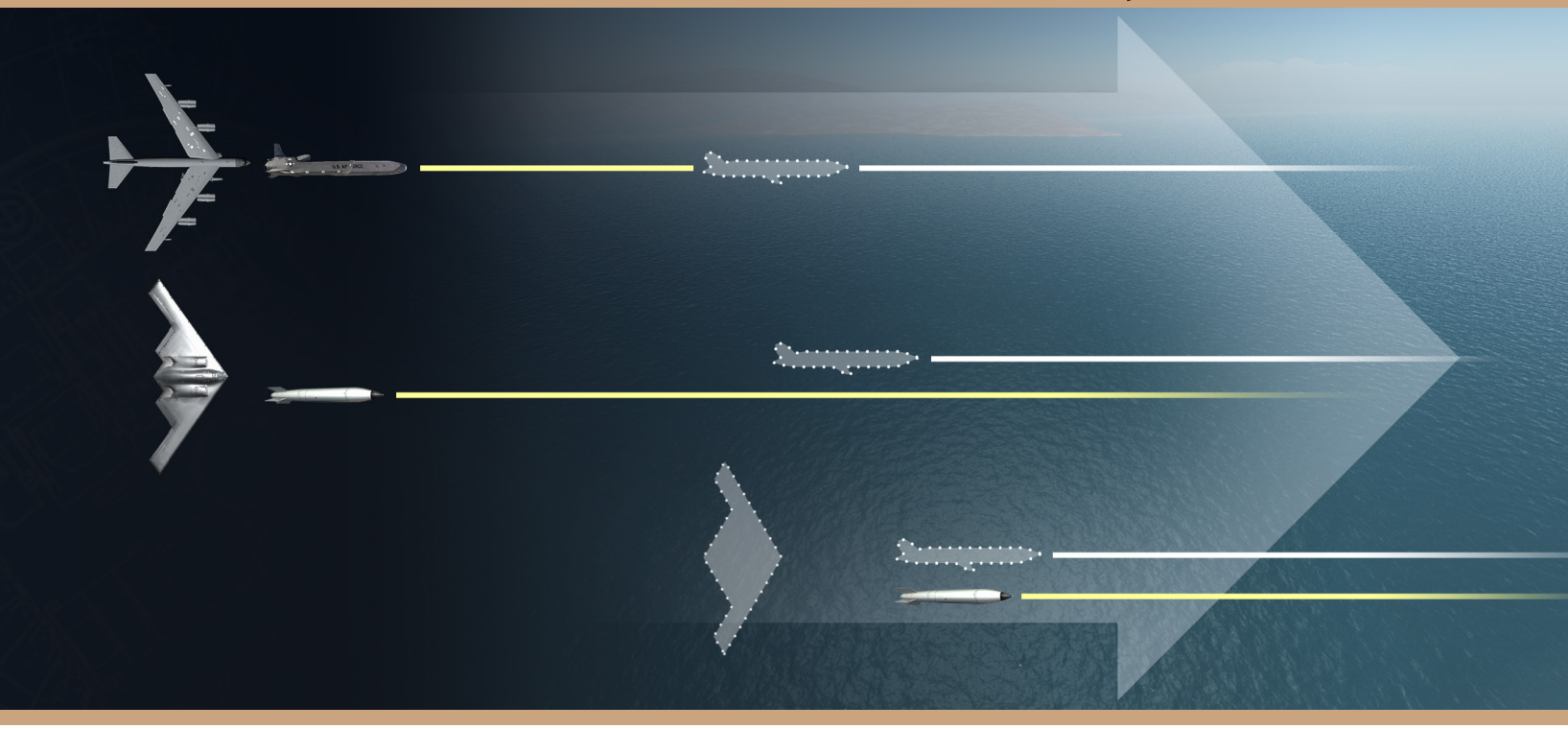
THE LONG-RANGE STANDOFF (LRSO) CRUISE MISSILE AND ITS ROLE IN FUTURE NUCLEAR FORCES

National Security Perspective



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JHU/APL has conducted classified analyses that are relevant to discussions on the need for LRSO and/or ICBMs in the future. Other such analyses deal with nonstrategic nuclear weapons. Requests for such briefings can be made by contacting Dennis Evans (dennis.evans@jhuapl.edu or 240-228-6916) or Jonathan Schwalbe (jonathan.schwalbe@jhuapl.edu or 240-228-6439) or by contacting JHU/APL management at david.underhill@jhuapl.edu, matthew.schaffer@jhuapl.edu, or preston.dunlap@jhuapl.edu.

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Summary

The United States has a nuclear triad that consists of 14 *Ohio*-class ballistic missile submarines (SSBNs), of which 12 SSBNs are normally operational; 400 Minuteman III land-based intercontinental ballistic missiles (ICBMs), almost all of which are operational at any time; 76 non-stealthy B-52 bombers, of which about 44–56 can be operational at one time; and 20 stealthy B-2 bombers, of which about 15 or 16 can be operational at one time. The non-stealthy B-52 relies entirely on the AGM-86 Air-Launched Cruise Missile (ALCM) in the nuclear role, whereas the B-2 penetrates enemy airspace to drop unguided B61 bombs. The current SSBNs, ICBMs, ALCMs, and B61 bombs will all reach end of life between the early 2020s (for the B61 bomb) and the early 2040s, whereas the B-52 should last until at least 2045 and the B-2 should last until at least 2050. The formerly nuclear-capable B-1 bomber will probably reach end of life by 2040 or before.

Programs are well under way for the new *Columbia*-class SSBN, the stealthy B-21 Raider bomber, and the B61-12 guided bomb, whereas programs have just started for a new ICBM to replace Minuteman III and for the Long-Range Standoff (LRSO) cruise missile that is planned to replace the AGM-86. Very little funding has been expended on the ICBM replacement program or on the LRSO program, but there seems to be a general consensus on the need for ICBMs in the future, even though details need to be worked out on a number of issues pertaining to force structure and technical characteristics.

This triad recapitalization program is well entrenched within the corridors of the Pentagon. By contrast, numerous open-literature opinion pieces have called for the cancellation of LRSO. Hence, LRSO is likely to be a topic of intense discussion during the Nuclear Posture Review, and LRSO is probably at greater risk of cancellation than any other program in the nuclear recapitalization portfolio. Consequently, additional analysis on LRSO is warranted, which this paper strives to provide to better inform public and other unclassified discussions on the topic. A classified version is also available.

The argument for continuing with the LRSO program has four main elements:

(1) The United States needs bombers in the nuclear role, especially for smaller-scale contingencies but also to help with crisis management and to deter a major nuclear war against a nuclear peer. Additionally, nuclear-capable bombers provide some risk mitigation against problems with the new SSBN or the new ICBM, or against unexpected advances in enemy anti-submarine warfare.

  – Beyond their direct contributions, US bombers and their cruise missiles are cost imposing, by forcing potential adversaries to devote large resources to air defenses.

(2) LRSO is probably critical to the long-term viability of the bomber force in the nuclear role.

  – The B-52—our most numerous bomber for at least the next 15 years—is completely dependent on long-range cruise missiles and cannot continue in the nuclear mission beyond 2030 without LRSO.

  – The B-2 will probably need cruise missiles against the most advanced foreign air defense systems by 2030.

  – The B-21 is barely past the Preliminary Design Review stage in its development, and it is too early to know how survivable the B-21 will be against the most advanced air defenses of 2030 and beyond, or whether it will need cruise missiles for reasons pertaining to range. Hence, it is reasonable to hedge against the risk that the B-21 will eventually be unable to penetrate state-of-the-art air defenses.

(3) If there is eventually a conventional variant of LRSO—which is still uncertain—it would probably be superior to the current JASSM (Joint Air-to-Surface Standoff Missile) and JASSM-ER (Joint Air-to-Surface Standoff Missile, Extended Range) cruise missiles. This could significantly enhance bomber utility in a conventional war against a geographically large adversary with advanced air defenses. LRSO termination would end the opportunity for such a conventional spin-off.

(4) Russia has a large numerical and technological advantage over the United States in nonstrategic nuclear weapons (NSNWs) and in accurate low-yield, survivable nuclear weapons (whether classified as strategic or nonstrategic). The military significance of this disparity is unclear but possibly major. Among existing and funded weapons, LRSO could be the most feasible US nuclear option for deterring, or responding to, foreign usage of accurate low-yield weapons against military targets.

   – More research is needed on whether improved US nuclear weapons are essential in responding to this Russian challenge. Better defenses, better conventional weapons, better readiness and doctrine, or some combination thereof might be preferable to better US nuclear weapons, or needed in addition to such weapons.

The arguments above suggest that the operational benefits of proceeding with the LRSO program would be substantial. By comparison, the cost of LRSO is likely to be minor in comparison to the costs of the bombers themselves (10–20 times less), let alone in comparison to the cost of the entire triad recapitalization effort. Thus, LRSO termination might have a major detrimental effect on US nuclear capabilities and sacrifice the potential for obtaining the world's best air-launched conventional cruise missile, all in exchange for a tiny percentage reduction in spending within the bomber portfolio, let alone the entire strategic portfolio.

The United States has had a triad of land-based intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs) on ballistic missile submarines (SSBNs), and long-range bombers since about 1960. This triad has played a key role in US security for decades, but the current SSBNs, ICBMs, Air-Launched Cruise Missiles (ALCMs), and B61 bombs will all reach end of life between the early 2020s (for the B61 bomb) and the early 2040s. The B-52 should last until at least 2045, and the B-2 should last until at least 2050. The formerly nuclear-capable B-1 bomber will probably reach end of life by 2040 or before.

The triad includes 14 *Ohio*-class SSBNs, of which 12 SSBNs are normally operational. Each SSBN has 24 Trident D-5 SLBMs, although this number will drop to 20 by 2018 in compliance with New Strategic Arms Reduction Treaty, or New START, limits. Further, the *Ohio*-class SSBNs will begin reaching end of life around 2027. The program for the new *Columbia*-class SSBN, which has been under way for several years, is planned to deliver 12 new SSBNs, each with 16 SLBMs.

The Minuteman III ICBM will reach end of life in the early to middle 2030s. The Department of Defense has just started a program to sustain the ICBM force, but details are still lacking on program cost, missile characteristics, basing mode, or the planned size of the ICBM force in 2040. Very little funding has been expended on this ICBM program, but there seems to be general consensus on the need for ICBMs in the future, even though details need to be worked out on a number of issues.

The United States has 96 nuclear-capable bombers (76 B-52s and 20 B-2s). Under New START, the number of nuclear-capable bombers will be cut to 60 when some B-52s are modified so that they cannot carry nuclear weapons. The non-stealthy B-52 relies entirely on the AGM-86 ALCM in the nuclear role, whereas the B-2 currently relies on penetrating enemy airspace to drop unguided B61 bombs. A new stealthy bomber, the B-21 Raider, has been under development for several years, and the Air Force plans to procure at least 100 B-21s. However, the Air Force has not announced the initial operational capability (IOC) date for this aircraft. Current plans call for some or all B-21s to be nuclear capable, although the Air Force has not announced how many nuclear weapons it will be able to carry or when nuclear IOC will occur relative to conventional IOC.

The Air Force is also developing two nuclear weapons for aircraft: the Long-Range Standoff (LRSO) cruise missile to replace the ALCM, which will reach end of life around 2030, and the B61-12 guided bomb. The new bomb will be used by stealthy bombers and the F-35A (the Air Force variant of the F-35). LRSO is planned for use by all three nuclear bombers but not by fighters.[1] The B61-12 program has been under way for several years and does not appear to be very controversial. By contrast, very little funding has been expended on the LRSO program, and numerous opinion pieces have called for its cancellation.[2] Hence,

[1] External carriage by the F-35A might be possible, but doing so would cause the F-35A to count as a nuclear heavy bomber under New START unless the range of LRSO is less than 600 kilometers. This would place the United States in violation of New START limits on warheads and delivery vehicles. Carriage by the currently conventional B-1 is not likely because the B-1 cannot carry weapons externally, and internal carriage is restricted to weapons that are much smaller than ALCM. If the B-1 were to carry LRSO or any other nuclear weapon, this would cause B-1s to count against New START limits on warheads and delivery vehicles, and this would cause the United States to violate New START limits on warheads and delivery vehicles.

[2] Examples include: Dianne Feinstein and Ellen O. Tauscher, "A Nuclear Weapon That America Doesn't Need," *New York Times*, June 27, 2016, https://www.nytimes.com/2016/06/18/opinion/a-nuclear-weapon-that-america-doesnt-need.html; William J. Perry and Andrew Weber, "Mr. President, Kill the New Cruise Missile," *Washington Post*, October 15, 2015, https://www.washingtonpost.com/opinions/mr-president-kill-the-new-cruise-missile/2015/10/15/e3e2807c-6ecd-11e5-9bfe-e59f5e244f92_story.html?utm_term=.b2bbc694f7d8; Kingston Reif, "Overkill: The Case Against a New Nuclear Air-Launched Cruise Missile," *Arms Control Association Issue Brief* 7, no. 13 (October 19, 2015), https://www.armscontrol.org/Issue-Briefs/2015-10-19/Overkill-The-Case-Against-a-New-Nuclear-Air-Launched-Cruise-Missile; Stephen Young, "Kendall's Telling Mistake on the LRSO," *All Things Nuclear*

the LRSO is likely to be a topic of intense discussion during the Nuclear Posture Review, so additional analysis on LRSO is warranted, which this paper aims to provide.

The remainder of this report is organized as follows:

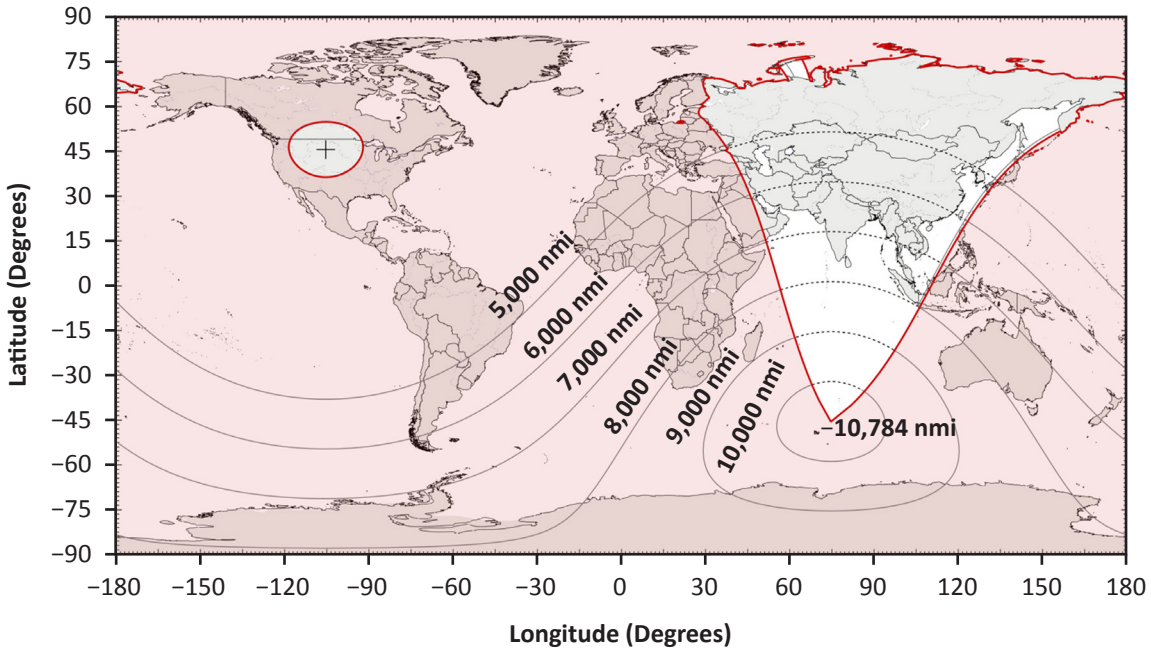
- The need for bombers in the nuclear role
- The need for cruise missiles—conventional and nuclear—by the bombers and LRSO's possible impact on the conventional mission
- Russian advantages in nonstrategic nuclear weapons (NSNWs) and the possible role for LRSO in responding to these Russian advantages
- A discussion of public arguments against LRSO
- Conclusions

The Need for Bombers

The importance of bombers in the nuclear role is heavily dependent on the scenario. For example, in a nuclear exchange between the United States and Russia, an ICBM–SLBM dyad might well be satisfactory under some conditions, partly because ICBMs have easy access to Russia on transpolar trajectories. In practice, however, reliance on an ICBM–SLBM dyad would involve various risks—technical, programmatic, and operational—that a nuclear-capable bomber force might help mitigate:

- The long-term survivability of ICBMs in the current, 1960s-era silos is uncertain (at least without the use of "launch on warning," a tactic that runs the risk of catastrophic escalation in response to a false alarm), whereas bombers on a high state of alert might be more survivable against a preemptive attack.
  - Bombers are not currently on nuclear alert during routine conditions (not survivable against an enemy first strike). Bombers would likely be on alert only in the context of a prolonged crisis, or a change in policy on the bombers' day-to-day alert level.
- The Minuteman III ICBM will reach end of life in the early 2030s, and the replacement program (the Ground-Based Strategic Deterrent, or GBSD) has barely started.
  - Given that the United States has not developed a new ballistic missile since the Trident D5 in the 1980s, there may be considerable technical risk in this program.
  - Given Air Force funding constraints, there is a risk of budget-driven delays to the GBSD program. (Competitors include the F-35, the B-21, the LRSO, the KC-46 tanker, and a new trainer to replace the T-38.)
- *Ohio*-class SSBNs will start reaching end of life in about a decade, and there is still both budgetary and technical risk associated with the program for the replacement *Columbia*-class SSBNs.
  - The new SSBN is very expensive, and the risk of budget-driven cuts to the procurement rate is considerable.
  - The new SSBN incorporates multiple technological advances, with some appreciable level of technical risk.
- It is impossible to rule out major improvements in foreign anti-submarine warfare in the 2020s or 2030s, and such advances could reduce the survivability of *Columbia*-class SSBNs in the 2040s, relative to that of *Ohio*-class SSBNs today.
- Future improvements in the accuracy of foreign ballistic missiles could endanger the survivability of silo-based ICBMs, even with harder silos.

(blog), May 4, 2016, http://allthingsnuclear.org/syoung/kendalls-mistake; Cora Henry and Noah Williams, eds., "Policymakers Condemn New Cruise Missile," Ploughshares Fund, June 21, 2016, http://www.ploughshares.org/issues-analysis/early-warning/policymakers-condemn-new-cruise-missile; Steven Pifer, "Cancel the Long-Range Standoff Missile," *Order from Chaos* (blog), Brookings Institution, June 28, 2017, https://www.brookings.edu/blog/order-from-chaos/2017/06/28/cancel-the-long-range-standoff-missile/.



The ellipse in North America bounds the region containing the US bases. Reaching regions in white or gray, south of Russia, requires overflight of Russia. Depending on the world situation at the time, overflight of Russia to reach another country might or might not be acceptable, but it would be good to have effective options that do not rely on such overflight. Results shown do not include any shadowing due to the small Russian enclaves in Kaliningrad and Crimea or the impact of the Earth's rotation.

Figure 1. Target Coverage from Current ICBM Bases without Flying over Russia

- The LRSO will probably rely on a different warhead than any of the ballistic missiles. Having greater diversity in types of warheads helps to protect against problems with one type of warhead.

In addition, the world of the 2040s will likely be more multipolar than the world of today, and thus a range of scenarios involving opponents other than Russia and also smaller-scale contingencies against great powers need to be considered when determining requirements for nuclear forces. ICBMs are of doubtful utility against many non-Russian countries due to overflight of Russia (as shown in Figure 1).[3]

SLBMs are slightly better but still questionable. Hence, bombers are the best option—within the bounds of the current program of record—for operations against lesser adversaries and for any kind of potentially limited nuclear exchange in a regional war. US NSNWs could, in principle, obviate the need for bombers in some scenarios, but existing and planned US NSNWs suffer from major deficiencies (to be described later), and starting one or more programs for new and better NSNWs would be expensive and controversial.

Moreover, bombers force potential adversaries to devote major resources to air defense systems. (In general, this diverts resources away from offensive systems, although strategic nuclear arms might be limited by treaties and not just resources.) If the bombers have sufficient range and survivability, then

[3] This is not an argument against proceeding with the program for a new ICBM. In a non-Russian scenario, the United States could rely on bombers, possibly SSBNs, and future NSNWs (if applicable), while keeping ICBMs as a strategic reserve for deterring Russia later. Moreover, ICBMs are invulnerable to any sort of small or inaccurate attack, whereas SSBNs in port and bombers that are not on alert are highly vulnerable to even small attacks by nuclear weapons with accuracy levels that were common in the 1990s. In other words, there is a compelling case for all three legs of the triad.

this factor would exist even if the bombers do not carry cruise missiles. On the other hand, if the bombers need standoff weapons either for survivability or for reaching certain targets, then the combination of the bomber and the weapon would be the driving factor. This cost imposition factor also exists, to some extent, for US fighters, but geographically large adversaries do not need to worry about attacks by fighters deep in their territory, whereas air defenses deep inside the adversary's borders are needed for protection against bombers and long-range cruise missiles.

There is another, somewhat indirect, argument in favor of having nuclear bombers. According to Jane's reference guides, there is no commonality between any of the warheads used by US bombers and the warheads used by the ICBMs or SLBMs. In the absence of nuclear-capable bombers, a failure in one or more warhead types used by ballistic missiles could have a severely detrimental effect on overall US nuclear capabilities. Hence, retaining bombers in the nuclear role provides a hedge against problems with one or more of the warheads used by US ballistic missiles.

Finally, bombers are essential in conventional war, and the cost to make bombers usable in the nuclear mission is relatively modest, if incorporated into the design from the beginning, regarding both the aircraft and associated weapons. Consequently, bombers can be cost-effective in the nuclear role (depending somewhat on the counting rules in treaties) and also as a bargaining chip in arms-control negotiations.

Conversely, bombers suffer from some disadvantages in the nuclear mission. For example, the bomber force has virtually no survivability, even against a small attack, unless it is on alert. Further, if the adversary observes that the United States is in the process of elevating the alert status of the bomber force, this could also be destabilizing and give the enemy an incentive to strike while the bombers are vulnerable. In addition, bombers provide a slow response in comparison to ballistic missiles.

The Need for LRSO by the Bombers

In 2020, the United States will have 60 operationally deployed nuclear-capable bombers—16 B-2s and 44 B-52s—plus some operational B-52s that have been modified so they cannot arm nuclear weapons and some B-1s that have not carried nuclear weapons for 20 years. The B-21 is probably a decade or more away from IOC for conventional war, and nuclear IOC may occur significantly later than conventional IOC. The United States has only 20 B-2s, of which 15 or 16 are usually operational. This is an ample number for a limited nuclear strike against a lesser adversary but potentially inadequate against a great nuclear power, especially if some of the B-2s are destroyed on the ground by an enemy first strike (or get shot down).

The situation with the B-52. Because of the small number of B-2s, it would be necessary to have the B-52 play a primary role in the nuclear mission in war against a great nuclear power, at least until the B-21 is operational in the nuclear role in large numbers. Of course, the B-52 is slow and completely non-stealthy, so it is totally dependent on long-range cruise missiles for survivability. Over the near term, ALCM can fill this role for the B-52, but ALCM is already well beyond its originally planned end of life and also was not designed to penetrate state-of-the-art air defenses in the 2020s or beyond. Without LRSO, the B-52 will be useless in this mission once ALCM is retired, and ALCM retirement might occur well before the B-21 is operational in the nuclear role in significant numbers. If ALCM becomes obsolete well in advance of retirement, then the problems for the B-52 would be even worse.

The situation with the B-2. Apart from issues pertaining to the small size of the B-2 force, two other factors are relevant to assessing the B-2's adequacy in the nuclear mission: in-flight survivability and range. Of these two factors, survivability has been the subject of more discussion. The B-2 is a highly stealthy aircraft by today's standards, but it will probably need a standoff weapon for survivability against advanced

air defenses at some point in the future. Given that ALCM will reach end of life in the foreseeable future, LRSO is the only candidate for such a weapon in the 2030s. (In the near term, it might be possible to integrate ALCM on the B-2, but this would reduce the B-52's utility in the nuclear role and would not help beyond about 2030.)

Issues with range and mission-planning flexibility, however, could also be important. When carrying bombs, a B-2 would have to fly directly over every target. When delivering conventional bombs, a B-2 would probably drop all of its weapons within an area of a few thousand square miles. When delivering nuclear weapons against a geographically large country, by contrast, a B-2 would probably drop one bomb per target and might, therefore, need to use a substantial amount of fuel to fly over several (potentially up to 16) widely separated targets. Hence, range limitations could restrict the B-2 to striking a smaller number of targets than the number of bombs that it could carry. By contrast, a B-2 armed with long-range cruise missiles could strike a number of targets equal to the number of cruise missiles that it could carry.

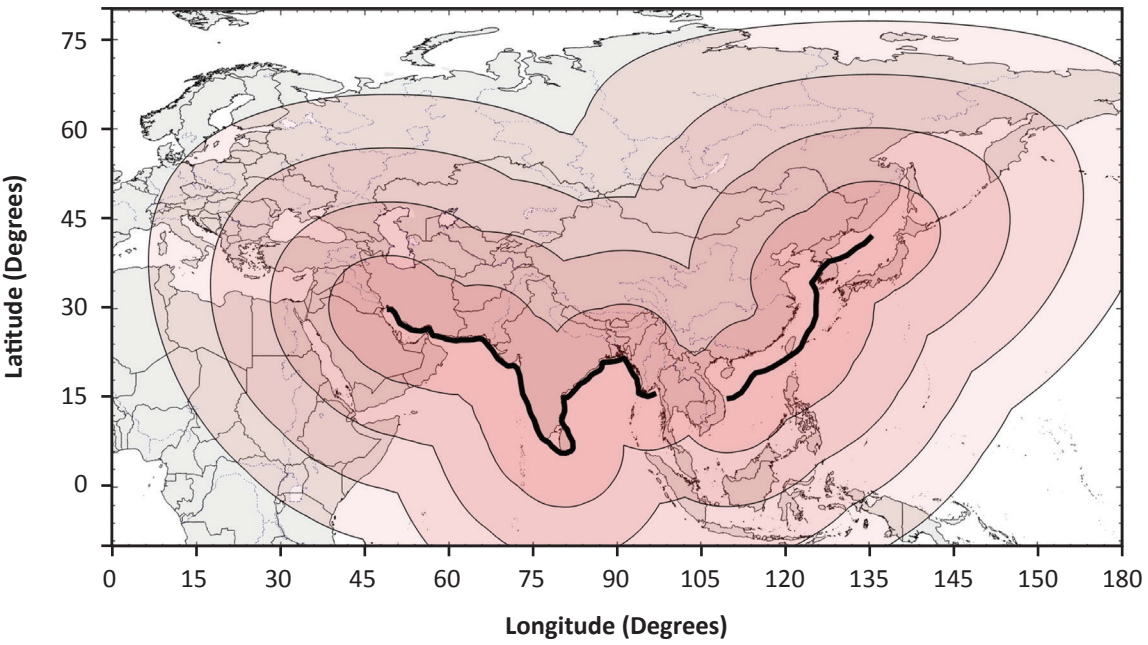
The situation with the B-21. The B-21 is still in an early stage of development, and it is too soon to be sure when it will be operational or to know how effective it will be. Hence, it is prudent to hedge against the risk that the B-21 will eventually need standoff weapons for reasons of survivability. Moreover, even if the B-21 is extremely survivable, it may need LRSO for reasons pertaining to range and mission planning (same argument as for the B-2). Hence, it is premature, at best, to assert that the B-21 will never need cruise missiles, and LRSO is the only candidate for such a cruise missile, if the United States wants to keep the B-52 viable in the nuclear mission through the 2030s.[4]

An alternative approach to the nuclear bomber force in 2035. It would be possible to change current plans and accept removal of the B-52 from the nuclear mission when ALCM reaches end of life, and to try (perhaps without success!) to get slightly more life out of ALCM. Under this approach, the nuclear bomber force of the late 2030s would consist entirely of B-2s and B-21s, and it might be possible to cancel LRSO now, revive LRSO in a few years, and optimize the future cruise missile for the B-2 and the B-21. For this approach to be practical, it would be necessary to have the B-21 become available in the nuclear role—in significant numbers—by the time ALCM reaches end of life. The likelihood of this being the case cannot currently be assessed with confidence, but this approach definitely embodies some—possibly large—degree of risk.

Summary of need for LRSO in the nuclear role. Far from being unnecessary, LRSO may be absolutely critical to the utility of the current bomber force in the nuclear mission in 2030—except possibly against countries such as North Korea—and remain important even after the B-21 is fully operational in the nuclear mission.

Conventional war. If there eventually turns out to be a conventional version of LRSO—a plausible but not certain eventuality—this conventional LRSO might be significantly superior to the existing JASSM-ER (Joint Air-to-Surface Standoff Missile, Extended Range) in range, in-flight survivability, lethality against some targets, or some combination thereof. JASSM-ER is about 14 feet long, and this length is determined by the requirement for internal carriage by the B-1, which has three relatively short weapon bays in tandem. LRSO, by contrast, could be up to about 50 percent longer than JASSM-ER and still be

[4] It would be theoretically possible to cancel LRSO and have the B-21 rely on a different cruise missile that reaches IOC in the 2040s, but this would cause problems for the B-52 and the B-2 in the meantime. Also, LRSO could remain operational for the full service life of the B-21 (based on LRSO IOC in 2030 and an operational life of 45 years for LRSO), so there is no reason to defer LRSO development in order to ensure that LRSO lasts throughout the likely operational life of the B-21.



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 1,000, 2,000, 3,000, and 4,000 kilometers.

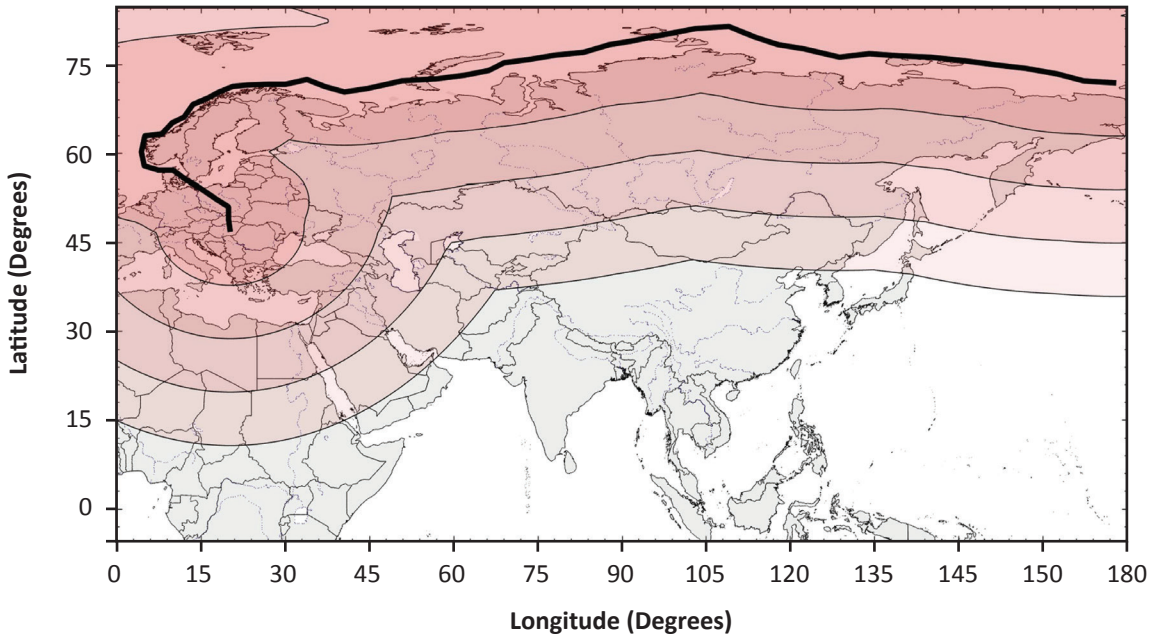
Figure 2. Target Coverage for Air-Launched Cruise Missiles versus Southern Asia

suitable for internal carriage by the B-2 and B-52.[5] If the LRSO design takes full advantage of the extra length available in the B-2 and B-52 weapon bays, then LRSO could be larger than JASSM-ER, with corresponding increases in warhead size, range, or both. Hence, substituting LRSO-conventional for JASSM-ER might enhance bomber utility in conventional war, and LRSO termination would preclude the opportunity for the Air Force to reap whatever benefits would accrue from having this new missile.

The impact of range. Figure 2 illustrates the impact of range versus geographic coverage for an air-launched cruise missile, for targets ranging from southwest Asia to northeast Asia. It shows geographic coverage for cruise missiles launched from a "black line" that runs through international airspace and South Korea and stays about 200 nautical miles away from China. Figure 2 treats range parametrically, with values of 1,000, 2,000, 3,000, and 4,000 kilometers. For comparison, Jane's reference guides list ranges of 926 kilometers for JASSM-ER, 1,320 kilometers for the conventional version of the AGM-86 ALCM, 1,610 kilometers for the latest version of the Tomahawk ship- and submarine-launched conventional cruise missile, 2,500 kilometers for the nuclear version of the AGM-86 ALCM, and 2,800 kilometers for both the conventional and nuclear versions of the new Russian bomber-launched cruise missile (the Kh-101 and Kh-102).[6] Figure 2 suggests that a range of 2,000 kilometers would probably be adequate in almost all cases. Of course, the military utility of a cruise missile also depends on lethality, survivability, and collateral damage, and not just range. Figure 3 is conceptually similar to Figure 2, but it illustrates the impact of range versus

[5] The Air Force has not released information on the maximum length for weapons carried by the B-21. Hence, the maximum acceptable length for LRSO might be less than that for the AGM-86 ALCM.

[6] Some other sources, such as Wikipedia and GlobalSecurity.org, attribute longer ranges to the new Russian cruise missiles.



The cruise missiles are launched from the black line, which runs through international airspace and over Europe. The cruise missiles have notional ranges of 1,000, 2,000, 3,000, and 4,000 kilometers.

Figure 3. Target Coverage for Air-Launched Cruise Missiles versus Northern Eurasia

geographic coverage of northern Eurasia. In this case, the black line runs through the Arctic, around Scandinavia, and over Germany. Range values are the same as those in the previous figure. Figure 3 suggests that a range of 2,000 kilometers would usually be adequate, although a range of 2,500–3,000 kilometers might occasionally be needed. Both figures indicate that ranges exceeding 3,000 kilometers are probably overkill.

Russian Advantages in Nonstrategic Nuclear Weapons

Open-source estimates suggest that Russia has 1,000–6,000 NSNWs of many types.[7] Russia is also modernizing these weapons, with heavy emphasis on accurate low-yield weapons that could combine substantial lethality with reduced collateral damage. In other words, these weapons are designed to be *usable*. Russian NSNWs, and other nuclear weapons potentially suitable for use in limited regional war, include the following:

- A mobile land-based cruise missile with a range of more than 500 kilometers (a violation of the Intermediate Nuclear Forces [INF] Treaty)
- INF-compliant ground-mobile ballistic missiles and cruise missiles
- Nuclear-tipped missile-defense interceptors and surface-to-air missiles
- Various short-range battlefield, aerial, and naval weapons
- Cruise missiles on aircraft and submarines

Moreover, Russian nuclear doctrine has apparently become more aggressive since the Cold War.[8] Russia

[7] The article by Hans Kristensen and Robert Norris, "Russian Nuclear Forces 2016," *Bulletin of the Atomic Scientists* 72, no. 3 (2016): 125–134, estimated the number at 2,000. The report by Amy Woolf, *Nonstrategic Nuclear Weapons* (Washington, DC: Congressional Research Service, February 21, 2017), estimated the number at 1,000–6,000.

[8] Mark B. Schneider, "Escalate to De-escalate," *Proceedings Magazine* 143, no. 2 (February 2017): 1368, https://www.usni.

abandoned the Soviet pledge of "no first use" of nuclear weapons in the 1990s. Open-source articles indicate that Russia, under its current "escalate to de-escalate" strategy,[9] may use nuclear weapons if it is losing a conventional war, if it is faced with a sufficiently adverse correlation of conventional forces at the outset of a conflict, or possibly even to consolidate gains from conventional war. These accurate low-yield weapons might be able to inflict major military damage on other countries without causing tens of thousands of civilian casualties, at least if usage were restricted to military targets outside of urban areas.

By contrast, current US NSNWs are limited to a fairly small number of unguided bombs carried by non-stealthy short-range fighters at several bases in NATO countries. These aircraft have questionable survivability against modern air defenses and provide limited geographic coverage without aerial refueling (which would be infeasible within range of enemy air defenses). The bases in NATO countries are also vulnerable to preemptive attack. Moreover, the unguided bombs have an uncertain ability to achieve high lethality against hard targets except at high yields that produce major collateral damage. Hence, current US NSNWs do not provide survivable, proportionate retaliatory options to limited Russian use of low-yield nuclear weapons.

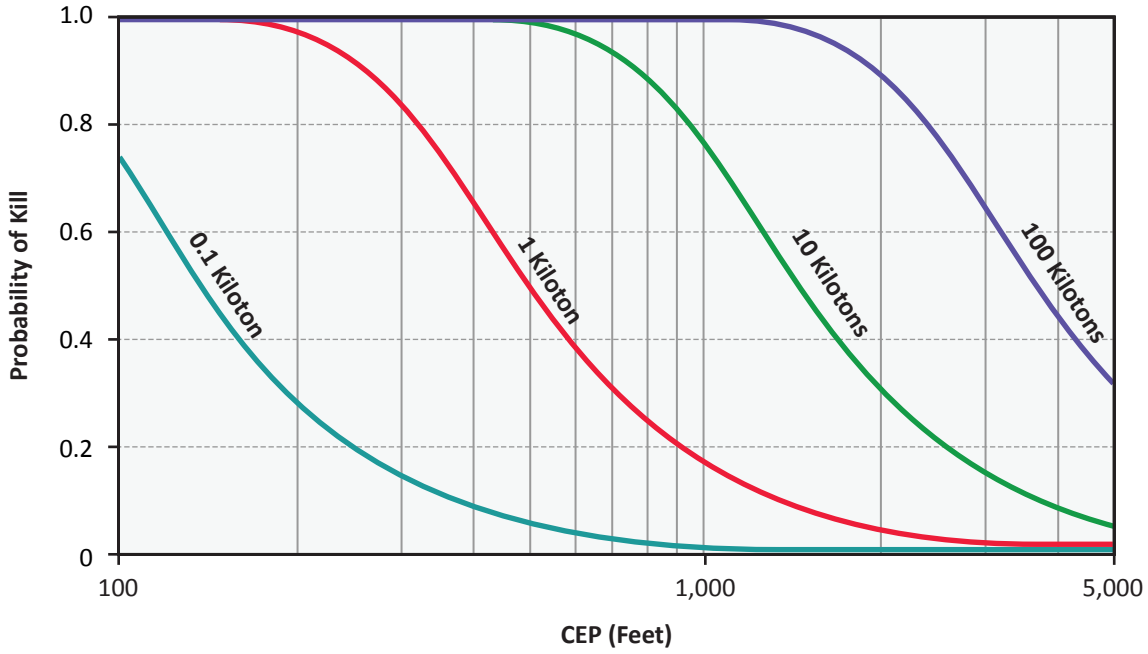
The B61-12 guided bomb is under development for use by the B-2, F-35A, and B-21. The B61-12 will provide improved accuracy, and more lethality in relation to collateral damage, compared with existing US nuclear weapons. However, the B61-12 will add little when carried by existing non-stealthy, short-range fighters, and this weapon may not be integrated on the B-2 and the F-35A for another decade or so. Moreover, the F-35 and the B-2 may have survivability issues against advanced air defenses in the future, at least when carrying short-range weapons such as the B61-12. Finally, deployment of a new bomb on F-35s at the current vulnerable bases would do nothing to address preflight survivability of the US NSNWs unless accompanied by major improvements in air and missile defenses at the relevant bases.

Bombers coming from the United States are suitable for use in a limited regional nuclear war, but the B-2 is armed only with unguided bombs that have a poor ratio of effectiveness to collateral damage. In addition, it is uncertain whether the B-2 will be survivable against the most advanced air defenses of the 2020s and 2030s. As noted earlier, the B-52 lacks survivability against modern air defenses, so it relies on the ALCM. At present, the ALCM may possibly provide a "good enough" response option, although its design dates back to pre-stealth days and it may not match current Russian cruise missiles in yield–accuracy combinations. In addition, the ALCM will be gone around 2030.

If fielded, LRSO will probably be more survivable than ALCM—possibly by a large margin—and has the potential for improved yield–accuracy combinations. Taken together, Figure 4 and Figure 5 show that an accurate low-yield nuclear weapon could be highly lethal against almost all point targets, except those associated with ICBMs or underground facilities. To illustrate this phenomenon, Figure 4 shows the probability of kill, as a function of accuracy (measured by CEP—circular error probable), for nuclear weapons of several different explosive yields, against a point target with a hardness of 21 pounds per square inch. This is near the upper limit of hardness for a medium-sized aboveground structure, such as a hardened aircraft shelter. With a CEP of 100 feet (a value that would be very easy to obtain with modern technology, if incorporated into the design of the weapon from an early stage in development), yields in the 0.1- to 10-kiloton range, and detonations occurring a few hundred feet in the air, lethality

org/magazines/proceedings/2017-02/escalate-de-escalate.

[9] "Escalate to de-escalate" is a Western term that may be derived from the title of a June 1999 article in the prestigious Russian journal *Military Thought*. The title of the article was "The Use of Nuclear Weapons to De-escalate Military Operations."



X axis = accuracy of weapon, as measured by CEP. *Y axis* = probability of destroying the target. Each curve represents a warhead of the indicated yield and is based on a reliability of 100 percent. The hardness of the target may be near the upper limit for a medium-sized aboveground structure.

Figure 4. Probability of Kill versus CEP for a Target with a Hardness of 21 Pounds per Square Inch

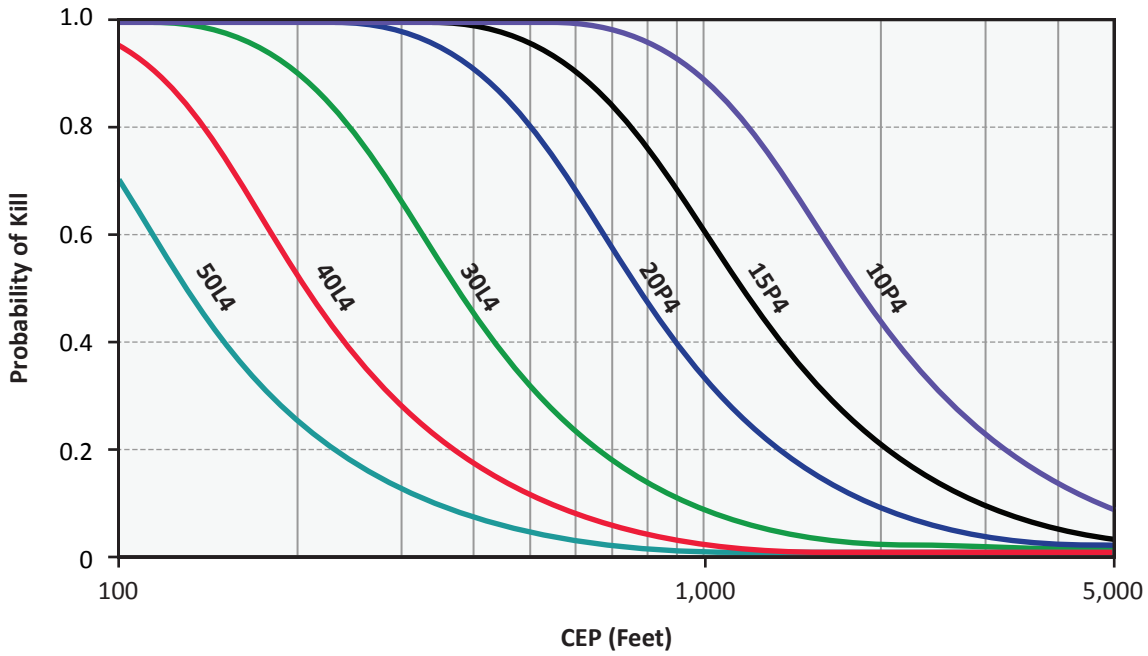
would be very high against the intended target, and the collateral damage might well be acceptable for targets outside urban areas.[10] Figure 5 approaches this issue in a different way by showing the probability of kill, again as a function of CEP, for a 5-kiloton nuclear weapon against targets of several hardness levels.[11] It shows that an accurate 5-kiloton weapon would be highly effective against most targets.

The military significance of the discussion immediately above, and of Figure 4 and Figure 5, is not clear. However, Russian military modernization has—since the beginning of the Putin administration—emphasized accurate low-yield nuclear yield that could *possibly* be used to significant benefit militarily without provoking an escalation to general nuclear war. Hopefully, this Russian idea will never be put to the test. However, for benefits of deterrence, it might be desirable for the United States to have comparable options of its own. LRSO is still early in development, and it should be possible for LRSO to provide a combination of survivability, effectiveness, and low collateral damage similar to items discussed in Russian writings on the topic.

Within the constraints of the current program of record, this leaves LRSO as the best US nuclear weapon in terms of the ability to provide a survivable, proportionate response to a Russian attempt to exploit its advantages in NSNWs. US possession of such a response option might help deter Russian use of accurate low-yield nuclear weapons in a previously conventional war. The exact margin of LRSO's superiority over other options would depend on its range, accuracy, yield options, and in-flight survivability. New and improved US NSNWs might be comparable to, or better than, LRSO in this regard, but the cost, time, and controversy associated with starting a new

[10] The question of how much collateral damage is "acceptable" is, of course, subjective.

[11] Information is not available about the planned LRSO yield values. Figure 4 and Figure 5 are based on approximate yield values, for various weapons, that have been reported in the open literature.



X axis = accuracy of weapon (CEP). *Y axis* = probability of destroying the target. Each curve is based on the assumption that warheads are perfectly reliable. One curve for each level of target hardness is shown, as measured by the vulnerability number (VN). 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 a main battle tank. The other curves are for targets that are very hard. The VNTK values ending in P4 are appropriate for air blast against a surface structure. The VNTK values ending in L4 are appropriate for a slightly buried target or a partially underground target that slightly pierces the surface.

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

development program and fielding such weapons would likely exceed the cost, time, and controversy associated with continuing with LRSO.[12]

On the other hand, some people have asserted that US advantages in conventional weapons (possibly combined with better defenses, better training and doctrine, and improved resiliency against radiation and electromagnetic pulse) might suffice to deter limited foreign use of accurate low-yield nuclear weapons, or to respond to such usage. Such claims may be correct and deserve additional analysis. Conversely, US advantages in conventional weaponry, including conventional escalatory responses to small-scale foreign nuclear usage, might simply stimulate larger-scale use of NSNWs. While it is probably not feasible to assess whether an adversary with advanced NSNWs would terminate use of such weapons in response to high-impact US conventional strikes, physics-based and operational modeling could help in assessing the importance of LRSO, better US NSNWs, better US defenses, or some combination of these factors.

[12] For example, forward-deployed NSNWs could provide a faster response than could subsonic bombers coming from the United States, if the state of readiness for the NSNWs made it possible to initiate a strike as rapidly as would be possible with bombers. Also, the use of bombers in regional war might precipitate an attack on US bomber bases, whereas the use of forward-deployed NSNWs might be less likely to provoke attacks against targets in the United States. Another key factor is prelaunch survivability. Some types of NSNWs, such as cruise missiles deployed in the field on ground vehicles and cruise missiles on attack submarines, would be more resistant to a preemptive attack than would aircraft at known air bases, especially bases that are close to a powerful enemy.

To sum up, it is not yet possible to conclude that improved US nuclear weapons (either LRSO or new NSNWs) are a necessary response, or the single best response, to Russian advantages in NSNWs and other advanced nuclear weapons. However, it is plausible that better nuclear weapons might need to be part of the US response, and, if so, LRSO would be a good candidate for providing a symmetrical nuclear response.

Other Issues Pertaining to LRSO

This section deals with three topics: cost, the need for a new cruise missile (rather than keeping ALCM indefinitely), and various open-source arguments against LRSO.

Cost. Cruise missiles tend to be inexpensive in comparison to submarines, large ballistic missiles, or major combat aircraft. Table 1 quantifies this in a very rough manner, by bounding development and procurement costs for an entire force of advanced cruise missiles, versus comparable figures for a new ICBM, a new bomber, and a new SSBN. Table 1 suggests that canceling LRSO would result in only a minor percentage reduction in the cost of the nuclear modernization program, or even of the bomber portfolio. Unless the impact of LRSO termination on operational effectiveness turned out to be more minor than was suggested earlier, LRSO termination probably could not be justified on the basis of cost.

New missile versus ALCM life extension. Assuming that bombers need cruise missiles, does the bomber force need a new cruise missile instead of further life extension for ALCM? ALCM is an old missile, with questionable survivability against modern air defenses in the 2020s and beyond. Even if ALCM would be good enough in the future, it is well beyond its planned operational life, and life extension into the 2040s may not be practical. But even if ALCM can be extended into the 2040s, it is uncertain that the number of ALCMs is adequate to support usage by multiple types of bombers in the 2030s, plus multiple annual flight tests into the 2040s. (Of course, the issue of inventory size would be less serious if the United States were willing to remove the B-52 from the nuclear mission in the early 2030s or defer use of the B-21 in the nuclear role until 2040, but these approaches involve operational risks.) Finally, ALCM life extension might not provide a missile that would be compatible with the B-21, so such an extension might only defer, rather than avoid, the need for a new cruise missile.

Arguments against LRSO. Various articles have argued against continuing the LRSO program for the following reasons, which will be partially addressed after the list.

- We do not need LRSO because stealth bombers will be able to reach any plausible target. This point was discussed earlier.
- We do not need LRSO because the overall need for US nuclear weapons is declining, and the United States can get by with both many fewer nuclear weapons and fewer types of nuclear weapons. Assessing the validity of this argument would be a

Table 1. Notional Costs for Cruise Missiles, Relative to Other Systems

System	Development Cost	Unit Cost	Number Needed	Total Cost
Cruise missile	$2 billion (B) to $5B	$2 million (M) to $5M	400–1,000	$2.8B to $10B
ICBM	$15B to $25B	$40M to $60M	500–600	$35B to $61B
Bomber	$15B to $30B	$500M to $700M	100–150	$65B to $120B
SSBN	$10B to $20B	$5B to $6B+	10–13	$60B to $100B

Costs are approximate and do not include infrastructure costs (which could be large at the ICBM bases) or operating costs after the weapons are built. Operating costs tend to be very low for cruise missiles, relative to the other types of systems. The costs for the cruise missiles and the ICBMs include a rough estimate of the number of missiles procured for routine annual flight tests.

major endeavor in its own right and is beyond the scope of this report. Moreover, if this argument is valid, it is not unique to LRSO, and proponents of this view could (and sometimes do) argue against providing nuclear capability for the B-21, against replacing the Minuteman III ICBM, and against procuring more than perhaps eight new *Columbia*-class SSBNs.

- LRSO is destabilizing, in two ways:
  (1) It offers the potential for a no-warning decapitation strike.
  (2) In a crisis/war, a nuclear-armed adversary might mistake a conventional cruise missile attack for a nuclear attack.
- Flexible nuclear-strike options of the type provided by LRSO make nuclear use more likely and are undesirable. Once the nuclear threshold has been crossed, escalation probably cannot be controlled, and a full-scale nuclear exchange would likely be the result.
- Killing LRSO could help lead to a global ban on nuclear cruise missiles, or perhaps even all cruise missiles.[13]

LRSO is destabilizing. This argument about LRSO has some merit, but nothing about it is unique to the LRSO. This risk already exists for both US and foreign cruise missiles as well as for existing and planned stealth aircraft, and it will not go away if LRSO is cancelled. For example:

- A conventional attack by Tomahawk could be mistaken for a nuclear attack by ALCM, especially if B-52s were in the general vicinity. There is also a non-zero risk of mistaking JASSM or JASSM-ER for ALCM. The B-52 is a key delivery aircraft for JASSM-ER and the only delivery aircraft for ALCM, which will presumably be around until 2030.
- The situation is even worse regarding cruise missile attacks by Russia. Russia has nuclear and conventional cruise missiles on bombers, nuclear and conventional cruise missiles on submarines, and nuclear and conventional cruise missiles on ground vehicles.
- China has long-range conventional cruise missiles on bombers and mobile ground vehicles. We do not know whether China has any nuclear cruise missiles, but—if they do—a nuclear cruise missile attack could be mistaken for a conventional attack until nuclear warheads start detonating.[14]
- It is possible that LRSO may have some potential for a decapitation strike, especially if delivered by a stealthy bomber that can avoid detection before launching LRSO. However, if the B-2 and the future B-21 are stealthy enough that they will never need LRSO, then these bombers could also be used for a no-warning decapitation strike. Hence, this argument about LRSO also implies that no country should have nuclear-capable stealth aircraft—something that is very unlikely to happen.

Flexible options for limited nuclear strike are bad. This argument appears to be based on the idea that *any nuclear exchange, even if initially limited, will almost certainly escalate to general nuclear war.*[15] This assertion has never been tested, hopefully never

[13] See, for example, Reif, "Overkill"; and Aaron Mehta, "Democrats Renew Attack on New Nuclear Cruise Missile," *Defense News*, March 8, 2017, http://www.defensenews.com/articles/democrats-renew-attack-on-new-nuclear-cruise-missile.

[14] *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2014* (Washington, DC: Office of the Secretary of Defense, April 2014), https://www.defense.gov/Portals/1/Documents/pubs/2014_DoD_China_Report.pdf; and Eric Heginbotham, Michael Chase, Jacob Heim, Bonny Lin, Mark R. Cozad, Lyle J. Morris, Christopher P. Twomey, Forrest E. Morgan, Michael Nixon, Cristina L. Garafola, and Samuel K. Berkowitz, *China's Evolving Nuclear Deterrent* (Santa Monica, CA: RAND Corporation, 2017), doi:10.7249/RR1628.

[15] This presumably refers to an initially limited nuclear exchange against a country like Russia or China. The phrase "escalate to general nuclear war" might have little meaning if applied to a

will be tested, and may or may not be correct. If no foreign country had flexible nuclear-strike options, then it might well be undesirable for the United States to introduce "usable" nuclear weapons.[16] However, Russia has been aggressively pursuing accurate low-yield nuclear weapons since the beginning of the Putin administration and reserves the right use such weapons under various poorly understood conditions (as described earlier). To deter limited foreign first use of nuclear weapons—especially accurate low-yield weapons—the United States may well need weapons that offer a credible, survivable,[17] proportionate response to whatever nuclear weapons are available to the relevant adversary. Absent such US capabilities, an adversary might foresee significant advantages from first use of modern nuclear weapons, and the United States or its allies might be forced to accept defeat or the United States might conduct a disproportionate nuclear retaliation with a high risk of uncontrolled escalation. *In other words, a lack of US survivable, proportionate retaliatory options may encourage foreign adventurism and possibly foreign first use of selected types of nuclear weapons.*

Killing LRSO could lead to a global ban on nuclear cruise missiles. LRSO opponents mostly envision a ban on nuclear cruise missiles. If the ban only applied to nuclear cruise missiles, then it would require extremely intrusive inspection procedures—probably well beyond what most countries would accept—to verify compliance. The United States, Russia, and China all have large inventories of conventional cruise missiles, and a conventional cruise missile typically has a warhead of greater weight and volume than a modern low-yield nuclear warhead. Hence, any typical cruise missile belonging to a nuclear power that has modern nuclear warheads could also carry a nuclear warhead—thus the difficulty in verifying compliance. Consequently, the potential conventional–nuclear ambiguity could lead to a ruinous breakout where a large, and supposedly purely conventional, inventory of cruise missiles turns out to contain nuclear missiles. In addition, quite apart from verification issues, Russia has a mini-triad of nuclear cruise missiles on aircraft, submarines, and mobile ground vehicles, and it is producing several types of modern nuclear cruise missiles. Why would Russia agree to eliminate these weapons in exchange for US cancellation of a program that is a decade or more away from IOC and that faces significant opposition within the United States?

A global ban on all cruise missiles would eliminate the nuclear–conventional ambiguity issue and avoid the potential for a nuclear breakout of the type mentioned above. However, global inventories of cruise missiles are so large, and disseminated over so many countries, that it is hard to envision that such a global ban would be feasible. A ban that was limited to the United States and Russia would impose significant disadvantages on both countries, especially relative to China, so a bilateral ban on all cruise missiles is also very unlikely.

Conclusions

There is a solid basis for proceeding with the LRSO program, for several reasons.

The United States needs bombers in the nuclear role, especially for smaller-scale contingencies but also to some extent against great powers. Bombers also provide risk mitigation against problems with the programs for new nuclear delivery systems and against unexpected advances in foreign anti-submarine warfare or improved abilities to destroy ICBMs. Finally, bombers and their associated cruise missiles also impose major costs on potential adversaries by

country with a small number of nuclear weapons, none of which are global in range.

[16] John R. Harvey, "Sustaining Consensus on Triad Modernization: Transition to the Next Administration" (talk presented to the Air Force Association—Peter Huessy Breakfast Seminar Series at the Capitol Hill Club, Washington, DC, July 29, 2016).

[17] This includes both in-flight survivability and survivability against a preemptive attack.

forcing them to have dense air defenses over large geographical areas.

LRSO is probably critical to the long-term viability of the bomber force in the nuclear role, although additional analyses on this are warranted (especially regarding the B-21). In addition, if there is eventually a conventional variant of LRSO, this weapon might significantly enhance bomber utility in a conventional war against a geographically large adversary with advanced air defenses.

Russia has a huge numerical and technological advantage over the United States in NSNWs and in accurate low-yield, survivable nuclear weapons. While it is not certain that better US nuclear weapons are necessary in dealing with this situation, LRSO could be the best US nuclear option (among currently funded weapons) for deterring, or responding to, such nuclear usage by Russia. (Improved US NSNWs, possibly combined with better defenses, might provide utility comparable to or better than LRSO in this respect, but no such weapon is currently funded or planned.) Follow-on analyses of the sort described earlier could help illuminate this piece of the puzzle.

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