, robustness against damage in minor accidents, and compact size for ease of handling

A subsequent section examines candidate US weapons for suitability in limited regional nuclear war and considers how each candidate weapon rates on several of the factors listed above.

As noted, it is important for a US weapon to have a high probability of destroying its intended target while minimizing the number of civilian casualties resulting from each US strike. This is important both for adhering to accepted morals and rules of engagement and for enhancing deterrence by giving an adversary more reason to think that the United States would actually use nuclear weapons if sufficiently provoked.[13] For example, if the United States could not destroy a target without inflicting civilian casualties in numbers grossly excessive in relation to any military goal, the enemy might not believe that the United States would conduct such an attack and would, therefore, not be deterred by the available US nuclear weapons.

Estimating weapon effectiveness is easier than estimating casualties because the number of casualties depends on the direction in which the wind carries fallout and also on second-order effects from the breakdown of electrical production, agriculture, transportation, and medical care. For surface targets, the lethality of a nuclear weapon depends on the hardness of the target, the explosive yield of the weapon, the accuracy of the weapon, the reliability of the weapon, and the height of burst. For hard targets (such as an ICBM silo or an underground facility), the detonation usually occurs at or very near the surface to increase ground shock. For underground targets, weapon lethality can be increased by a factor to 10 to 30 if the weapon can penetrate about 10 to 20 feet into the ground (assuming rock of typical hardness starting a few feet under the surface) or reinforced concrete before detonation, but no such weapons are known to be fielded. Accuracy is more important than yield in determining lethality against hard targets. For example, a 50-kiloton weapon with a circular error probable (CEP) of 200 feet[14] could achieve the same lethality against an ICBM silo as a 400-kiloton weapon with a CEP of 400 feet. (Weapon lethality is linear in terms of yield but varies as the inverse cube of the CEP.)

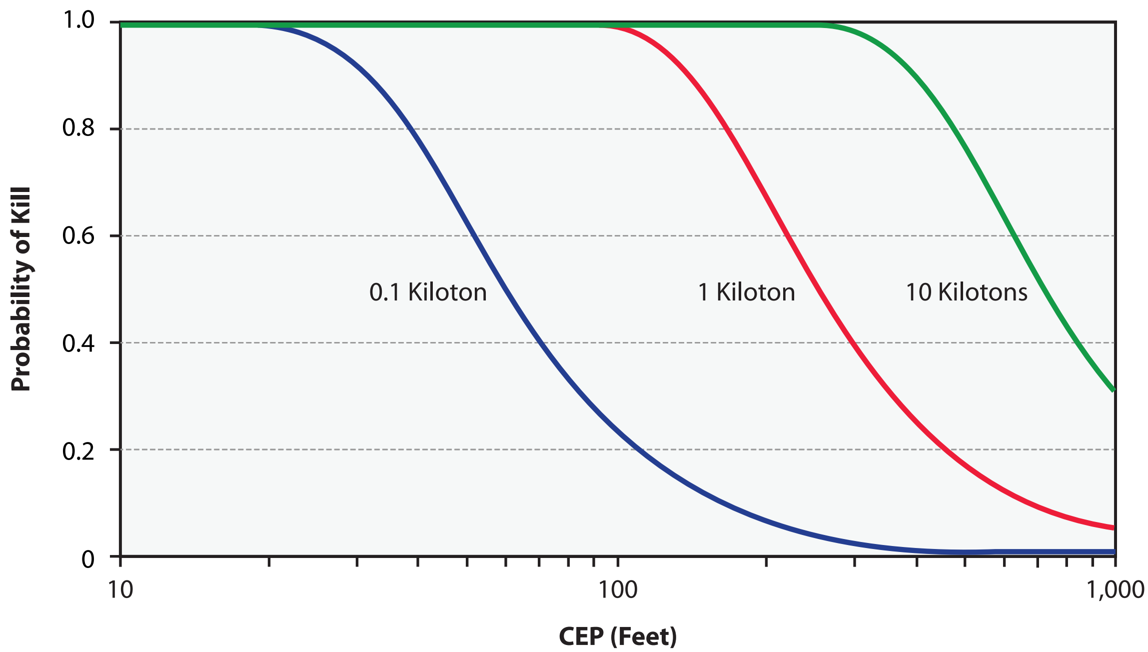
Figure 2 and Figure 3 illustrate this phenomenon, showing that accurate low-yield weapons can achieve high lethality[15] against almost all targets except underground facilities. For example, a 1-kiloton weapon with a CEP of 100 feet is highly lethal against small targets with hardness levels of up to about 100 pounds per square inch (a value that might be appropriate for an unburied weapon storage bunker and harder than a hardened aircraft shelter or a mobile ballistic missile launcher vehicle, both of which might have hardness values in the range of 20 to 30 pounds per square inch).[16] Similarly, a 0.1-kiloton weapon would be extremely lethal with CEP values of about 40 feet (for a target with a hardness of 100 pounds per square inch) to 75 feet (for a target with a hardness of

[13] The Law of Armed Conflict forbids use of weapons or tactics that cause noncombatant casualties that are disproportionate to the military objective achieved. *Disproportionate* is a subjective term, but an accurate, low-yield nuclear weapon would appear to be more compliant with this provision than would an inaccurate, high-yield weapon, especially if there were a large number of civilians relatively close to the target. Similarly, use of an inaccurate conventional missile (like the Iraqi Scuds from Operation Desert Storm) would be permitted against an isolated military base but not against a military target in a city.

[14] If a weapon has a CEP of *x* feet, this means that the weapon has a 50 percent chance of landing within x feet of its aimpoint.

[15] Lethality is measured in terms of the probability of damage calculations generated by the Probability of Damage Calculator (PDCALC), which is the standard computer model for evaluating the lethality of nuclear weapons.

[16] National Research Council, *Effects of Nuclear Earth-Penetrator and Other Weapons*, 30–50.



The *x* axis shows the accuracy of the weapon, as measured by CEP. The *y* axis shows the probability of destroying the target. Each curve represents a warhead of the indicated yield, with a reliability of 100 percent. The hardness level used in the graph may be fairly typical for an unburied weapon storage bunker. All weapons were detonated at a height of burst of 100 feet, which would be reasonable for the sub-kiloton warhead but suboptimal for the larger yields, which would benefit from detonating at somewhat greater heights.

Figure 2. Probability of Kill vs. CEP for a Target with a Hardness of 100 Pounds per Square Inch

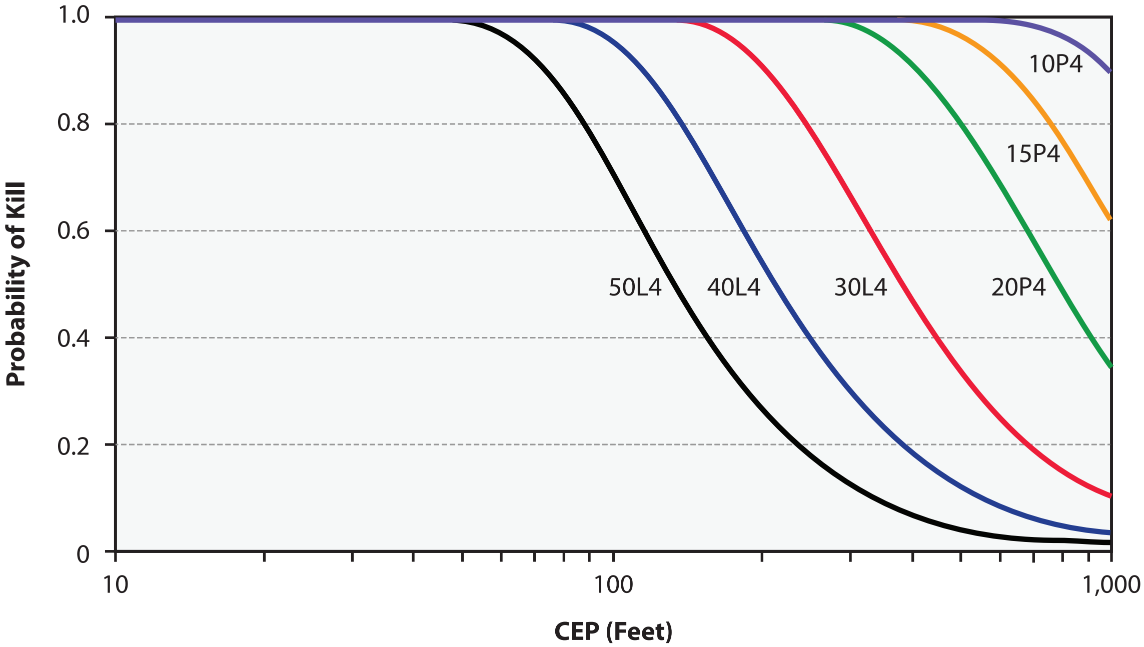
30 pounds per square inch).[17] A 5-kiloton weapon[18] with a CEP of 100 feet is highly lethal against almost all surface targets or shallow underground targets, except possibly for ICBM silos and ICBM launch-control centers. With rural targets, it would often be possible to combine very high effectiveness with relatively low civilian casualties.

Figure 2 and Figure 3 are illustrative, but they are not closely keyed to the hardness of real targets in potentially relevant countries. In addition, we calculated the lethality for various real and plausible US weapons against a wide range of potential targets. In each case, we calculated the lethality twice, once for a surface burst and once for an airburst at an altitude just high enough to minimize fallout. Most US weapons are effective against the vast majority of targets. For many targets, the surface burst and airburst are equivalent in effectiveness, but the airbursts are not effective against underground targets. Of course, high-yield surface bursts produce large amounts of fallout, whereas the effects from the airbursts are more localized.

We also examined the effectiveness of various real and plausible US weapons against a subset of (subjectively) high-priority hard or underground targets in several countries. With this smaller set of targets, we also investigated the number of casualties likely to result from the attacks. A key conclusion from this modeling is that an accurate 10-kiloton weapon that can penetrate 15 feet into the ground before detonation can achieve at least as much lethality against an underground target as a surface-burst weapon with

17 Of course, if several hardened aircraft shelters were clumped closely together, it would probably make more sense to aim an accurate weapon with a yield of a few kilotons at the center of a cluster of shelters than to aim at each shelter individually with a sub-kiloton weapon.

18 This yield was attributed to a US warhead (see Kristensen, "W80-1 Warhead Selected"). The CEP is notional.



The *x* axis shows the accuracy of the weapon, as measured by CEP. The *y* axis shows the probability of destroying the target. The warhead reliability is 100 percent. The graph includes one curve for each level of target hardness, as measured by the vulnerability number for thermonuclear kill (VNTK). (VNTK is a standard measure of target hardness for calculating the lethality of a nuclear weapon.) The TK values within VNTK (which identify the kill mechanism and the sensitivity to blast duration) are varied to be appropriate for a target of a type with the indicated VN. A hardness of 10P4 is probably appropriate for a typical reinforced concrete office building, and 15P4 may be appropriate for a hardened aircraft shelter. A hardness of 20P4 may be appropriate for disabling a main battle tank. The other curves are for very hard targets. The height of burst was adjusted to be appropriate for each type of target.

Figure 3. Probability of Kill vs. CEP for a 5-Kiloton Nuclear Warhead against a Point Target

a yield of 400 to 600 kilotons but will inflict many fewer casualties.[19]

In addition, maximizing the fraction of energy that a weapon obtains from fusion would often increase the lethality or reduce the collateral damage with no adverse effect on lethality. Table 1 compares the effects of a fission weapon (like the Hiroshima bomb and the Nagasaki bomb) and a pure fusion weapon of the same yield. Depending on the intended application, either weapon might be better, but the fusion weapon is superior most of the time. A pure fusion weapon is probably not practical, but it is possible to enhance the fraction of energy from fusion. A low-yield weapon with a high fraction of its energy from fusion might be particularly useful for neutralizing ground forces, for destroying underground targets, and for missile defense. We are not aware of any recent US research on enhanced fusion weapons. Little is known about the fusion fraction of Russian weapons. However, some Russian research papers discuss ways to achieve pure fusion, and Russian public statements about advanced warheads may be suggestive of work on, or fielding of, weapons with a high fusion fraction.[20]

19 In many cases, the weapon would need to penetrate hard rock, such as granite. In other cases, the terrain might consist of nothing harder than frozen soil. Penetrating 10 feet or more into hard rock, such as granite, without exceeding the acceleration limits of the weapon's nuclear explosives package, might be technically challenging.

20 Frankel, Scouras, and Ullrich, *Nonstrategic Nuclear Weapons at an Inflection Point*, 10–12.

Table 1. Comparison of Fission and Fusion Weapons of the Same Yield

Parameter	Fission	Fusion	Advantage
Human/structure lethal radius from air blast[a]	50% more	Less	Varies[b]
Human lethal radius from heat	100% more	Less	Varies[b]
Human lethal radius from radiation	Less	70% more	Varies[b]
Lethal depth against underground targets by ground shock from ground burst (depth to 1-kilobar pressure)	Less	50% more	Fusion
Lethal radius to kill electronics	Less	20% more	Fusion
Lethal radius to sterilize anthrax spores	Less	150% more	Fusion
Lethal radius against underwater targets by causing shock wave in water from surface burst	Less	More	Fusion
Fallout from ground burst[c]	More	Less	Fusion

[a] Lethal radius is defined so that the weapon with the smaller range to effect is effectively set to "one unit." Hence, "50% more" means that the weapon with the larger range to effect can achieve the same effect at 1.5 times the range of the less effective weapon. Some entries on "lethal radius" are quantified approximately. For example, a 10-kiloton fission warhead would collapse a given structure from overpressure at about 1.5 times the range at which a 10-kiloton pure fusion warhead could do the same. The lethal radius against electronics depends on the manufacturing technology and the design of the electronic device, but the value shown may be typical. It is hard to quantify the ratio of lethal radii against biological weapons of multiple types. The lethal radius against underwater targets is not known as accurately as the lethal radius against underground targets, but fusion weapons would have an advantage because of the high coupling of neutrons with water.

[b] Depends on the application and the intent of the user.

[c] The available information did not quantify the difference in fallout. However, any reduction in fallout would be desirable unless the goal is to maximize civilian deaths.

Current Nuclear Weapons and Regional Imbalances

In the 1980s, the United States was a world leader in NSNWs. Since 1990, however, the US–Russian balance of power for this category of weapons has shifted strongly in favor of Russia. Moreover, several countries—China, India, Pakistan, and (probably) North Korea—have deployed NSNWs, in addition to deploying large numbers of conventional weapons of types that the United States cannot deploy because of the INF Treaty.

The United States and Russia

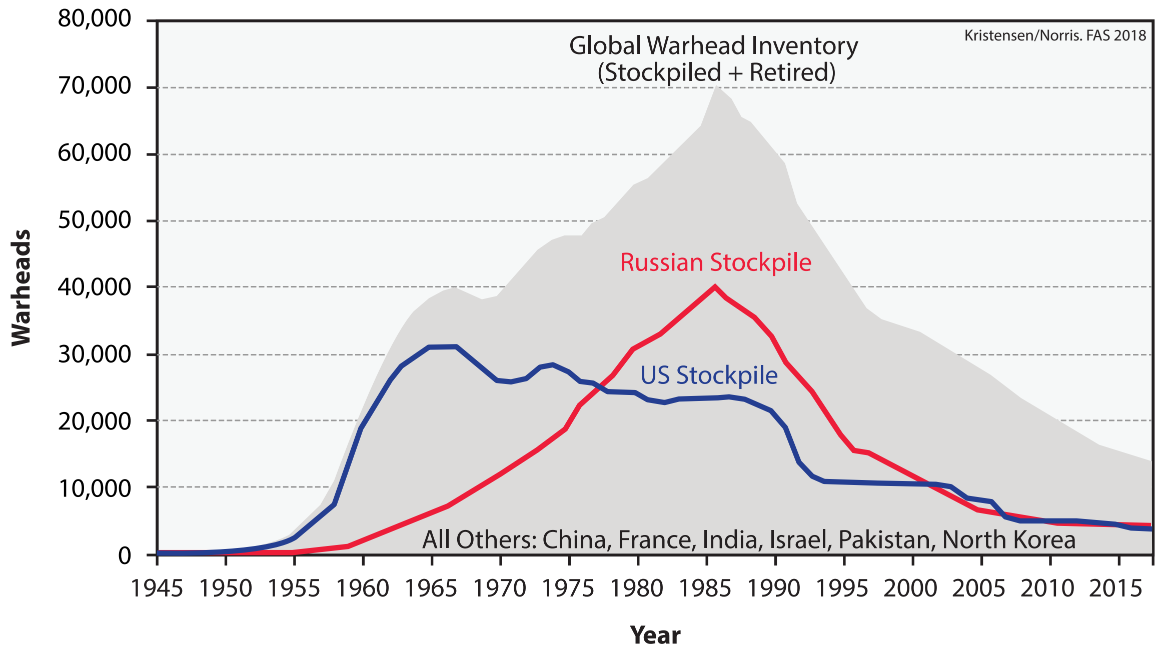
In the 1970s and 1980s, the United States and the Soviet Union had a large number and variety of NSNWs (with a reported 7,000 US weapons deployed in Europe in 1971).[21] Many of these weapons had basing modes[22] that were more survivable than air bases located close to a powerful adversary. Notable US theater weapons from the past include the following:

- The Safeguard BMD system. It was briefly deployed at one ICBM base in the 1970s.[23]

[21] Frankel, Scouras, and Ullrich, *Nonstrategic Nuclear Weapons at an Inflection Point*.

[22] For example, there were several types of mobile nuclear ballistic missiles. The problems in finding such mobile launchers in real time, due in part to the difficulties in conducting airborne reconnaissance despite advanced air defenses, would make such systems less vulnerable than known, soft, fixed targets such as air bases that are within range of a wide variety of nuclear and conventional weapons.

[23] Lang, "SMDC History."



The United States has approximately 4,000 nuclear warheads. No country is required to divulge the number of nuclear warheads that it possesses, and no foreign country has done so. Estimates for the number of Russian and Chinese warheads vary substantially.

Figure 4. Size of Global Nuclear Arsenals over Time

- The Pershing I and Pershing II IRBMs. Both missiles were launched from ground vehicles. Pershing II was briefly deployed in Europe during the 1980s, and it was eliminated in accordance with the INF Treaty. The Pershing II reportedly had a range of 1,770 kilometers, a CEP of 100 feet, and yields ranging from 5 to 50 kilotons.[24]
- The BGM-109G Gryphon GLCM. The Gryphon, which was launched from ground vehicles, was briefly deployed in Europe during the 1980s, and it was eliminated in accordance with the INF Treaty. The Gryphon reportedly had a range of 2,300 kilometers and carried the W84 warhead.[25]
- The BGM-109A Tomahawk Land-Attack Missile–Nuclear (TLAM-N) nuclear cruise missile on SSNs. The United States unilaterally withdrew this weapon from service in accordance with the PNI of 1991 and scrapped the missiles around 2010. TLAM-N had a range of about 2,500 kilometers.[26] Russia did not reciprocate.
- Various tactical systems (Army battlefield weapons, various naval weapons, surface-to-air missiles, and air-to-air missiles). These were deployed between the late 1950s and the early 1980s. All were retired unilaterally for a variety of reasons. In particular, advances in precision-guided munitions reduced the incentive to use nuclear weapons in battlefield roles.[27]

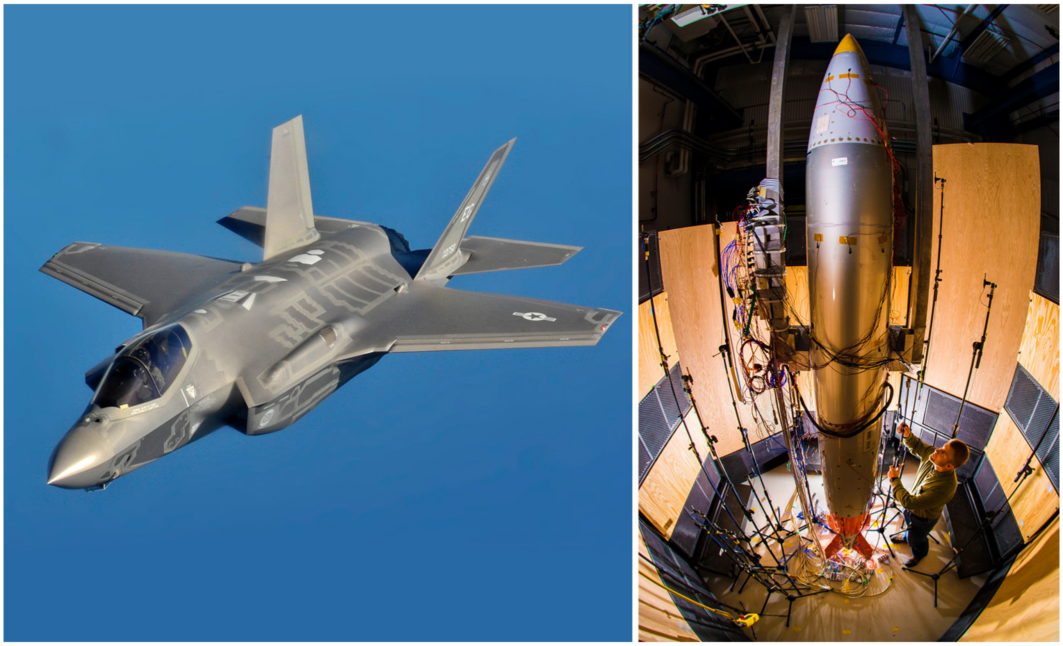
Current US and Russian nuclear forces are much smaller than they were at the height of the Cold War, and the US arsenal peaked in size much earlier than the Russian arsenal, as shown in Figure 4. In particular, the United States eliminated all but one type of

[24] Parsch, "MGM-31," Directory of U.S. Military Rockets and Missiles.

[25] "BGM-109 Ground Launched Cruise Missile," Federation of American Scientists.

[26] "Tomahawk Cruise Missile," US Navy Fact File.

[27] Nichols, Stuart, and McCausland, *Tactical Nuclear Weapons and NATO*.



Once deployed in the mid-2020s, the F-35A (left) with the B61-12 guided nuclear bomb (right) will be the most advanced US/NATO NSNW. Among NATO countries, Denmark, Italy, the Netherlands, Norway, and Turkey currently plan to buy the F-35A.

Figure 5. F-35A Fighter and B61-12 Nuclear Bomb

its NSNWs and reduced its NSNW inventory by more than 90 percent, in accordance with the INF Treaty of 1987, the 1991 PNI, and other unilateral decisions.

US NSNWs now consist exclusively of unguided bombs on short-range, non-stealthy fighters at several potentially vulnerable bases in NATO countries. Non-stealthy aircraft can be detected by foreign radar at long ranges, which raises questions about their survivability against modern air defenses.[28] Moreover, fighters provide limited target coverage without aerial refueling, which would be impossible within the airspace of an adversary with any significant air defenses. The F-35A will eventually take over the nuclear role from some of these fighters, and it will bring survivability advantages over current non-stealthy fighters, although it is uncertain whether the F-35 will be survivable against the most advanced air defenses of 2025 and beyond. The F-35 has a combat radius of about 590 nautical miles, which is less than that of the F-15E Strike Eagle and the Panavia Tornado (two current nuclear-capable fighters), so the partial transition to the F-35A will not address the range limitations noted above.[29]

Strategic bombers based in the continental United States could play a role in a limited regional nuclear war in Europe, but they do not provide a fast response (about 12 hours if on nuclear alert, days otherwise), and the B-2, which is currently armed only with unguided bombs in the nuclear role, may have in-flight survivability issues against the most advanced air defenses in the future. Moreover, the B-52 depends exclusively on long-range cruise missiles, and the AGM-86 Air-Launched Cruise Missile (ALCM) will reach the end of its life by 2030 and may have questionable survivability in the 2020s.

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[28] Kopp, "Surviving"; Cate, *Air Superiority*; and Grant, *Radar Game*.

[29] "Lockheed Martin F-35 Lightning II," *Jane's All the World's Aircraft*; "Boeing F-15E Eagle," *Jane's All the World's Aircraft*; and https://janes.ihs.com/janes/search?q=LRSO&pg=1#q=Panavia Tornado.

Current unguided B61 bombs may have undesirable ratios of effectiveness to collateral damage due to accuracy limitations. The B61-12 guided bomb is under development, and it will likely be more accurate than existing nuclear bombs. It will be integrated on the F-15E, F-16, F-35A, B-2, and the B-21 (a bomber that is currently under development to replace some or all existing bombers). (Figure 5 shows an F-35A and a prototype B61-12 bomb.)[30] The LRSO cruise missile is in an early stage of development, and it will eventually replace the ALCM. The LRSO is designed to penetrate and survive advanced integrated air defense systems, so it will probably be more survivable than the ALCM.[31] It may also be more accurate, but little information about LRSO characteristics is available. The LRSO will initially be carried by the B-52, with carriage by the B-2 or the B-21 possibly occurring later.[32] The F-35A or the F-15E might be able to carry the LRSO externally, but doing so would cause them to count as heavy bombers under New START if the LRSO's range exceeds 600 kilometers.

Russia has followed a different path than the United States has over the last 30 years. In the 1980s, the Soviet Union had approximately the same types of NSNWs as the United States (as previously listed). Since then, Russia has had significantly fewer NSNWs, but it still has many types of NSNWs and is modernizing these weapons. In particular, and unlike the United States, Russia heavily emphasizes nuclear cruise missiles of multiple types. Figure 6 shows a Backfire medium bomber with cruise missiles. Figure 7 shows a modern Russian SLCM. Unconfirmed reports suggest that Russia has fielded this missile on land vehicles.[33]

Backfire bombers armed with the new Kh-32 cruise missile (which has a range of 800 to 1,000 kilometers) can cover the eastern parts of NATO from launch areas that should be safe for the Backfire, and the Kh-32's hypersonic speed (Mach 4 or higher) should enhance its survivability.[34]

Figure 6. Backfire Bomber with Cruise Missiles

Russian NSNWs provide a broad spectrum of capabilities, and some provide advantages over current US NSNWs. For example, Russian submarines and mobile missiles are difficult to find, which enhances prelaunch survivability relative to aircraft operating from known, fixed bases. Russian cruise missiles and ballistic missiles most likely have better in-flight survivability than US non-stealthy fighters armed with direct-attack weapons. Russian cruise missiles launched from submarines, bombers, and (possibly) ground vehicles have more range (and, hence, more target coverage) than US short-range fighters.[35]

[30] US Department of Defense, *Nuclear Posture Review 2018*, 50. Also see Osborne, "Have American Scientists?"; and US Government Accountability Office, *B61-12 Bomb*.

[31] US Department of Defense, *Nuclear Posture Review 2018*, X. Also see "Long-Range Stand-Off (LRSO) Missile," *Jane's Air-Launched Weapons*.

[32] The Air Force budget for fiscal year 2019 announced a plan to retire the B-2 and the B-1 shortly after the B-21 becomes operational. If this plan is implemented, the B-2 would never receive the LRSO. Of course, Congress may object to early retirement of the B-2 and/or the B-1, so it may be premature to think that the B-2 will not be around long enough to need the LRSO.

[33] Woolf, *Russian Compliance*.

[34] See "Kh-22 (AS-4 'Kitchen'/Burya), Kh-32," *Jane's Air-Launched Weapons*. The Kh-32 is an improved version of the earlier Kh-22.

[35] See "Kh-101, Kh-102," *Jane's Air-Launched Weapons*; "3M-14 'Kalibr' (SS-N-30A)," *Jane's Weapons: Naval*; "Kh-22 (AS-4 'Kitchen'/Burya), Kh-32," *Jane's Air-Launched Weapons*; and "Pentagon Mulling New Submarine- or Surface-Based Nuclear Cruise Missile," *Jane's Defence Weekly*.

Finally, some Russian weapons may combine high accuracy with low yields in a manner that could improve their ratio of lethality to collateral damage.[36]

With an estimated missile range of 2,000 to 2,500 kilometers, Russian submarines armed with the SSN-30 SLCM (also called 3M-54) could cover all of western Europe from launch sites near Europe and most or all of the United States from launch sites near both coasts.[37]

Figure 7. Russian SSN-30 Kalibr SLCM

The US State Department has asserted (under both the Obama administration and the Trump administration) that Russia has tested (or maybe even fielded) a mobile GLCM, probably known as the SSC-8, that violates the INF Treaty.[38] The Director of National Intelligence has stated that this missile has both nuclear and conventional versions and that it has a range significantly greater than 500 kilometers (but with no specific number cited).

Figure 8 shows target coverage for a Russian missile based in Kaliningrad, with the range varied parametrically from 500 kilometers (the INF limit) to 3,500 kilometers. The US government has not issued an estimated range for the new Russian GLCM, so range is treated parametrically. If the range of the new Russian GLCM is 2,000 kilometers or more, it would be able to reach targets almost anywhere in western Europe from Kaliningrad, thereby posing a risk to the vast majority of NATO facilities. Apart from the Baltic states, coverage of NATO countries would be somewhat less extensive for missiles based in the far western parts of contiguous Russia.

Russia has also tested a ballistic missile that may have arms-control implications. The RS-26 missile has been tested to a range exceeding 5,500 kilometers and counts as an ICBM.

However, most flight tests of this missile have reportedly been to ranges of less than 5,500 kilometers. Some have speculated that the test(s) to a range exceeding 5,500 kilometers involved one warhead, whereas the shorter-range tests involved multiple warheads per missile. This missile raises potential issues regarding both the INF Treaty and New START. In February 2018, Russia declared that it possessed 527 deployed strategic delivery vehicles (versus a limit of 700), 779 total delivery vehicles (versus a limit of 800), and 1,444 deployed warheads (versus a limit of 1,550).[39] Consequently, Russia could deploy only 21 of these new missiles—absent corresponding reductions to other systems—without violating the New START limit on total delivery vehicles.[40] Alternatively, Russia could designate the RS-26 as an IRBM and withdraw from the INF Treaty (if the treaty is still in effect at that time). At that point, Russia would also have no reason to

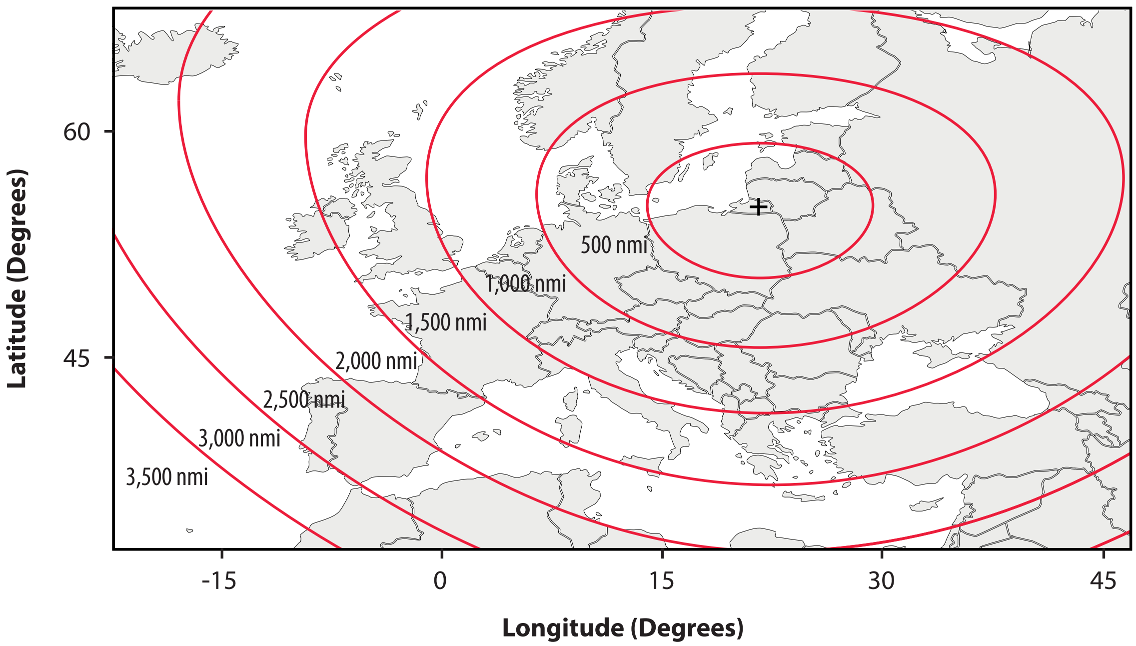
[36] "Moscow Rethinks Nuclear Strategy," *Moscow News*; public statements by Viktor Mikhailov, chief scientist of the Russian Research Institute of Theoretical Physics, 1999 and 2002; Vice Admiral Oleg Burtsev in Ria Novosti, March 2009; and US Department of Defense, *Nuclear Posture Review 2018*, 53–54. See also "9K715 Iskander/9K720 Iskander-M/9K720E Iskander-E," *Jane's Strategic Weapon Systems*.

[37] See "3M-14 'Kalibr' (SS-N-30A)," *Jane's Weapons: Naval*.

[38] Woolf, *Russian Compliance*. Russia denies this charge and has accused the United States of violating the INF Treaty. Russia claims that the vertical launch system at the Aegis Ashore missile defense site in Romania, and at the future site in Poland, can be used to launch Tomahawk cruise missiles (which have a maximum range between 500 and 5,500 kilometers) and not just missile defense interceptors.

[39] Woolf, *New START Treaty*.

[40] Woolf, *Russian Compliance*.



Ranges from the launch point are shown as rings and measured in kilometers. A second launch point, near Estonia, would slightly improve coverage against Baltic targets for missile ranges under 1,000 kilometers. A notional third launch point in western Belarus would improve coverage for missile ranges up to about 2,500 kilometers.

Figure 8. Geographic Coverage for Missiles in Kaliningrad

deny that the new GLCM violates the INF Treaty (if it actually does).[41]

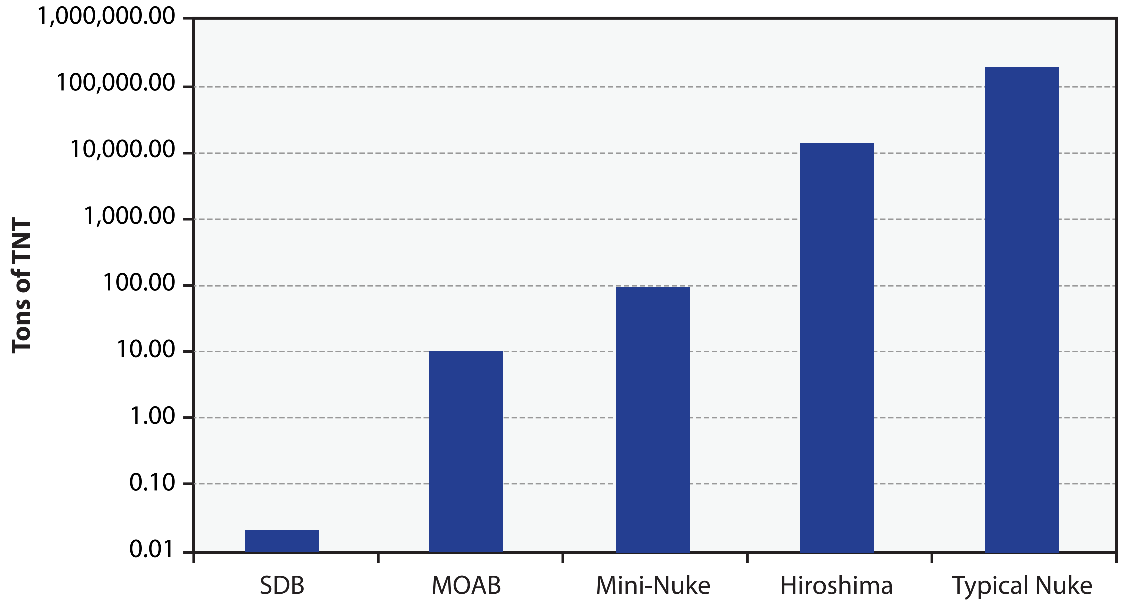
Finally, Russia is fielding a nuclear ballistic missile—called the Kh-47M2 Kinzhal—on the Mig-31 fighter. This missile reportedly has a range of about 2,000 kilometers.[42] Although this weapon is not a technical violation of any treaty (because the New START provisions on long-range air-delivered nuclear weapons apply only to cruise missiles), it is surely a real-world subject of concern.

As another complication, accurate, very-low-yield nuclear weapons of types that Russia may possess partially blur the distinction between very large conventional weapons (such as the US Massive Ordnance Penetrator, or MOP, and the Massive Ordnance Air Blast, or MOAB) and "traditional" nuclear weapons. Figure 9 illustrates this phenomenon. The figure is not meant to imply that the effects of a 1-kiloton nuclear weapon are identical to those of a 1,000-ton pile of TNT. In particular, the pile of TNT would generate more blast but less heat than the nuclear weapon, and no x-ray or gamma radiation. Nevertheless, these low-yield, highly accurate nuclear weapons may be far more "usable" than Cold War nuclear weapons, and it is uncertain whether use of a sub-kiloton or 1-kiloton nuclear weapon—against a purely military target in a rural area—would necessarily lead to a nuclear response.

Over the course of the last 25 years, troubling asymmetries in nuclear doctrine have emerged in parallel with asymmetries in NSNW arsenals and capabilities. Since the breakup of the Soviet Union, the power of Russia's conventional military has declined greatly compared to that of the United States, and Russia may be trying to compensate for these changes by increasing its emphasis on nuclear

41 Woolf, *Russian Compliance*; and Podvig et al., "Current Status."

42 Pyadushkin, "Russia Turns Attention to Hypersonic Weapons," 65.



The *y* axis shows energy in tons of TNT. Values for the mini-nuke and typical nuke are arbitrary. The *y* axis uses a logarithmic scale. MOAB, Massive Ordnance Air Blast; SDB, Small Diameter Bomb.

Figure 9. Energy of Mini-Nuke and Other Weapons

weapons.[43] Russian nuclear doctrine has become more aggressive since the end of the Cold War. Russia abandoned the long-standing Soviet pledge of "no first use" of nuclear weapons in the 1990s. Some open-source articles suggest that Russia, under its current strategy sometimes called "escalate to de-escalate" in the West, might use nuclear weapons under a variety of ambiguous and poorly understood conditions. Russian news has described Russian doctrine as follows:[44]

> Russia is ready to use nuclear weapons not only in retaliation against a nuclear attack, as was previously the case, but in response to "a large-scale conventional aggression in a situation critical for the national security of the Russian Federation and its allies." . . . Russia will have to equip all services of the Armed Forces with permanently combat-ready nuclear weapons. Nobody can guess who will use them first. This only concerns tactical, rather than strategic, nuclear weapons. It is clearly impossible to counter terrorist threats in the South-East direction, or neutralize U.S. ABM deployment in Europe [a reference to the Aegis Ashore sites in Romania and Poland], with intercontinental ballistic missiles or their submarine counterparts. In other words, Russia will need a very broad range of non-strategic nuclear weapons. Such weapons are designed to destroy battlefield targets, rather than entire cities, and could take the form of medium and shorter-range missiles launched from air, land or sea, as well as artillery ammunition and nuclear demolition charges.

Russia might consider the use of accurate, low-yield theater nuclear weapons—at least in limited numbers and against military targets—stabilizing and de-escalatory. Russian military exercises (such as

[43] Colby, *Russia's Evolving Nuclear Doctrine*; Johnson, *Nuclear Weapons in Russia's Approach*; Oliker, *Russia's Nuclear Doctrine*; Van Herpen, *Russia's Embrace of Tactical Nuclear Weapons*; and Durkalec, "Russia's Evolving Nuclear Strategy."

[44] "Moscow Rethinks Nuclear Strategy," *Moscow News*.

ZAPAD-1999, ZAPAD-2009, and VOSTOK-2010) sometimes simulate the use of such weapons.[45]

In other words, while there is no definitive evidence that Russia has drastically lowered its nuclear threshold in the last 20 years, such a lowering is plausible, or even likely. Moreover, even if Russia would hesitate to use nuclear weapons under circumstances short of a major threat to its regime's survival, the *perception* that it is willing to use nuclear weapons, combined with its arsenal of modern NSNWs, could have a powerful deterrent/coercive effect on other countries. This concern is reflected in the 2018 NPR executive summary:[46]

> Russia's belief that limited nuclear first use, potentially including low-yield weapons, can provide such an advantage is based, in part, on Moscow's perception that its greater number and variety of non-strategic nuclear systems provide a coercive advantage in crises and at lower levels of conflict.

Nuclear Weapons in Asian Countries

China has SSBNs, ICBMs, and theater-range nuclear ballistic missiles and is fielding new missiles of these types (such as the DF-26 IRBM). China also has large numbers of conventional ground-launched ballistic missiles and cruise missiles, and ALCMs. Many of these ground-launched missiles have a maximum range between 500 and 5,500 kilometers and are denied to the United States and Russia by the INF Treaty. Estimates on the number and nature of Chinese nuclear weapons vary, although the Chinese nuclear arsenal is much smaller than US or Russian arsenals. Nevertheless, China has the resources and technology to rapidly expand and modernize its nuclear arsenal.

North Korea has a small number of nuclear warheads today and may be beginning to field nuclear-tipped mobile ballistic missiles with theater and intercontinental ranges. North Korea is also developing an SLBM and has conventional ballistic missiles of types that are denied to the United States and Russia by the INF Treaty.

Although neither country is a likely adversary, India and Pakistan have nuclear bombs on fighters, IRBMs, shorter-range nuclear missiles, and short-range to intermediate-range nuclear weapons on submarines. Pakistan also has battlefield weapons.[47]

Iran has no nuclear weapons today but could be a nuclear power in the future. Iran has an aggressive program for ballistic missiles and has a large inventory of conventional ballistic missiles of types that are denied to the United States and Russia by the INF Treaty.

Candidate US Nuclear Weapons for Use in Regional War

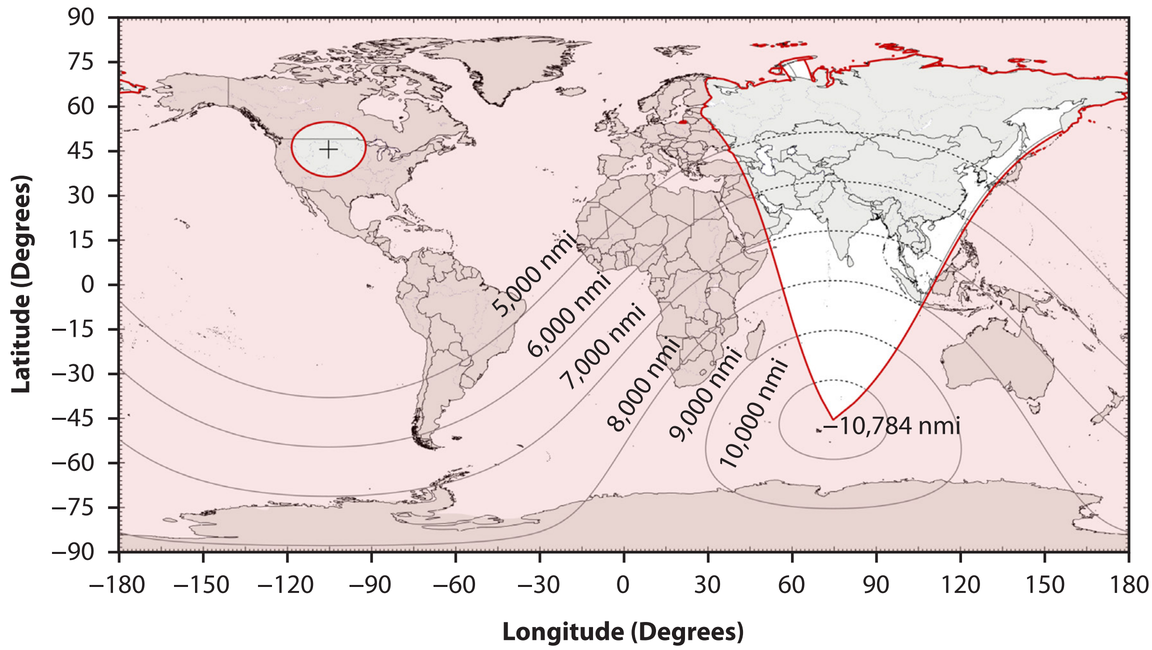
Each of the following subsections analyzes one type of candidate US nuclear weapon for use in regional war. In most cases, desirable characteristics were listed earlier in this report. Range requirements would vary, depending on where the delivery systems could plausibly be relative to the most likely targets.[48]

[45] Briefing presented by the Potomac Foundation in July 2015. ZAPAD (west) refers to Russian exercises near NATO, and VOSTOK (east) refers to Russian exercises in Asia. These are typically held every four years to enable exercise of the latest military doctrine and technology.

[46] US Department of Defense, *Nuclear Posture Review 2018*, XI–XII.

[47] Pillalamarri, "Pakistan's Nuclear Weapons Program."

[48] Almost by definition, the US nuclear weapon has to be lethal against the intended target, unless the point of using it is simply to make a political statement. Determining the extent to which limited nuclear weapon usage poses the risk of uncontrolled escalation is difficult and subjective, but we think that high collateral damage increases the risk of such escalation. (There are also allusions to this effect, although somewhat more vague than the previous sentence, in the 2018 NPR report [pp. XI–XII of the executive summary plus several in the main text] and in various Russian statements about the desirability of low and super-low yields.) Similarly, it is complex and subjective to determine how much survivability is enough, but poor in-flight survivability



Reaching regions in white (ocean) or gray (land) over Asia and the Indian Ocean requires overflight of Russia. Results shown do not include any shadowing due to the small Russian enclaves in Kaliningrad and Crimea. The ellipse in North America bounds the region containing the US bases. All launches occur from the cross near the center of the ellipse in North America. If three launch points were used (to correspond to the three bases), then the figure would be slightly more complex.

Figure 10. Target Coverage from Current ICBM Bases without Flying over Russia

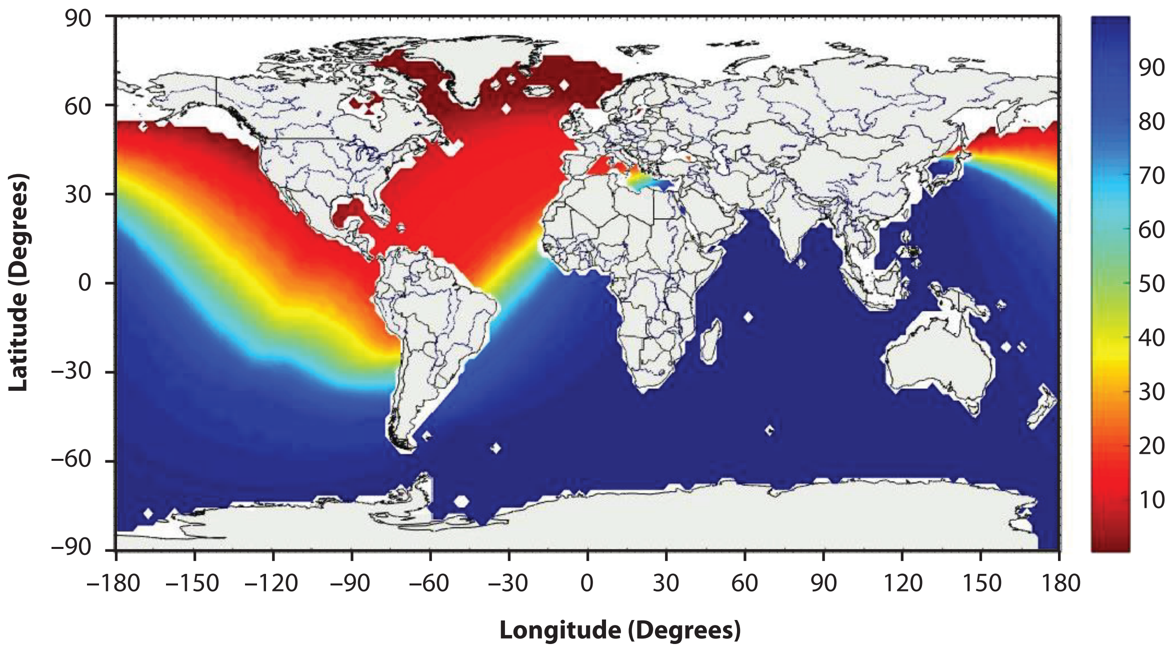
Intercontinental Ballistic Missiles

ICBMs provide a very fast response, are highly survivable in flight, and offer good geographic coverage, but they are problematic for use against rogue countries and they may be problematic for use in a limited regional nuclear war against a great power. ICBMs at the current bases can reach Russia without flying over any country except Canada, and all of Russia is within range of plausible future ICBMs.

However, if the United States were to use ICBMs against Russia in a limited war, Russia might misinterpret the attack as a general strategic attack. The level of risk would depend on the number of ICBMs used and on Russia's ability to quickly and accurately determine the target(s) being attacked and the scale of the ICBM attack. Under current plans, US ICBMs will be limited to one warhead per missile, and it might be necessary to use several missiles. Unfortunately, Russia might think that these ICBMs actually carried three warheads per missile, which some Minuteman III missiles did at various times in the past. Further, it is hard to predict how accurately and how quickly Russia could determine the intended impact points.

Moreover, unlike a few decades ago, the world of 2030 may hold several potential nuclear adversaries. Figure 10 shows coverage from the current US ICBM bases, without flying over Russia, with a missile range that is parametrically varied from 5,000 to 10,800 nautical miles (9,260 to 20,000 kilometers). Ballistic missiles at the current bases cannot reach non-Russian targets in Asia without flying over Russia, and flying over Russia would be problematic, especially if relations with Russia do not improve.

would make it hard to achieve the desired effects on the selected target, thereby reducing both military effectiveness and deterrent value (in our opinion). Similarly, poor survivability against an enemy first strike might encourage such a first strike, thereby undermining stability and deterrence.



The regions in dark blue are the best launch areas for reaching the ballistic shadow of Russia from Figure 10 without overflight of Russia. These areas are a long distance from the two US SSBN bases in Georgia and Washington. The figure assumes an unlimited range for the SLBM, so some plausible targets may be out of range (for the Trident D5) from some launch points in the dark blue regions.

Figure 11. Target Coverage for SLBMs without Flying over Russia

If the United States wants the ability to use ICBMs against targets in the "ballistic shadow" of Russia, it would probably need to find a way to avoid flying over Russia (which would be hard).[49] Even if the United States avoids flying over Russia, its use of ICBMs could still lead Russia to misinterpret its actions, especially if the trajectory comes close to Russia. Similarly, the Chinese could misinterpret US actions if the United States were to use ICBMs against other countries in eastern Asia.

Another issue pertains to yield and accuracy. Current US ICBMs deliver high-yield nuclear weapons and have accuracy keyed to such yields. For use in limited regional war, yields in the sub-kiloton to 10-kiloton range would likely be preferred to reduce collateral damage,[50] and it might be necessary to develop and use guided reentry vehicles to obtain accuracy good enough for high effectiveness, at least against hard targets, at yields of a few kilotons.

Submarine-Launched Ballistic Missiles

Like ICBMs, SLBMs also provide a fast response (in most cases), are highly survivable in flight, and offer good target coverage; they also have a highly survivable launch platform. SLBMs have some advantages over ICBMs but may still be problematic for use in a regional conflict.

First, SLBMs can cover all of Africa and much of the "Russian ballistic shadow" from Figure 10 without flying over any third-party great power. However, the launch points required to cover the ballistic shadow

[49] For a discussion of techniques for reducing ICBM overflight, see Evans and Schwalbe, *Intercontinental Ballistic Missiles*.

[50] Reducing collateral damage might help reduce the risk of uncontrolled nuclear escalation. This is the apparent motivation for the direction, in the 2018 NPR report, to develop and field a low-yield warhead on the Trident D5, and the same considerations would apply to ICBMs. See Figure 2 and Figure 3 for information on the interplay between effectiveness, yield, accuracy, and target hardness.

from Figure 10 are mostly far south of the US SSBN bases in Georgia and Washington, as shown in Figure 11.

Second, SLBMs provide a fast response if the SSBN launches the SLBM from where it is at the time of the decision to launch an attack. However, if the SSBN has to travel to a more desirable launch point, the response time could be several days.

Third, and as with ICBMs, SLBM launches are potentially subject to detection by satellites, and an SLBM strike may be subject to misinterpretation if its trajectory comes close to a great power that is not being targeted. Further, if an SLBM were to be used against a great power in a limited nuclear war, the enemy country might misjudge the intended impact point and think the target being struck was more escalatory than the actual intended target.

Fourth, and as with ICBMs, yield and accuracy are issues for SLBMs. Current US SLBMs deliver high-yield nuclear weapons and their accuracy may be keyed to such yields. For use in limited regional war, low yields would likely be preferred to reduce collateral damage, and it might be necessary to improve accuracy for high effectiveness, at least against hard targets.

Finally, the number of warheads for the Trident D5 is more ambiguous than that for the Minuteman III. All US ICBMs have one warhead per missile, although it is possible for the Minuteman III to carry three warheads. By contrast, US SLBMs carry a variable number of warheads per missile, possibly up to 12.[51] Hence, an enemy might assume that an incoming Trident D5 is carrying eight or more high-yield warheads, even if it was actually carrying many fewer warheads, and all of them low yield.

Land-Based Fighter Aircraft

Nuclear-armed fighters—at bases in NATO countries—could theoretically cover a fairly wide geographic area if they are able to refuel in the air and host countries agree to execution of the strikes. However, the lack of stealth (for current fighters) and standoff weapons would impair survivability against modern air defenses, although the F-35A will be more survivable. These fighters operate from a small number of bases that are undoubtedly known to Russia. These bases are highly vulnerable to preemptive attacks—small nuclear attacks or large conventional attacks—potentially the most vulnerable of any type of NSNW considered in this report. If on nuclear alert, these fighters could provide a rapid response within their range and survivability limitations.

The United States has no nuclear-armed fighters at bases that would be useful in eastern Asia. Deploying such fighters at bases in the western Pacific would require host-nation agreements (which might take years, if such permission could be obtained at all) and—at least for extended deployment—construction of nuclear-weapons infrastructure at the selected bases (which also might take several years). Moreover, fighter bases close to potential adversaries would be vulnerable to missile attacks. Deployment at Guam would not involve host-nation issues and basing in Guam would likely be more survivable than basing closer to potential adversaries, but fighters at Guam would require multiple aerial refuelings to reach any plausible adversary.

Vulnerability issues surrounding both the current fighters and the bases suggest that increasing the number of nuclear bombs in Europe would not be a good response to Russia's asymmetric advantages in NSNWs. On the other hand, integrating cruise missiles on land-based fighters would improve the in-flight survivability and target coverage of the

51 Woolf, *New START Treaty: Central Limits and Key Provisions*; and "UGM-133 Trident D-5," *Jane's Strategic Weapon Systems*. These sources list a maximum load of 8 to 12. The US declared a maximum load of 8 warheads in a memorandum of understanding that accompanied the original START Treaty (https://1997-2001.state.gov/global/arms/starthtm/mou/us/usmou798.html). However, there is no corresponding declaration under New START.

aircraft by an amount depending on the range and survivability of the cruise missiles. (Of course, the overall utility of the cruise missile would also depend on its yield, accuracy, and in-flight survivability, not just its range and its ability to enhance target coverage and fighter survivability.) If the nuclear cruise missile had a range exceeding 600 kilometers and New START limits and counting rules were still in effect,[52] fielding such a missile would require that fighters equipped to carry this missile be counted as heavy bombers under New START, and the United States would violate treaty limits.[53] In addition, the United States and its NATO partners would have to decide whether these cruise missiles would be carried only by US fighters or also by fighters belonging to selected NATO partners. Of course, such a cruise missile would do nothing to enhance base survivability, so its impact would be maximized if the missile were combined with robust defenses of the relevant bases.

There are three general approaches to fielding nuclear cruise missiles on US fighters:

(1) Integrating LRSO externally on the F-15E, the F-35A, or both[54]

(2) Integrating a new missile other than LRSO externally on the F-15E, the F-35A, or both

(3) Integrating a new, small missile internally on the F-35A

We discuss each of these three options below.

LRSO: The easiest way to field nuclear cruise missiles on fighters might be to integrate the LRSO externally on the F-15E and the F-35A, if LRSO dimensions and weight are within the limits for those two fighters (and the spacing of the connection points is compatible with the fighters).[55] Of course, doing this would cause any fighters equipped to carry LRSO to count as heavy bombers against New START limits (if those limits are still relevant when LRSO becomes available), unless LRSO's range is far shorter than that of the AGM-86 ALCM. If LRSO has a conventional variant, then LRSO-Conventional would probably confer some advantages over existing US cruise missiles (such as a longer range), so this integration would be beneficial in conventional war as well.

Treaty-compliant external cruise missile for the F-15E and the F-35A: It would likely be possible to develop a nuclear cruise missile with a range of perhaps 580 kilometers, thereby avoiding any problems with New START limits. This weapon might be a completely new missile or it could be a visually distinctive modified version of LRSO. However, the cost of a short-range LRSO or an all-new missile would be greater than the cost of integrating LRSO on fighters (unless LRSO is too large for easy integration). Moreover, a conventional version of a nuclear cruise missile with a range of 580 kilometers would likely have a range of 500 kilometers or less (due to the probable increase in warhead weight and volume, relative to the W80 nuclear warhead[56]). By comparison, Jane's attributes a range of 925 kilometers to the existing Joint Air-to-Surface Standoff Missile, Extended Range (better known as JASSM-ER)[57] conventional cruise missile, which is already carried by several types of US aircraft. Hence, a conventional variant of a New START-compliant cruise missile

[52] Fighters can carry conventional cruise missiles that have a range exceeding 600 kilometers without counting against New START limits, if the conventional cruise missile is visually distinctive from all nuclear missiles.

[53] This New START issue might be avoided if the weapon carried by the fighters did not meet the New START definition of a cruise missile.

[54] Replacement of the F-16 will be well under way by 2030.

[55] The F-15E and the F-35A can carry weapons as large as the AGM-86 ALCM.

[56] According to the Nuclear Weapon Archive ("W80 Warhead"), a W80 ALCM warhead weighs only 290 pounds. By comparison, the conventional warhead for JASSM and JASSM-ER is reportedly in the 1,000-pound class (see "AGM-158 JASSM").

[57] "AGM-158A JASSM and AGM-158B JASSM-ER," *Jane's Air-Launched Weapons*.

might not bring any operational advantages over JASSM-ER.[58]

Treaty-compliant internal cruise missile: It might also be possible to develop a nuclear cruise missile that the F-35A could carry internally with no impact on the aircraft's radar cross section. Such a weapon would have to be relatively small, so, compared with a larger weapon limited to external carriage, it would have a shorter range, a smaller warhead volume, or both. Such a weapon could also be carried externally by the F-15E, but the benefits of doing so would depend on the actual range of the weapon.

Carrier-Based Fighter Aircraft

The United States no longer has any nuclear-capable fighters on aircraft carriers, but the similarities between the F-35C and the F-35A suggest that it would not be difficult to integrate the B61-12 on the F-35C. Moreover, the B61-12 is well within the size range of conventional weapons currently stored on aircraft carriers. Integrating the B61-12 on the F-35C would not greatly enhance target coverage in Europe but would be beneficial in areas of the world where the United States has no NSNWs. Moreover, aircraft carriers are more survivable than land bases close to powerful adversaries. Implementing this approach would require a high level of security for nuclear bombs on aircraft carriers, and various foreign nations might not allow nuclear-capable aircraft carriers to visit their ports.

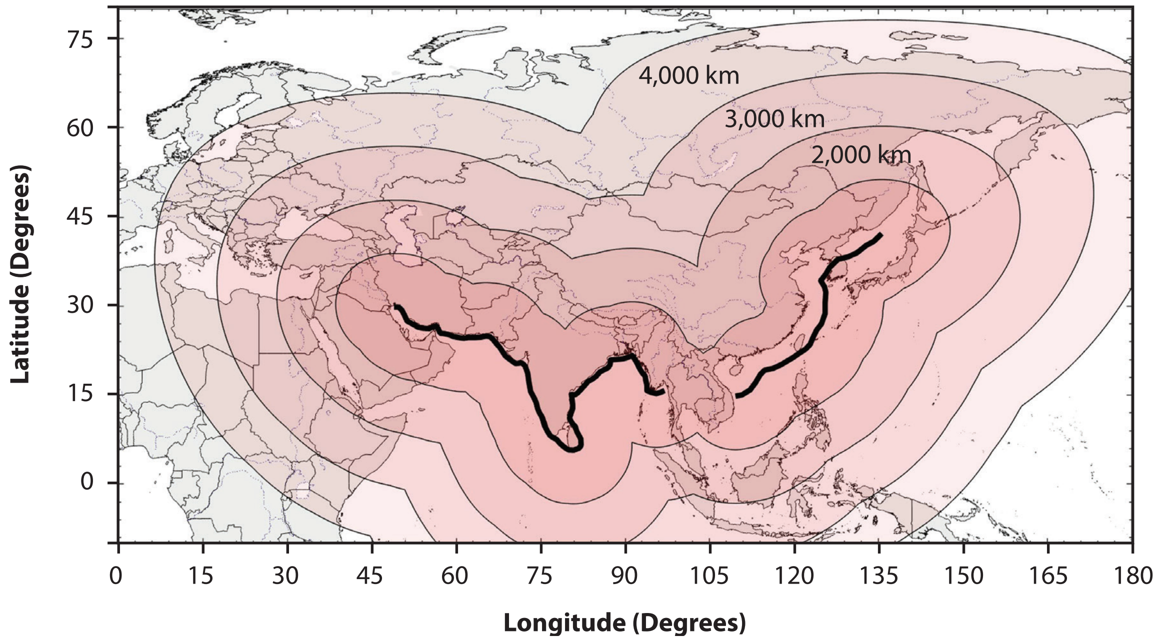
Considerations about arming these fighters with cruise missiles are similar to those for fighters on land, but the upper limit on weapon size for carrier-based fighters is smaller than the corresponding limits for the F-15E and the F-35A. Requiring a cruise missile to be suitable for delivery by the F-35C, and not just Air Force aircraft, could lead to a smaller missile with less range than for a weapon designed strictly for the Air Force.

Bombers with Cruise Missiles and Direct-Attack Weapons

Bombers play a key role in conventional war and can augment other US forces in regional nuclear war. If refueled while airborne, bombers coming from the United States can provide nearly worldwide coverage, within the limits of their survivability. However, their response time is very slow—roughly 12 to 24 hours if the bombers are already on nuclear alert and even longer if they are not. Moreover, bombers coming from the United States would have to fly over several countries, sometimes including countries that are not US allies, to reach parts of the Middle East or south Asia. Using Diego Garcia as a base would mitigate overflight concerns for missions against some countries but would require Britain's permission.

The B-52 is totally reliant on long-range standoff weapons against advanced adversaries, whereas the B-2 relies exclusively on gravity bombs in the nuclear role. The B-2 is more survivable than other bombers, but it may have survivability problems against advanced air defenses in the future, and it will have no nuclear standoff weapon until the 2030s (if ever). Moreover, range limitations might be significant if the B-2's mission is to deliver direct-attack weapons against multiple targets deep in the interior of a large country. Hence, long-range standoff weapons would also be desirable for the B-2. A bomber armed with cruise missiles that have a range of 3,000 kilometers or more could provide nearly complete coverage of Eurasia from plausible launch points. Figure 12 shows the geographic coverage for ALCMs with three notional ranges. Using standoff weapons would not enhance response time with subsonic missiles, and the delivery aircraft would often take a long time to

[58] Depending on the radar cross section of the cruise missile, carrying such a missile externally could have a serious adverse effect on the radar cross section of an F-35 plus weapon combination. Hence, for an F-35, the range of the weapon would need to be great enough to outweigh the adverse radar cross section effects, or the weapon and connection points would have to be designed in such a way as to minimize the effect on the overall radar cross section of the aircraft. Any significant standoff range would be beneficial for the F-15E.



The cruise missiles are launched from the black line, which runs through international airspace and over South Korea. The black line is interrupted over Vietnam, Burma, and Laos. The cruise missiles have notional ranges of 2,000, 3,000, and 4,000 kilometers. GlobalSecurity.org indicates that the new Russian Kh-102 nuclear cruise missile has a range exceeding 3,000 kilometers.

Figure 12. Geographic Coverage for ALCMs

reach the "black-line launch points," so using a faster missile would not always produce a significantly faster response.

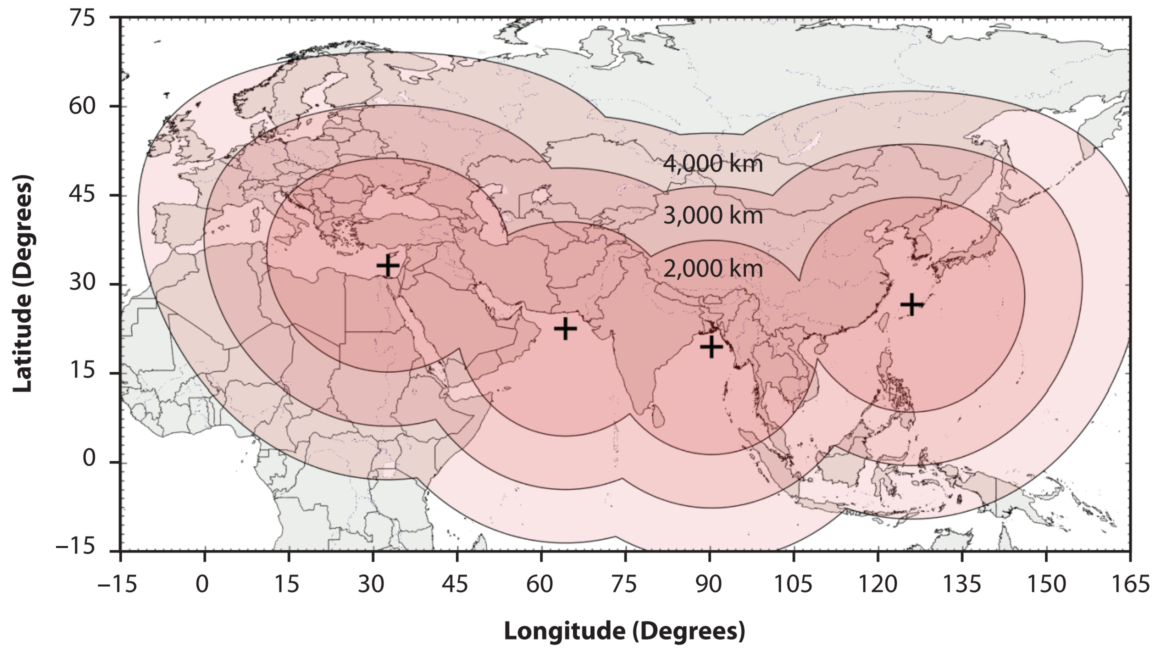
Of course, a nuclear cruise missile's suitability for use in limited regional war depends on its having desirable yield–accuracy combinations, not just good in-flight survivability and sufficient range to reach the selected targets. The Defense Department has not released any information on the expected range or accuracy of the LRSO or the yield of its warhead. An April 2018 Center for Strategic and Budgetary Assessments report suggested that requirements for the LRSO should account for limited regional nuclear war instead of focusing solely on all-out nuclear war against a great power, and we agree with this recommendation.[59]

Finally, the B-2 could carry two or more large, guided, nuclear penetrator bombs. Such bombs could be highly effective against underground targets, at weapon yields low enough that a surface burst would be ineffective. Such a weapon would provide a much higher ratio of lethality to collateral damage—against underground targets—than any funded weapon. Of course, delivery of such a direct-attack weapon would not always be feasible against the most advanced air defenses in the future.[60]

Hence, it would be desirable to investigate the feasibility of some sort of cruise missile with a nuclear penetrator warhead. It is uncertain whether such a missile could combine a range great enough to enhance aircraft survivability with the ability to

[59] Gunzinger, Rehberg, and Evans, *Sustaining the US Nuclear Deterrent*.

[60] A B-2 could carry two extremely large weapons of up to about 30,000 pounds using the connection mechanism employed for the MOP bomb. A B-2 could carry eight weapons in the 5,000- to 7,000-pound range using the rotary launchers. The Air Force has not released information on the maximum weapon size or maximum weapon load (by weight or volume) for the future B-21, although it has released an artist's conception indicating that the B-21 will resemble the B-2.



The cruise missiles have notional ranges of 2,000, 3,000, and 4,000 kilometers and are launched from four arbitrary points that might be accessible to US SSNs. A range of 4,000 kilometers or more should be possible in a larger missile that would be carried only in the *Virginia* Payload Module (VPM) that will be incorporated on Block V *Virginia*-class submarines (procurement beginning in 2019).

Figure 13. Geographic Coverage for SLCMs

penetrate 10 feet or more into hard rock, while still complying with constraints on length, diameter, and weight for the B-2 and the B-21. Of course, it would be possible for a B-52 to carry two very large cruise missiles with penetrator warheads externally, but the B-52 would need a weapon with a very long range to provide a desirable combination of target coverage and aircraft survivability. Regardless of the delivery aircraft, however, a nuclear standoff penetrator weapon would need a high level of in-flight survivability.

A final consideration pertains to possible enemy responses to US small-scale employment of nuclear weapons by bombers. The enemy would have an incentive to attack US bomber bases to prevent subsequent, and possibly larger, US nuclear strikes. By contrast, US actions involving forward-deployed weapons or weapons on SSNs might be less likely to provoke attacks on the United States. For example, by the time the United States decided to use nuclear weapons in a regional war, all operational SSNs would probably be at sea, so enemy attacks on US SSN bases would be of little military relevance.

Submarine-Launched Theater Missiles

US SSNs once carried the TLAM-N SLCM, but the United States removed the missiles from service unilaterally in accordance with the PNI of 1991 and destroyed them around 2010. Russia still has such cruise missiles, and other countries may be working on nuclear SLCMs.

SLCMs offer many advantages. Unlike aircraft, submarines can stay on station near a potential adversary for weeks and can, therefore, often provide a much faster response (measured from receipt of an order to execute a mission) than aircraft coming from thousands of miles away.[61] Moreover, modern

[61] Conversely, the United States might not always be able to quickly and easily get a launch order to a submerged submarine operating near the coast of a powerful enemy, whereas it could

US submarines offer substantial survivability advantages over land bases close to a powerful enemy, and they offer survivability advantages over most types of aircraft (unless the aircraft use long-range standoff weapons). In addition, if the SLCMs have a range of 3,000 kilometers or more, they could provide geographic coverage of most of Eurasia from four launch points close to the Eurasian coast. This is illustrated in Figure 13. Moreover, the SSNs carrying the SLCMs would not be dependent on foreign bases, and SLCMs launched from near the coast of Eurasia could strike most plausible adversaries without flying over any third-party great power. Finally, cruise missiles fly low (often under the clouds) and have a small infrared signature compared to ballistic missiles, so cruise missiles almost certainly would not be seen by launch-detection satellites. Hence, launching SLCMs might pose less risk that the targeted country would misinterpret US intentions than would launching ballistic missiles.

A plausible approach to fielding a nuclear SLCM would be to develop a nuclear version of the Next-Generation Land-Attack Weapon (NGLAW), which is expected to enter production as a successor to the current Tactical Tomahawk missile in the late 2020s.[62]

On the other hand, costs associated with restoring this capability include the following:

usually get such an order to a bomber or fighter bases quickly by using satellite communications.

[62] The current Tactical Tomahawk is nearing the end of production, and it would be hard to get a nuclear version into production while the current production line is still warm. It would also be difficult to provide nuclear warheads for such a missile in the next few years, because the National Nuclear Security Administration (NNSA) is facing challenges delivering modernized or life-extended warheads that are already in their plan. See NNSA, *Fiscal Year 2017 Stockpile Stewardship and Management Plan—Biennial Plan Summary*; and NNSA, *Fiscal Year 2018 Stockpile Stewardship and Management Plan—Report to Congress*. The authors discussed warhead issues with NNSA personnel.

- Developing and procuring the missiles
- Adding nuclear fire-control systems to SSNs built in the future[63]
- Increasing security at bases used by SSNs, possibly including the construction of expensive nuclear weapon storage facilities
- Starting a personnel reliability program for individuals involved with the nuclear weapons
- Building nuclear weapons handling facilities at the bases used by SSNs or accepting the opportunity cost for these submarines to travel to SSBN bases to load or unload their nuclear weapons
- Accepting the likely restrictions on US submarines visiting ports in foreign countries because of the presence of nuclear weapons on US submarines[64]

Starting around 2024, the Navy will began commissioning Block V *Virginia*-class submarines, each of which will have a *Virginia* Payload Module (VPM) aft of the sail. Each VPM will have four in-line tubes, each with a diameter of 87 inches, that can accommodate missiles up to about 33 feet long (compared to a significantly shorter length for the vertical-launch tubes forward of the sail on Block III and Block IV *Virginia*-class submarines or the tubes on cruisers and destroyers). Each tube could hold seven missiles with the same diameter as the Tomahawk, three missiles with diameters up to about 34 inches, or two missiles with diameters up to about 40 inches. Incorporating the VPM adds about 84 feet to the length of a *Virginia*-class submarine.[65]

Hence, a Block V *Virginia*-class submarine could carry 8 or 12 IRBMs if all four VPM tubes were devoted to such missiles. Geographic coverage

[63] Retrofitting such systems would be even more expensive.

[64] Such restrictions might apply to all nuclear-capable submarines, without regard for whether an individual submarine was actually carrying nuclear weapons.

[65] O'Rourke, *Navy Virginia (SSN-774) Class Attack Submarine Procurement*.

would be as shown in Figure 13 (unless the range were longer than 4,000 kilometers or shorter than 2,000 kilometers), but the time of flight would be much shorter than for an SLCM. Such a weapon might have major advantages over an SLCM against time-critical targets, if the mission-planning system can operate quickly enough to provide for use against such targets.

On the other hand, the unit cost for an IRBM would likely be higher than that for an SLCM, and the number of weapons per submarine would likely be smaller (due to the greater size of an IRBM, compared to an SLCM in the Tomahawk size class). A final disadvantage is that, unlike an SLCM, a submarine-launched IRBM with a range exceeding 600 kilometers would count against New START limits as an SLBM, and the United States has already reached the limit. If a naval IRBM-like weapon used boost-glide technology (with the reentry vehicle gliding for more than half the distance to the target), it would not count as a ballistic missile under New START definitions, and New START imposes no limits on submarine-based weapons that are not ballistic missiles. However, there is no guarantee that Russia would accept such an explanation. Hence, deploying such a weapon might lead Russia to withdraw from New START or to insist on modifying the treaty to count boost-glide weapons against treaty limits.

The discussion above focuses on submarines as potential delivery platforms for nuclear SLCMs, but surface ships are also possible delivery platforms. For example, the *Iowa*-class battleships reportedly carried the TLAM-N in the 1980s and early 1990s. Surface ships are at some disadvantage in survivability, compared with modern submarines, and a surface ship probably would not be able to get as close to a great power as a submarine could. Depending on the range of the SLCM, this need to stay farther away from the enemy could lead to a serious reduction in target coverage. Finally, the VPM can hold larger missiles than can existing or planned vertical-launch systems on surface ships, which could lead to a greater range for missiles on submarines. Hence, submarines would be preferred over surface ships for delivering SLCMs.

Ground-Launched Theater Missiles

The United States has no GLCMs and no theater ballistic missiles, except for the conventional Army Tactical Missile System (ATACMS), which has a range of about 300 kilometers. If on alert, theater ballistic missiles could provide a fast response and good in-flight survivability, with minimal overflight issues. GLCMs could also provide good target coverage with minimal overflight issues, albeit with a longer time of flight than for a ballistic missile.

Mobile ground-launched ballistic missiles and GLCMs would be highly survivable against an enemy attack if they were already deployed in the field at the time of that attack. However, they would be highly vulnerable to a preemptive attack if they were in garrisons at the time of the attack (much like aircraft at known, fixed bases close to a powerful enemy), so their survivability depends on keeping an appreciable fraction of the force operationally deployed at all times or deploying the force rapidly at the start of a crisis. Moreover, the local populace might object if such missiles were deployed outside of garrisons in significant numbers under routine conditions. Hence, modern submarines at sea are almost certainly superior to ground-launched missiles in terms of prelaunch survivability.

Another key factor is that the United States cannot deploy GLCMs or theater ballistic missiles that provide useful target coverage of potential adversaries without encountering treaty issues, possible problems in getting host nations to accept such weapons, or both. For example, a ground-launched missile would need a range of at least 4,200 kilometers to provide good geographic coverage from Guam, a range of at least 7,200 kilometers to provide good geographic coverage from Midway Island, and a range of at least 8,000 kilometers to provide good geographic coverage from Hawaii.

Coverage for a missile based in Europe would depend on the basing location, the missile's range, and the location of the target set. Such a missile would need a range of about 3,500 to 4,000 kilometers to reach western Russia from Spain, and the range requirements would decrease (but not to 500 kilometers) as the basing locations moved toward Poland. (If there were a requirement to reach targets farther east, range requirements might increase more.) Hence, any missile with enough range to be useful would likely violate the INF Treaty.

A GLCM with a range exceeding 5,500 kilometers could provide some military utility without technically violating the INF Treaty or counting against New START limits, but it is difficult to see how such a weapon would offer intrinsic advantages over ALCMs or SLCMs. In addition, if the United States were to field a GLCM with a range exceeding 5,500 kilometers, Russia might insist on modifying New START to count such a weapon in a manner similar to how it counts an ICBM.

There are two definite or potential ways to get around issues arising from the INF Treaty and New START. First, a ground-launched boost-glide missile would not meet the definition of either a ballistic missile or a cruise missile under current treaties. However, such weapons did not exist when the INF Treaty was signed, so Russia might choose to disagree that a land-based boost-glide weapon with a range of, for example, 3,000 kilometers is not a violation of the INF Treaty.

Second, the United States could deploy ground-based weapons with a range of less than 500 kilometers. Such weapons would not encounter any arms-control problems, but this option would depend entirely on gaining consent from a host nation immediately adjacent to a potential adversary. The existing ATACMS already falls into this category, but ATACMS has a maximum range of only 300 kilometers, whereas a value closer to the INF limit of 500 kilometers would increase utility. In addition, there is no nuclear variant of ATACMS.[66]

Finally, the fiscal year 2018 National Defense Authorization Act (NDAA) directs the Defense Department to develop an INF-violating cruise missile, with conventional and nuclear versions. This missile could be deployed in Europe as a response to the Russian GLCM mentioned earlier. Paths toward fielding a GLCM include the following options:[67]

- Adapt LRSO for ground launch by adding a rocket motor to get the missile up to a suitable speed and altitude and then integrate the boosted LRSO on a suitable ground vehicle.
  - LRSO is designed for launch from a bomber, which does not subject the missile to high acceleration. Using LRSO as a GLCM would be feasible only if the boost motor could get the missile above its stall speed without exceeding the acceleration limits for LRSO.
  - If LRSO has a conventional variant, a ground-launched missile could fully meet the act's mandate. If LRSO has no conventional variant, it would be necessary to forego the conventional GLCM or provide a separate weapon for that purpose.
- Field NGLAW on a mobile ground launcher.
  - NGLAW would be designed for boosted launch, so there would be no significant risk that the boost motor would subject the cruise missile to unacceptable acceleration.
  - If NGLAW has a nuclear variant, a ground-launched NGLAW could fully meet the act's mandate. If NGLAW has no nuclear variant, it would be necessary to forego the nuclear GLCM (which would be unlikely since the Russian SSC-8 has a nuclear variant),

[66] "Army Tactical Missile System Block IA Unitary," Lockheed Martin.

[67] US House Armed Services Committee, "Reform and Rebuild."

adapt LRSO for that purpose, or develop an entirely new weapon.

  - Overall, if there is going to be a nuclear version of NGLAW, the best approach would be to adapt NGLAW for ground launch, as was done in the 1980s with the Tomahawk missile (under the name Gryphon).

- Develop an entirely new missile.
  - This option would likely be more expensive than adapting LRSO or NGLAW, but the missile could be larger than LRSO or NGLAW. This approach would be warranted only if the GLCM needed more range than could be attained by adapting LRSO or NGLAW, or if there were some technical difficulty in using LRSO or NGLAW.

While the United States may want to deploy GLCMs or land-based IRBMs again in the future, we believe that SLCMs or naval IRBMs would probably have greater utility, and would face fewer political obstacles, than land-based theater weapons. Hence, GLCMs or IRBMs would best be deployed, if at all, as a complement to SLCMs rather than instead of SLCMs. If the United States does deploy weapons on land, a GLCM would likely be preferred over an IRBM, unless time of flight is important. A GLCM would likely be smaller than an IRBM, and a GLCM might be a derivative of a funded cruise missile (LRSO or NGLAW), whereas an IRBM would be a completely new weapon design.

BMD Interceptors and Other Improved Defenses

As noted earlier, Russia has nuclear-tipped BMD interceptors near Moscow. A BMD interceptor with a low-yield warhead would not have to hit an enemy reentry vehicle directly to destroy it, so such an interceptor might have a higher single-shot probability of kill than would a conventional interceptor. Hence, there may be merit to further investigating US low-yield nuclear BMD interceptors in a later report. The main emphasis of this report is offensive weapons, so we did not pursue this topic further here.

Improved regional, conventional defenses, however, could help mitigate some of the imbalances discussed in this report. A small number of nuclear missiles can inflict a large amount of damage (even at yields as low as a few kilotons), so it is unlikely that any plausible air and missile defense system could protect key US bases against a large-scale nuclear attack. (One missile that gets through defenses may be one too many.) However, improved defenses might be effective against a small nuclear attack, thereby forcing a peer competitor to launch a large nuclear attack, with high uncertainty in the number of warheads that would detonate, the corresponding number of civilian casualties, and the amount of collateral damage to civilian infrastructure. Further, improved defenses in Europe would make it harder for conventional missiles to negate NATO's nuclear assets in Europe. Of course, the existing short-range non-stealthy nuclear-capable fighters in Europe have drawbacks in range and possibly in-flight survivability, so improved defenses would have the greatest effect if combined with measures to improve the in-flight performance of the nuclear-capable fighters (such as nuclear cruise missiles). In other words, it is necessary to consider the nuclear system in its entirety—offense, defense, readiness, command and control, and political feasibility—to ensure overall force-level effectiveness at deterrence.

Comparison of Weapon Types Considered

The previous subsections describe individual types of new or improved nuclear weapons in detail, but it is important to consider an overall comparison of the weapon types. Consequently, Table 2 compares the military benefits that might be provided by several types of new or improved nuclear weapons (the three weapons mentioned in the NDAA and NPR, plus other weapons that we think deserve consideration), along with some disadvantages. In addition, the preceding discussions suggest that:

- The ability to respond rapidly is best for long-range ballistic missiles and for systems that are close to the enemy and already on nuclear alert.
- Target coverage is best, exclusive of overflight concerns, for long-range ballistic missiles and long-range cruise missiles, unless a long-range aircraft has enough survivability to reach all plausible targets.
- Prelaunch survivability is best for submarines and worst for systems at fixed bases close to a powerful enemy.
- In-flight survivability is best for ballistic missiles and highly stealthy missiles and worst for non-stealthy aircraft.
- The ratio of lethality to collateral damage can be good or poor for any type of weapon but tends to be best for guided bombs and accurate cruise missiles.
- Tactical suitability depends on multiple weapon design characteristics and how well these characteristics are matched to an intelligent concept of operations. This quality could be poor or good for most types of weapons.

Warhead Considerations for Candidate Weapons[68]

Discussions so far deal mainly with the technical and operational desirability of different delivery systems and, to a much lesser extent, the political burdens associated with deploying them. We assumed that suitable warheads would be available, but this may not be the case, especially before 2030 and/or without production capability and capacity improvements for the National Nuclear Security Administration (NNSA).

From the late 1940s through the late 1980s, NNSA and its predecessor organizations followed a "build and test" concept of operations. Because they assumed that warheads would be replaced by the time they were 20 to 25 years old, they gave little thought to how to maintain very old warheads.

In 1989, the major weapon production program was the W88 warhead for the new Navy Trident D5 SLBM. Also in 1989, Rocky Flats, the plutonium "pit"[69] production plant in Colorado, was closed because of severe environmental concerns, and NNSA was not able to produce a pit for the next 18 years. In response to its inability to produce weapons, NNSA initiated the Stockpile Stewardship Program to maintain weapon capability until it again could produce weapons.

The large number of Navy W76 warheads produced for the earlier Trident C4 program compensated for the lost production capability for the W88, and there was no major production program for the Air Force at that time. NNSA converted much of its budget from producing weapons and modernizing infrastructure to maintaining and improving the science base for nuclear weapons.

When NNSA made these decisions—mostly in the early to middle 1990s—the general expectation seemed to be that the salience of nuclear weapons in the world would slowly but inexorably decline. However, this has not turned out to be the case, given the emergence of nuclear weapons in North Korea, India, and Pakistan, China's gradual expansion of its nuclear arsenal, and Russia's nuclear modernization.

[68] In addition to consulting NNSA documents (*Fiscal Year 2017 Stockpile Stewardship and Management Plan—Biennial Plan Summary* and *Fiscal Year 2018 Stockpile Stewardship and Management Plan—Report to Congress)*, the authors discussed some of the topics in this section with NNSA personnel.

[69] A pit is a hollow, usually spherical, shell made of fissile material. Plutonium-239 is generally the material of choice for pits, but uranium-235 can be used. To initiate fission, a neutron generator illuminates the pit with neutrons simultaneous with the compression by high explosives.

Table 2. Military Benefits and Other Factors for Potential New Weapons

Parameter	Cruise Missile on		Low-Yield Reentry Vehicle on		Penetrator Weapon for B-2 or B-21	Nuclear Bomb on F-35C	BMD Intercep-tor	IRBM on SSN	In Europe	
	SSN	F-35A	Trident D5	Minute-man III					IRBM	GLCM
Less need for vulnerable bases	Yes, major	Maybe	Yes, major	Yes	Same as B-2 or B-21 with another weapon of the same range	Yes	N/A	Yes, major	Maybe[a]	Maybe[a]
Faster response	Yes	No	Yes, major	Yes, major		In Asia	N/A	Yes, major	Maybe[a]	Maybe[a]
Improved prelaunch survivability[b]	Yes, major	No	Yes, major	Yes		Yes	N/A	Yes, major	Maybe[a]	Maybe[a]
Improved target coverage[b]	Yes	Yes	Yes	Somewhat		Yes	N/A	Yes	Maybe[a]	Maybe[a]
Improved in-flight survivability[b]	Yes	Yes	Yes, major	Yes, major	For some enemies		N/A	Yes	Yes	Yes
Improved lethality[b]	Maybe[c]	Maybe[c]	Doubtful	Doubtful	Yes, major	No	Yes, major	Maybe[c]	Maybe[c]	Maybe[c]
Less collateral damage	Maybe[c]	Maybe[c]	Doubtful	Doubtful	Yes, major	No	N/A	Maybe[c]	Maybe[c]	Maybe[c]
Technical challenges	Medium–low	Medium–low	Low	Low	Medium–high	Low	Medium	Medium	Medium	Medium–low
INF violation	No	No	No	No	No	No	No	No	Yes	Yes
New START problems	No	Maybe[d]	No	No	No	No	No	Maybe	No	No
PNI violation	Yes	No	No	No	No	Yes	Maybe[e]	Yes	No	No
Political controversy	Medium	Medium	Medium–high		Medium	Medium	High	High	Very high	
Overall desirability[f]	Highest	Medium	Medium	?	Medium	Medium	?	Medium?	Low	Low

[a] Depends on the range of the missile, the locations of its bases, and (for faster response and improved prelaunch survivability) the operating posture of the system at the start of a war (in garrison vs. deployed in the field).

[b] Improvements are measured relative to the program of record in 2025 (AGM-86 ALCM plus B61-12 bombs on fighters and the B-2), not to current ICBMs or SLBMs.

[c] Depends on the accuracy of the weapon and the yield and fusion fraction of the warhead.

[d] If range > 600 kilometers.

[e] If sea based.

[f] IRBMs provide a shorter time of flight than SLCMs or GLCMs, which would sometimes be useful, but tend to be less desirable due to higher costs and technical risks. In addition, an IRBM on a submarine might end up counting against New START limits, whereas an SLCM would not pose such a risk.

NNSA continues to devote about one-third of its budget (of about $15 billion in fiscal year 2019) to science, and its production capability may be inadequate to support plausible future needs.[70] Its ability to meet the schedule even for currently planned warhead work is questionable. If the requirement is expanded to provide warheads for new, more, or different delivery systems, the production challenges would be extreme. Specific problems include those identified below.

Complex-Wide Issues

More than one-half of the current NNSA facilities are more than 40 years old, 30 percent were built during the Manhattan Project, and 61 percent are in less than adequate condition. Under these current conditions, almost none of the critical components needed to produce war reserve nuclear weapon components can be manufactured from raw materials. In many cases, the existing stockpile of material is limited and is inadequate to support future needs. The sections below describe the status of the major elements needed for production of war reserve weapons.[71]

Plutonium

The current facility is TA-55 at Los Alamos National Laboratory in New Mexico. It is not currently producing pits for the stockpile, and its capacity is limited to test pits for development testing. The next war reserve pit is scheduled for production in 2023. Pit production capability was paused in 2013 and marginally resumed in 2016. New production facilities are needed. An analysis of alternatives was recently completed, but no specific plan for production capability is in place, even though increased production is almost certainly needed by 2030. Production levels will likely need to be on the order of at least 80 pits per year (for currently planned delivery systems), exclusive of any possible additional pit production for new NSNWs. In addition, the Pantex Plant, northeast of Amarillo, Texas, needs a new pit storage facility.

Uranium

Most facilities are at the Y-12 National Security Complex, in Oak Ridge, Tennessee. A new processing capability at Y-12 is needed by 2025 to replace a facility built during the Manhattan Project. No construction project is currently in place for a modern facility to process uranium. NNSA is continuing to explore centrifuge technology for production of highly enriched uranium, which will eventually be needed, but the United States will have no ability to make highly enriched uranium in the foreseeable future.

Tritium

Gas processing and support equipment will require replacement by 2025, and NNSA needs to establish full operation by the end of 2019. Production must ramp up by 2025 to meet requirements; this entails substantial investment because requirements cannot be met with existing facilities. The ability to meet the increased production rate is still unproven and will not be realized without alternative production capabilities and new production methods.[72]

Lithium

The main facility at Y-12 in Tennessee is over 70 years old, and basic material cannot currently be produced there. An analysis of alternatives on ways to provide full purification capability is under way, but no new capability will be available for at least a decade.

70 NNSA, *Fiscal Year 2017 Stockpile Stewardship and Management Plan—Biennial Plan Summary*; and NNSA, *Fiscal Year 2018 Stockpile Stewardship and Management Plan—Report to Congress.*

71 NNSA, *Fiscal Year 2017 Stockpile Stewardship and Management Plan—Biennial Plan Summary*; and NNSA, *Fiscal Year 2018 Stockpile Stewardship and Management Plan—Report to Congress.*

72 NNSA, *Fiscal Year 2017 Stockpile Stewardship and Management Plan—Biennial Plan Summary*; and NNSA, *Fiscal Year 2018 Stockpile Stewardship and Management Plan—Report to Congress.*

Nonnuclear Components and Materials

Nuclear weapons employ chemical explosives to compress a plutonium or uranium pit to create fission. X-rays from the fission may then compress a "secondary" to increase the yield of the weapon.[73] Work on explosives is focused at the Pantex facility near Amarillo, Texas. (Pantex derives its name from the panhandle of Texas.) Many Pantex facilities date back to the 1940s and do not meet modern safety standards. A new capability to reprocess available materials is under development. For insensitive high explosives, both key energetic components and the binder material in the existing formulation (tested underground) are no longer available. Moreover, the current stockpile of insensitive high explosives is inadequate to meet current needs, and vendor supply limitations and quality issues are a risk to the country's ability to meet future stockpile needs.

Formal risk analysis continues to show deteriorating infrastructure at the Savannah River Site complex in South Carolina. Its limited capacity to test gas transfer systems is forcing trade-offs between surveillance and research and development needs. Gas-transfer-system testing at the complex will be insufficient without facility modifications. In addition, production welding equipment at the Kansas City National Security Campus is inadequate for current needs. Because of its facility conditions, Sandia National Laboratories in Albuquerque, New Mexico, is becoming inadequate for power source production. Finally, a clear path is needed to sustain a sufficient supply of trusted strategic radiation-hardened advanced microsystems,[74] and the existing fabrication infrastructure at Sandia continues to deteriorate.

[73] "How Do Nuclear Weapons Work?," Union of Concerned Scientists.

[74] Space-rated microelectronic systems are frequently inadequate for the nuclear mission, because satellites do not normally experience any significant neutron flux and are unlikely to experience a high transient dose of ionizing radiation. On the other hand, a nuclear explosion will produce a large transient ionizing dose and a large transient neutron dose.

Conclusions on NNSA and Warheads

If the United States opts to redress imbalances in NSNWs or to ensure robust future US nuclear capabilities, it will need a more capable and versatile warhead production complex. The extra funding needed for these efforts would not be trivial, although some of it could possibly be obtained by diverting some fraction of the NNSA science budget to infrastructure modernization and additional work on warheads. This diversion could be done gradually, starting perhaps in fiscal year 2021. NNSA has devoted many billions of dollars to improving the science basis for understanding nuclear weapons over the course of the last quarter century. We believe that this undertaking might have entered the region of diminishing returns.

Further, the level of difficulty associated with providing warheads for the various systems described in the early parts of this section varies from weapon to weapon. The level of difficulty ranks approximately as listed below, with the easiest items at the top of the list and the most difficult at the bottom.[75]

- Diverting planned warheads to a use that is slightly different from what is currently planned
  - For example, it would be practical to divert some B61-12 bombs planned for Air Force use to support F-35C use on aircraft carriers. Of course, this specific example would involve some opportunity costs for the Air Force.
  - It would also be easy to divert some W76/Mark 4A reentry vehicles planned for use by the Trident D5 SLBM to a new IRBM, but doing so would involve opportunity costs for the SLBM force, and the yield option(s) for the W76 might not be optimal for an IRBM in regional war.

[75] We developed this ranking after discussions with JHU/APL staff and consultations with NNSA personnel.

- Increasing the production objective for a planned warhead by an amount compatible with the existing inventory of various components
  - One example is to increase the production objective for the B61-12 bomb to support use by both the Air Force and the Navy.
  - Another example is to increase the number of LRSO warheads, either to support an increase in LRSO procurement (e.g., for regional use) or to provide warheads for a new and different cruise missile.
- Making comparatively simple modifications to planned warheads, possibly in conjunction with a small increase in production quantities
  - One example might be to modify an existing Trident D5 warhead to lower its yield, as described in the 2018 NPR.
- Refurbishing a type of warhead that is currently in the inactive stockpile or in managed retirement
  - The most likely example might be to revive the W84 warhead that was once used on the BGM-109G Gryphon GLCM.
- Designing and producing a new warhead that is not a near clone of a planned warhead
  - A likely unwillingness to conduct underground test detonations of the new warhead would further complicate efforts to introduce any sort of all-new warhead that differs significantly from tested designs.

Two general points emerge from the discussion above. First, we think that the United States needs to undertake a serious effort to modernize the nuclear warhead production complex. It must guarantee that production capacity and versatility are adequate to support likely needs in the 2030s and beyond, preferably with some safety margin in case actual needs are underestimated. Second, we recommend that any decision to proceed with fielding new nuclear weapons (for either regional or strategic use) should consider the difficulties associated with providing the required warheads, in addition to issues associated with the delivery system, basing rights, and so on.

Conclusions and Observations

Russia's NSNWs have major advantages over those of the United States, both numerically and technically. US capabilities will improve after the F-35A is equipped with the B61-12 bomb, but the improvements will not address all US disadvantages. In addition, China has NSNWs, and North Korea either has, or soon will have, a small number of NSNWs, whereas the United States has no NSNWs that could be used in the near term in eastern Asia.

The United States should consider the following questions in the next year or two:

- Is there any plausible way that the United States and its allies could win an otherwise conventional conflict despite the adversary's limited use of low-yield NSNWs? If so, would winning the war be contingent on the United States having more or better conventional weapons? Would US success in battle, with conventional weapons, lead to US victory in the war or to the enemy's use of nuclear weapons on a larger scale?
  - While assessments can and should be made be made regarding our ability to "fight through" limited use of low-yields NSNWs, either with or without better US conventional capabilities, it may be hard to produce a reliable answer, because the political and psychological effects of limited nuclear weapon usage could greatly exceed the direct military impact. These political and psychological effects could possibly render the United States and its allies incapable of pushing to victory, even if the conventional balance of forces at that point greatly favored the United States and its allies. This consideration would be especially pertinent if the conventionally inferior

adversary had the ability to escalate nuclear usage if the war continued.

- The third question above is also difficult to answer, again due mainly to political and psychological issues, but it is highly pertinent for future conflicts against nuclear-armed adversaries. If the United States and its allies persist in trying to achieve success with conventional arms after an enemy that has the ability to escalate nuclear weapons usage engages in limited use, the path forward might depend on how aggressive US goals are. If the cost of defeat is high (e.g., possible regime collapse) and the adversary has the requisite capabilities, the enemy would probably resort to larger-scale use of NSNWs rather than accept defeat. Under such conditions, US success through use of conventional weapons would be unlikely.
- These factors highlight the importance of *deterring* an enemy from using nuclear weapons.

- How much would better US NSNWs contribute to warfighting capabilities, deterrence of potential adversaries (from starting a war or engaging in first use of nuclear weapons), and assurance of allies?
  - Better US NSNWs could contribute to improvements in warfighting capabilities, deterrence, and possibly assurance of allies, but we cannot currently quantify these benefits.
- Does Russia derive significant advantages from its superiority in NSNWs? Does the lack of US NSNWs in Asia matter? If the answer to either question is yes, should the United States develop and deploy new types of NSNWs, deploy NSNWs in Asia, or both?
  - No definitive answer is possible, but we think that the answer to the first question is yes, and the 2018 NPR report also contains statements to this effect. It is probable that the answer to the second question is also yes, but there is less discussion on this in the NPR.
  - It is hard to determine whether the best US response includes new or improved NSNWs. However, we think that the United States should pursue improved nuclear capabilities of some sort, better defenses against limited nuclear attacks (especially attacks by cruise missiles), or both.
- Given Russia's probable violation of the INF Treaty and China's possession of a large number of (mostly conventional) weapons of types that the INF Treaty does not allow the United States and Russia to possess, should the United States undertake a major effort to preserve the treaty?
  - We think that the collapse of the INF Treaty would benefit Russia relative to the United States, as discussed below. However, the United States needs to think about ways to secure Russia's compliance with the treaty.
- If the INF Treaty collapses, should the United States develop and deploy INF-violating weapons? If so, should the United States deploy such weapons worldwide or only in the Pacific in response to the large Chinese inventory of (conventional) intermediate-range weapons? A Pacific-only deployment might be better in terms of relations with Russia.
  - Potential difficulties in obtaining host-nation agreements for deploying such weapons suggest that new US air-launched and sea-launched weapons are likely preferable to new US weapons on land. Land-based weapons are also vulnerable while in garrisons.
  - By contrast, if the INF Treaty were to collapse, Russia could quickly deploy dozens or hundreds of long-range nuclear GLCMs on ground vehicles (possibly ground-launched

versions of existing missiles carried by submarines and bombers) in western Russia.

- If the United States decides to deploy new types of NSNWs, should its primary emphasis be on addressing the numerical imbalance in Europe, the lack of NSNWs in Asia, or the disparity in technical characteristics compared with Russian weapons?
  - We believe that all the factors listed above are relevant but deficiencies in technical and operational characteristics are the problems most in need of redressing. This conclusion is generally consistent with directions in the 2018 NPR report and the 2018 NDAA to develop three new types of weapons (a low-yield Trident D5, a new SLCM, and a new GLCM).
  - A new SLCM, in particular, could offer improved technical characteristics, without dependence on foreign bases, and also address the lack of US NWNWs in the western Pacific.

Better NSNWs would likely enhance deterrence, improve assurance to US allies, provide leverage in future arms-control negotiations, or achieve more than one of these goals. Conversely, any US efforts to improve or expand NSNWs would entail significant cost and political controversy. Consequently, any decision to develop new NSNWs should be preceded by detailed analyses on how such weapons might contribute to deterrence of enemies and assurance of allies, where such weapons should be deployed and whether host-nation agreements could be obtained (if relevant), and how the United States might actually use these weapons in a war if it had them. Following is a possible analysis plan for further investigations:

- Identify US and allied targets that an adversary might strike to achieve desired strategic and operational objectives while mitigating escalation risks. Repeat this process for an adversary's targets that the United States and its allies might strike, either with current or planned US weapons or with improved weapons. Model nuclear effects against both target sets identified above, including damage to the targets and casualty estimates. Compare, at least approximately, the price to attack (against a given set of targets) for nuclear and conventional weapons (most likely nuclear and conventional cruise missiles). Account for (at least approximately) the survivability of US and allied delivery systems. If feasible, evaluate the operational impacts (e.g., sortie generation) of these strikes.
- Consider analyzing how US and allied defenses, along with improved nuclear survivability of their systems, contribute to their ability to carry out missions.
- Use results from these analyses to develop playbooks for both sides that detail viable courses of action (on policy, arms control, new and better weapons, new and better defenses, target strategy, etc.). The investigation could culminate in one or more high-level war games informed by the results of the analyses.

On balance, it seems likely that the United States should improve its nuclear and/or INF-incompatible capabilities in response to imbalances in nuclear weapons in both Europe and the western Pacific and imbalances in INF-incompatible conventional weapons in the western Pacific. The improved nuclear capabilities could include new NSNWs, improvements to planned systems (including strategic systems), or both.

If the United States decides to field new or improved nuclear weapons of any of the types discussed earlier, the weapons should have yield–accuracy combinations that enable high lethality against the most likely targets without causing severe collateral damage. For ICBMs and SLBMs, in particular, meeting this requirement could favor guided low-yield reentry vehicles over low-yield versions of existing ballistic reentry vehicles, if there is a requirement to destroy hard targets. Weapons (or in some cases, delivery aircraft) must also have sufficient range and in-flight survivability to reach key regional targets. Survivability against a preemptive attack is another key consideration.

For new weapons, it would likely be better to emphasize weapons at sea, to avoid having to obtain basing rights and also because basing at sea (especially on submarines) could be more survivable than basing on land close to a powerful adversary.[76] Of the sea-based weapons, an SLCM on submarines would likely be the most useful, while integrating nuclear bombs on the F-35C or providing a low-yield ballistic reentry vehicle for the Trident D5 would be the easiest to field. An IRBM on submarines would be very useful, but it would be more expensive than an SLCM and would pose more risk of arms-control problems than an SLCM (because it could possibly be classified as an SLBM under New START). A low-yield reentry vehicle for the Trident D5 could also be useful, depending on its accuracy and risk of provoking escalatory actions, and would be much easier to field than a new IRBM.

This does not mean that improvements to land-based air-delivered capabilities are pointless. For example, standoff weapons for the F-15E and the F-35A could be useful, primarily if combined with improved defenses at the associated bases. The United States should also consider better weapons for bombers, such as penetrator weapons, LRSO upgrades to make it more suitable for use in limited regional war, or both.[77] A penetrator weapon would be valuable against countries that have many underground targets but do not have state-of-art air defenses, whereas more or better cruise missiles would be more broadly applicable against large adversaries that have advanced air defenses.

On the other hand, all-new land-based systems such as GLCMs and IRBMs probably should not be pursued unless it appears likely in advance that US allies will give permission to serve as hosts for such weapons. Absent such agreements, the United States risks wasting significant resources on weapons that cannot be deployed in any useful manner. In addition, such weapons would be vulnerable to an enemy first strike when they are in garrisons. There might, however, be an exception for a land-based weapon with sufficient range to cover most of eastern Asia from Guam.

Finally, decisions on future nuclear forces depend on policy questions that physics-based modeling cannot answer, although such modeling can provide useful insights into two or three of the questions below. Among the most important of these questions are the following:[78]

- **How much is enough?** What level of threatened retaliation is sufficient to support deterrence? How many survivable nuclear delivery vehicles and warheads, and of what types, do we need to ensure such retaliation?
- **What capabilities do we need for limited nuclear war or for deterring small countries?** Would potential adversaries believe that the United States would be willing to inflict severe collateral damage in response to limited use of low-yield NSNWs against military targets? If not, do US nuclear weapons have much deterrent value without improved capabilities to reduce collateral damage?
- **What role will Russia play in the future?** Future US relations with Russia are critical to determining what US nuclear forces are needed, especially with regard to ICBMs and NSNWs.
- **What role will or should treaties play in the future?** Except for the INF Treaty, existing treaties

[76] US Department of Defense, *Nuclear Posture Review 2018*, XIII.

[77] Depending on which characteristics LRSO will have with the program of record, and the flexibility of the current design, such enhancements might be either unnecessary (i.e., LRSO is good enough as is) or infeasible (i.e., the design is not flexible enough).

[78] Modified from Evans and Schwalbe, *Intercontinental Ballistic Missiles*.

apply only to strategic nuclear weapons. Further, all treaties limiting the size or nature of nuclear arsenals apply only to the United States and Russia. Meanwhile, China could become a great nuclear power by 2030 and has a large inventory of (mostly conventional) weapons of types that are banned for INF signatories. Hence, should future treaties include China, some types of NSNWs, or both? If treaty scope cannot be expanded, is it desirable to continue with bilateral treaties on long-range weapons?

- As a corollary, Russia may try to limit US national BMD in exchange for continued limits on strategic nuclear weapons. Given the threat from North Korea, should the United States be willing to accept any such limits on homeland defense?[79]

- **Should changes be made to NNSA's organizational structure and its position relative to the Defense Department and the Department of Energy?** Two options are discussed below.

1. Absorb NNSA into the Defense Department. When Congress enacted the Atomic Energy Act of 1954, it intended to keep nuclear warheads in civilian custody. At that time, many warheads had removable pits that would remain in the custody of the Atomic Energy Commission (a predecessor of NNSA) until it was necessary to provide the pits to the Defense Department in a crisis. The switch to "sealed pits" that were permanently installed in weapons contravened the intent of this approach within a decade, yet the separation between NNSA and the Defense Department lingers on. Hence, the portion of NNSA that deals with nuclear warheads could perhaps be absorbed into the office of a notional under secretary of defense for strategic warfare, an office that might also include responsibility for all nuclear delivery systems (or at least all delivery systems that are purely nuclear, instead of dual role) and nuclear command, control, and communications.

   Such an organizational change would probably increase the emphasis on nuclear weapon capability and production and decrease the emphasis on scientific research of limited near-term applicability to defense needs (e.g., inertial confinement fusion). Such research could remain in the Department of Energy, and much of it could be conducted at existing NNSA laboratories, but the associated funding could be separate from, and not in competition with, work of high near-term applicability to nuclear warheads.

   In addition, there is some duplication between nonproliferation activities at NNSA and similar activities at the Defense Threat Reduction Agency. NNSA absorption into the Defense Department, with this portion of the NNSA portfolio being transferred to the Defense Threat Reduction Agency, would allow consolidation and coordination between such activities.

   Finally, the portion of NNSA devoted to providing nuclear reactors for aircraft carriers and submarines could be absorbed into the Navy for better integration into design of propulsion systems.

2. Make NNSA independent of the Department of Energy. Making NNSA into a stand-alone organization independent of the Department of Energy might not, in and of itself, do anything to improve coordination with the Defense Department. However, all Department of Energy activities are overseen by the

[79] Russia seems to think that US BMD would be many times more effective against a Russian ballistic missile attack than would likely be the case in reality. If Russia's view of US BMD effectiveness is correct, then Ground-Based Midcourse Defense might be able to negate a Russian retaliatory strike after a US first strike. Hence, Russia is very eager to limit or eliminate Ground-Based Midcourse Defense.

House Committee on Energy and Commerce and the Senate Committee on Energy and Natural Resources. These committees are short of expertise on national security. If NNSA were moved outside of the Department of Energy, congressional oversight could transition to the two armed services committees, which would seem to be more sensible than the current arrangement. Moreover, oversight by the two armed services committees might provide a forcing function for improved coordination with the Defense Department, even if NNSA were not part of the Defense Department.

- **How much is the United States willing to invest in nuclear forces and defense in general?** How much risk are US leaders willing to accept in terms of deterrence or the balance of power? How can risk be quantified?
- **Given their technical limitations, do current US NSNWs in Europe play a useful military or political role or are they an anachronism?**
  - If these weapons do not appear to be useful, would the proper response be to upgrade capabilities, withdraw the NSNWs (if our allies agree), or leave things as is for political reasons?
- **What are the interactions and synergies between air and missile defense and offensive weapons (nuclear and conventional) for regional war?** This topic was neglected in the 2010 and 2018 NPRs, and the discussion on offense–defense synergy from the 2002 NPR focused on strategic war and, in addition, is now obsolete.[80]
- **What are the interactions among strategic nuclear weapons, NSNWs, and advanced conventional weapons?** How do potential investments in NSNWs compare with investments in strategic forces or other systems? Is there still an important distinction between strategic weapons and NSNWs? Does superiority in conventional forces outweigh advantages in NSNWs or merely invite the use of NSNWs?
- **Should the United States design new nuclear warheads again?** Several countries appear to be designing new warheads, and the benefits of US unilateral restraint are unclear.

In conclusion, no one yet knows the right answers to all the questions posed in this report, but we believe that NSNWs will remain important for decades to come. US thinking has neglected NSNWs for far too long. It is time to think seriously about NSNWs again. The 2018 NPR and the fiscal year 2018 NDAA are good starts in terms of drawing attention to this subject, but more work needs to be done before the United States decides which, if any, new NSNWs to develop and procure and how to exploit offense–defense synergies. An implementation plan (preferably with a classified appendix) for the NPR would be a good place to detail the needed analytical and policy efforts. In addition, the United States needs to begin taking steps—and preferably soon—to revitalize the manufacturing infrastructure at NNSA so that it can meet the most pressing plausible warhead stockpile needs for the 2030s and beyond.

[80] The 2019 *Missile Defense Review* devoted minor attention to offense–defense synergy, but only in the context of US conventional weapons and defending against enemy conventional weapons.

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