The Long-Range Standoff Cruise Missile

A Key Component of the Triad

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The US has initiated a major recapitalization of its strategic nuclear forces, including delivery platforms such as the B-21 Raider bomber and the *Columbia*-class ballistic missile submarine (SSBN), and both air-launched and ground-based weapons. Of the weapons that are currently funded, the Long-Range Standoff (LRSO) air-launched cruise missile (ALCM) is surely the most controversial. Many arguments have been proffered suggesting that this weapon is unnecessary, dangerous, or both. This article explains the program; describes why it is important based on the need for bombers in the nuclear role, the need for cruise missiles to make bombers effective, and the US–Russia mismatch in nonstrategic nuclear weapons (NSNW) and accurate, low-yield nuclear weapons in general; and discusses several leading criticisms of the LRSO ALCM. Our overall conclusion is that the continuation of the LRSO program is warranted.

The US has had a triad of land-based intercontinental ballistic missiles (ICBM), submarine-launched ballistic missiles (SLBM) on SSBNs, and long-range bombers since the 1960s. This triad has played a key role in US security for decades, but current US nuclear forces will reach end-of-life by about 2042, except for the B-2 Spirit and the B-52 Stratofortress bombers. The triad includes 14 *Ohio*-class SSBNs, 12 of which are normally operational. The *Ohio*-class SSBNs will begin reaching end-of-life about 2027. The program for the new *Columbia*-class SSBN has been underway for several years and is planned to deliver 12 new SSBNs. The Minuteman III ICBMs, of which 400 are operationally deployed in 450 underground silos, will reach end-of-life in the early to middle 2030s. The DOD has started a program to sustain the ICBM force, with a new ground-based strategic deterrent.

The US has 66 nuclear-capable bombers (47 B-52s and 19 B-2s), plus 29 B-52s and one B2 (a test aircraft) that have been modified such that they cannot carry nuclear weapons. The 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 nuclear bombs. A new stealth bomber, the B-21, has been under development for several years, and the Air Force plans to procure at least 100 B-21s, with initial operational capability (IOC) tentatively expected in the middle 2020s. Current plans call for some or all B-21s to be nuclear-capable, but the USAF 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 LRSO cruise missile to replace the AGM-86, which will reach end-of-life about 2030, and the B61-12 guided bomb. The new bomb is planned for use by stealth bombers, the F-15E Strike Eagle, and the F-35A (the Air Force variant of the F-35 Lightning II). The LRSO is planned for use only by bombers. The B61-12 program has been underway for several years and will reach IOC in the early 2020s. By contrast, very little funding has been expended on the LRSO program, and there have been numerous calls for its cancellation,[1] so additional analysis on the LRSO is warranted. The remainder of this article is devoted to discussing the rationale for the LRSO, cost issues pertaining to the LRSO, and various public arguments against the LRSO.

The Need for Bombers in the Nuclear Role

The importance of bombers in the nuclear role is heavily dependent on the scenario in which they might be used, but reliance solely on an ICBM–SLBM dyad would involve various risks—technical, programmatic, and operational—that nuclear-capable bombers 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/launch under attack," which is a risky tactic), whereas bombers on a high state of alert might be more survivable against an enemy's first strike. (Bombers are not currently on nuclear alert during routine conditions. Bombers would likely be on alert only in the context of a prolonged crisis or a change in policy on the day-to-day alert level.) This is not an argument against ICBMs. ICBMs are invulnerable to any sort of small or inaccurate nu-

clear attack, whereas SSBNs in port and bombers that are not on alert are severely vulnerable to even a small nuclear attack. Further, US possession of ICBMs drives up the "price to attack" for a great enemy nuclear power and favorably influences the postexchange balance of weapons.

Nuclear-capable bombers could compensate for delays in the program for a new ICBM. The greatest risk for such delays comes from budgetary shortfalls, although the risk of technical problems cannot be excluded. Of course, the LRSO and the new ICBM potentially compete for the same funding, although the LRSO would be much less expensive than a new ICBM.

Existing SSBNs will start reaching end-of-life in a decade due to issues with hull fatigue, and there are budgetary and technical risks associated with the replacement program, as noted in the Government Accountability Office report GAO-18-158, *Columbia-Class Submarine: Immature Technologies Present Risks to Achieving Cost, Schedule, and Performance Goals,* December 2017.[2]

Future improvements in foreign antisubmarine warfare could reduce the survivability of SSBNs at sea in the 2030s, relative to that of *Ohio*-class SSBNs today. The risk of this is small but perhaps not negligible. Bombers are not immune to the risk of improved enemy capabilities, but a more diverse portfolio of capabilities reduces US vulnerabilities to any single enemy advance. Further, bombers rely on different types of warheads, relative to ballistic missiles. Diversity in types of warheads helps to protect against problems with one type of warhead.

Also, the world of the 2040s likely will be more multipolar than the world of today, and thus a range of scenarios involving opponents other than Russia and also limited regional nuclear contingencies (i.e., short of all-out nuclear war) against great powers should be considered when determining requirements for nuclear forces. ICBMs are of doubtful utility against many non-Russian countries due to the need for overflight of Russia on the way to the country being targeted.[3] SLBMs can be better in terms of overflight, but it may not always be possible to avoid overflight without time-consuming transit to optimized launch points. Also, US ICBMs and SLBMs currently rely only on high-yield warheads, whereas lower yields would usually be preferred in limited contingencies. Hence, bombers may be the best option—within the current program of record—for operations against lesser adversaries and for any kind of limited nuclear exchange in a regional war. Improved US NSNWs—such as submarine-launched missiles and/or intermediate-range, forward-deployed ground-launched missiles—could, in principle, obviate the need for nuclear-capable bombers in some scenarios, but 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, which diverts resources away from offensive systems, although strategic nuclear arms might be limited by treaties and not just resources. 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. Bombers have much longer ranges than fighters, so air defenses deep inside the adversary's borders are needed for protection against bombers and long-range cruise missiles.

Finally, bombers are essential in conventional war, and the cost to make bombers usable in the nuclear mission is relatively modest. 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, if the bomber force is not on alert, and the bombers are at their normal operating bases, a small first strike could destroy the bombers on the ground, along with their associated nuclear weapons and base infrastructure. This could give an enemy an incentive to strike before the bombers are mobilized. Additionally, bombers provide a slow response relative to ICBMs and SSBNs that are on patrol.

The Need for Cruise Missiles for the Bombers

This section addresses the need for standoff weapons by each type of bomber, and also the benefits of a potential conventional derivative of the LRSO.

Because of the small number of B-2s, the B-52 will need to play a key role in the nuclear mission until the B-21 is operational in the nuclear role in significant numbers. The B-52 cannot penetrate adversary air defenses; therefore, it is totally dependent on long-range cruise missiles for survivability. Over the near term, the AGM-86 can fill this role, but it will reach end-of-life by 2030 and was not designed to penetrate state-of-the-art air defenses in the 2020s or beyond. Without the LRSO, the B-52 will cease to play a role in the nuclear mission once the AGM-86 is retired, and the retirement of this weapon might occur before the B-21 is operational in the nuclear role in significant numbers. If the AGM-86 becomes obsolete well in advance of retirement, then the B-52 could become irrelevant in the nuclear role by the late 2020s.

Apart from issues pertaining to the small size of the B-2 force, two 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 standoff weapons for survivability against advanced air defenses at some point in the future. The LRSO is the only candidate for such a weapon on a timeline that supports the B-52. The range issue, however, could also be important. When carrying bombs, a B-2 has to fly directly over every target. When delivering conventional bombs, the bomber 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 large amount of fuel to fly over 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. Moreover, these cruise missiles could complicate enemy efforts at defense by providing multiple attack vectors per bomber.[4]

It is too soon to know when the B-21 will be operational or how effective it will be, so it is prudent to hedge against the risk that the B-21 will eventually need

standoff weapons for survivability. Moreover, even if the B-21 is highly survivable, it may need the LRSO for other reasons (like the B-2). Hence, it is premature to assert that the B-21 will never need nuclear cruise missiles, and the LRSO is the only candidate for such a weapon on a timeline that could also support the B-52.

To summarize, the LRSO may be critical to the utility of the current bombers in the nuclear mission in 2030 and remain important even after the B-21 is operational in the nuclear mission. That is, without the LRSO the US may have a nuclear triad only on paper by 2035.

Finally, if a conventional version of the LRSO is developed (a plausible but not certain eventuality), this conventional LRSO would probably be superior to existing conventional ALCMs in range, survivability, lethality, or some combination thereof. Hence, the termination of the LRSO would preclude the opportunity to reap whatever benefits might accrue from having this new missile.

Russian Advantages in Nonstrategic Nuclear Weapons

Open-source estimates suggest that Russia has 1,000–6,000 NSNWs of many types.[5] Russia is also modernizing these weapons, with a 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 bomber-launched ALCMs, submarine-launched cruise missiles (SLCM), and ground-launched cruise missiles (GLCM). Further, the new SSC-8 GLCM violates the Intermediate Nuclear Forces Treaty, according to the 2018 *Nuclear Posture Review* (*NPR*) and the State Department.[6]

Moreover, Russian nuclear doctrine has apparently become more aggressive since the Cold War.[7] Russia abandoned the Soviet pledge of "no first use" of nuclear weapons in the 1990s. Open-source articles indicate that under its current "escalate to de-escalate" strategy,[8] Russia may use nuclear weapons under a variety of conditions that are not well-known in the West. These accurate, low-yield weapons could 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. To quote page xi of the 2018 *NPR*: "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 nonstrategic nuclear systems provide a coercive advantage in crises and at lower levels of conflict. Recent Russian statements on this evolving nuclear weapons doctrine appear to lower the threshold for Moscow's first use of nuclear weapons."

By contrast, current US NSNWs are limited to unguided bombs carried by nonstealth short-range fighters at several bases in North Atlantic Treaty Organization countries. These aircraft have questionable survivability against modern air defenses and provide limited geographic coverage without aerial refueling, which is feasible only in safe airspace. The bases are also vulnerable to preemptive attack without improved defenses, especially against cruise missiles. Hence, current US NSNWs probably do not provide survivable, proportionate retaliatory options to lim-

ited Russian use of low-yield nuclear weapons, so improved US capabilities are needed, such as better NSNWs, improved regional capabilities for strategic delivery vehicles, conventional prompt strike (as an adjunct to NSNWs), and/or better defenses for NSNWs. To again quote page xi of the *NPR*: "To address these types of challenges and preserve deterrence stability, the US will enhance the flexibility and range of its tailored deterrence options. . . to include low-yield options."

US options will eventually evolve beyond unguided bombs on nonstealth fighters. The B61-12 is under development for use by the B-2, F-35A, F-15E, and B-21. The B61-12 will be more accurate than current US nuclear bombs, but the F-15E has a poor ability to deliver bombs against heavily defended targets, and even the F-35 may have survivability issues against advanced air defenses in the future. Bombers coming from the US can be used in a limited regional nuclear war, but the B-2 may have survivability issues without standoff weapons, and 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, but the missile will be gone by about 2030 due to structural fatigue issues.

If fielded, the LRSO likely will be more survivable than the ALCM, due to major advances in technology since the ALCM was developed, and it has the potential for improved yield–accuracy combinations. Information on the LRSO's yield options and accuracy is not publicly available, but analyses done by the Johns Hopkins University Applied Physics Laboratory (JHU/APL) indicate that a nuclear weapon with a yield in the 1- to 10-kiloton range and a circular error probable (CEP) in the 50- to 100-foot range would be highly lethal against almost all point targets.[9] With CEP values of 50 feet or less, subkiloton weapons can also be effective against many, or perhaps most, targets. To illustrate this phenomenon, the figure shows the probability of kill, as a function of CEP, for weapons of three parametrically varied yields against a target with a hardness of 100 pounds per square inch (psi), which may be appropriate for a nonburied or slightly buried weapon storage bunker.[10]

Of course, the extent to which a US nuclear response is proportional or escalatory depends greatly on the nature and location of the target selected, and the population density around the target, and not just the characteristics of the US weapon employed. Nevertheless, accurate, low-yield weapons would reduce collateral damage, relative to higher-yield weapons, while still achieving major effects on the intended target. These weapons could enhance the credibility of US response options, with a favorable impact on the ability to deter adversaries from engaging in the limited use of nuclear weapons.

Moreover, should the US decide to field new NSNWs, it might be possible to leverage the LRSO for this mission, and LRSO termination would eliminate the possibility for such a spin-off weapon. For example, the National Defense Authorization Act for Fiscal Year 2018 directs the development of a dual-capable GLCM with a maximum range between 500–5,500 km, in response to Russia's fielding a new GLCM that violates the Intermediate Nuclear Forces Treaty.[11] The easiest way to field a nuclear GLCM might be to add a boost motor to the LRSO to allow the launch of the cruise missile from a ground vehicle.[12] If the LRSO has a conventional variant, then a ground-launched LRSO would fulfill the intent of the legislation. If the LRSO does not have a conventional variant, then it would be necessary to develop two GLCMs

or to have the new GLCM be single-role. It might also be possible to integrate the LRSO—possibly with modifications to reduce its range—on the F-15E and the F35A.[13] Finally, the 2018 *NPR* directs the development of a nuclear SLCM. The use of an LRSO derivative on submarines is more speculative than use as a GLCM or on fighters, but cannot be ruled out at present.

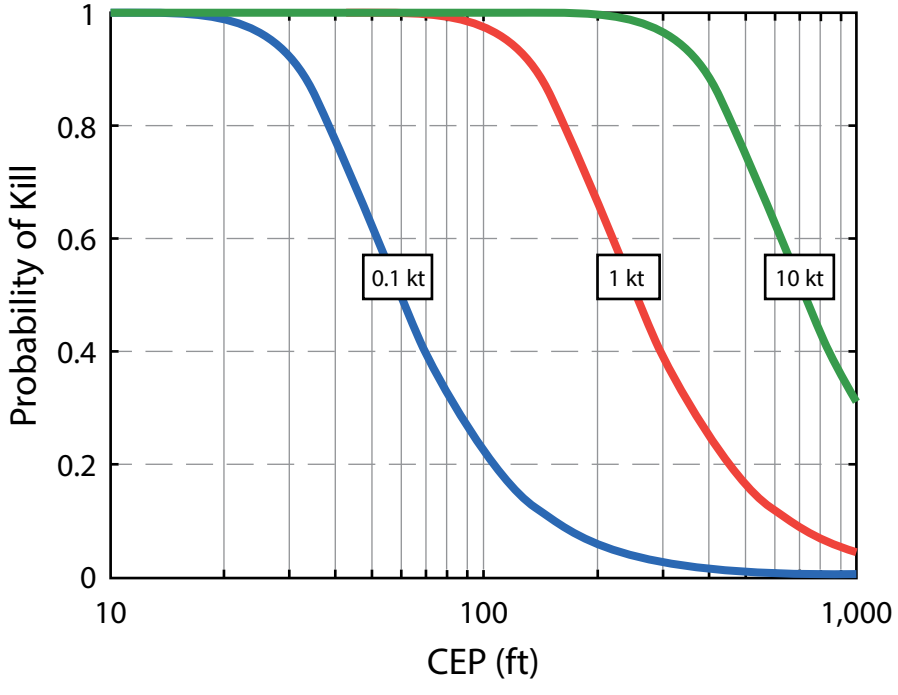

Figure. Probability of kill versus CEP for a target with a hardness of 100 psi. Note: *x-axis*=accuracy of weapon (in feet), as measured by CEP; *y-axis*=probability of destroying the target. Each curve represents a warhead of the indicated yield (range of 0.1–kilotons), with a reliability of 100 percent. (Reprinted from the Johns Hopkins University Applied Physics Laboratory.)

Thus, within the program of record, the LRSO will probably be 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 "usable" nuclear weapons. US possession of such a response option might help deter Russian use of accurate, low-yield nuclear weapons in a previously conventional war. The LRSO also has potential for spin-off use as an NSNW, which could further enhance US flexible response options.[14]

Other Issues Pertaining to the LRSO

This section deals with two topics: cost and various open-source arguments against the LRSO.

The LRSO is too expensive. Cruise missiles tend to be inexpensive in comparison to submarines, large ballistic missiles, or major combat aircraft. The table quantifies this in a rough manner, by bounding development and procurement costs for an entire force of new cruise missiles versus comparable figures for a new ICBM, a new bomber, and a new SSBN. The table suggests that canceling the LRSO would result in only a minor percentage reduction in the cost of the nuclear modernization program (2 percent of total nuclear costs, according to the Congressional Budget Office), or even of the bomber portfolio.[15]

Table. Order of magnitude costs for several types of nuclear systems

System	*Development cost*	*Unit cost*	*Number needed*	*Total cost*
Cruise missile	$3–6B	$4–8M	500–1,000	$5–14B
ICBM	$15–25B	$40–60M	500–600	$35–61B
Bomber	$15–30B	$500–700M	100–150	$65–120B
SSBN	$10–20B	$5–6B plus	10–13	$60–100B

Source: *JHU/APL*

Note: Costs are approximate and do not include infrastructure costs (which could be large at the ICBM bases) or operating costs (which tend to be large for SSBNs and bombers, but low for cruise missiles). The costs for the nuclear cruise missiles and the ICBMs include a rough estimate of the number of missiles procured for routine annual flight tests.

The LRSO is not needed because the overall need for US nuclear weapons is declining. *US conventional superiority implies that the US can get by with many fewer nuclear weapons and fewer types of nuclear weapons.* Assessing the validity of this argument would be a major endeavor. For the purposes of this article, it may suffice to say that the recent heavy Russian emphasis on NSNWs and general nuclear modernization, and the nuclear build-up by North Korea, cast doubt on this idea. Moreover, this assertion could also be used to argue against other elements of the US nuclear modernization effort.

The LRSO is destabilizing. *The LRSO offers the potential for a no-warning decapitation strike and, as long as the US has nuclear cruise missiles, an adversary might mistake a conventional cruise missile attack for a nuclear attack.* This argument has some merit, but it is not unique to the LRSO. Further, this also implies that no country should have either nuclear cruise missiles or highly stealthy nuclear-capable aircraft, because such aircraft also offer the potential for a no-warning decapitation strike. We are not convinced that real US aircraft will provide such a no-warning decapitation capability, but some potential adversaries may indeed fear that the LRSO and stealth bombers are destabilizing, and this could be a legitimate source of concern regarding nuclear stability. However, fully acting on this concern would

require a major reshaping of the US nuclear modernization effort (LRSO cancellation plus elimination of nuclear capability for the B-2, F-35A, and B-21), possibly combined with the early retirement of the AGM-86 ALCM. Unfortunately, moving away from the LRSO and stealthy nuclear-capable aircraft in this manner would further reduce US flexible deterrence options and exacerbate US disadvantages relative to Russia in nuclear weapons that are useful in a regional context. In other words, the disadvantages of trying to accommodate this possibly legitimate concern are too severe to accept.

If the B-21 needs the LRSO in the nuclear role, the B-21 should be canceled. This point is tangential to the need for the LRSO per se, but the argument is designed to place the LRSO in direct competition for funding with the B-21 bomber—a key national priority. The B-21 is being developed primarily for conventional war, which involves striking many thousands of targets, and it would likely be cost-prohibitive to rely on cruise missiles launched from nonstealthy aircraft for destroying thousands of targets. In addition, conventional war generally involves a protracted air-defense suppression campaign, and it is not necessary to be able to strike all targets while enemy defenses are intact. Hence, if the B-21 needs to use cruise missiles for a few days at the start of a war, this is not a severe drawback. The B-21 has only a secondary nuclear mission. The nuclear mission for bombers involves striking no more than a few hundred targets, and it is essential to be able to carry out this mission against advanced, fully intact air defenses without the benefit of support from radar-jamming aircraft. Hence, while it might be desirable for the B-21 to rely exclusively on direct-attack weapons in the nuclear role in the 2030s and beyond, reliance on the LRSO against some targets in the nuclear mission is not a major drawback in terms of the actual role of the B-21 in US strategy.

Killing the LRSO could help lead to a global ban on nuclear cruise missiles.[16] Such a ban would require extremely intrusive inspection procedures to verify compliance. The US, Russia, and China all have large inventories of conventional cruise missiles, and a conventional cruise missile is typically suitable for carrying a nuclear warhead. 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 weapons. In addition, Russia is producing modern nuclear cruise missiles of several types. Consequently, it is extremely unlikely that Russia would agree to eliminate these weapons in exchange for US cancellation of a single program that is far away from IOC and that faces significant opposition within the US.

Conclusions

There is a solid basis for proceeding with the LRSO program, for several reasons. First, the US needs the full triad of bombers, ICBMs, and SLBMs. Second, the LRSO is critical to the long-term viability of the bomber force in the nuclear role. Without the LRSO, the US will have a triad on paper, but perhaps not in any meaningful

sense, in 2035. Also, if there is a conventional variant of the LRSO, this weapon would enhance bomber utility in conventional war. Finally, Russia has major advantages over the US in NSNWs and in accurate, low-yield, survivable nuclear weapons. While it is not certain that better US nuclear weapons are necessary for dealing with this situation, the LRSO would probably be the best currently funded US nuclear option for deterring such nuclear usage by Russia or responding to an actual limited Russian attack using accurate, low-yield weapons. Further, the LRSO has the potential for spin-off use as an NSNW, which could further enhance US flexible nuclear response options and US abilities to deter the limited first use of nuclear weapons by adversaries. ✪

Notes

1. Examples include: Dianne Feinstein and Ellen O. Tauscher, "A Nuclear Weapon That America Doesn't Need," *New York Times*, 27 June 2016, https://www.nytimes.com/2016/06/18/opinion/a-nuclear-weapon-that-america-doesnt-need.html; William J. Perry and Andy Weber, "Mr. President, Kill the New Cruise Missile," *Washington Post*, 15 October 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=.4675c966b34d; Kingston Reif, "Overkill: The Case Against a New Nuclear Air-Launched Cruise Missile," *Arms Control Association Issue Brief* 7, no. 13 (19 October 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* (blog), 4 May 2016, http://allthingsnuclear.org/syoung/kendalls-mistake; Cora Henry and Noah Williams, eds., "Policymakers Condemn New Cruise Missile," Ploughshares Fund, 21 June 2016, http://www.ploughshares.org/issues-analysis/early-warning/policymakers-condemn-new-cruise-missile; and Steven Pifer, "Cancel the Long-Range Standoff Missile," *Order from Chaos* (blog), Brookings Institution, 28 June 2017, https://www.brookings.edu/blog/order-from-chaos/2017/06/28/cancel-the-long-range-standoff-missile/.

2. US Government Accountability Office (GAO), *Columbia Class Submarine: Immature Technologies Present Risks to Achieving Cost, Schedule, and Performance Goals* (Washington, DC: GAO, December 2017), https://www.gao.gov/assets/690/689133.pdf.

3. This is not an argument against intercontinental ballistic missiles (ICBM). In a non-Russian scenario, the US could rely on bombers, ship, submersible, ballistic missile, nuclear-powered missiles, and nonstrategic nuclear weapons (if applicable), while keeping ICBMs as a strategic reserve for deterring Russia later.

4. The president's FY 2019 Federal Budget proposes to retire the B-2 Spirit shortly after the B-21 Raider becomes operational. If this proposal—which will likely be very controversial—is enacted, then the question about the B-2's need for the Long-Range Standoff Weapon is moot. Our discussion is based on the assumption that the B-2 will still be involved in the nuclear role in the early 2030s.

5. The article by Hans Kristensen and Robert Norris, "Russian Nuclear Forces 2016," *Bulletin of the Atomic Scientists* 72, no. 3 (2016): 125–34, estimated the number at 2,000, https://thebulletin.org/2016/05/russian-nuclear-forces-2016/. The report by Amy Woolf, *Nonstrategic Nuclear Weapons* (Washington, DC: Congressional Research Service, 21 February 2017), estimated the number at 1,000–6,000.

6. *Nuclear Posture Review* (Washington, DC: Office of the Secretary of Defense, February 2018), https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF. The statement about the SSC-8 is on page 10.

7. Mark B. Schneider, "Escalate to De-escalate," *Proceedings Magazine* 143, no. 2 (February 2017): 1368, https://www.usni.org/magazines/proceedings/2017-02/escalate-de-escalate.

8. *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 Deescalate Military Operations."

9. Open-source articles (on *Wikipedia*, for example) attribute yield options in the 1.5 to 10 kiloton range to several US nuclear warheads.

10. National Research Council, *Effects of Nuclear Earth-Penetrator and Other Weapons* (Washington, DC: The National Academies Press, 2005: 30–50), https://www.nap.edu/read/11282/chapter/6.

11. This treaty bans the deployment or flight testing of ground-launched ballistic missiles and cruise missiles, nuclear or conventional, with a maximum range of 500–5,500 km. According to the State Department and the 2018 *Nuclear Posture Review*, Russia has fielded a cruise missile, the SSC-8, which violates the Intermediate Nuclear Forces Treaty. The State Department and the *Nuclear Posture Review* did not specify the exact range of the Russian missile, nor did they say whether it is for a nuclear, conventional, or dual role.

12. The Long-Range Standoff Weapon (LRSO) is designed to be launched from an aircraft, a technique that does not subject the missile to high acceleration. It would be necessary for the boost motor to get the LRSO above stall speed without exceeding the acceleration limits for the missile. This might or might not be easy. In the submarine-launched cruise missile role, it would also be necessary to investigate whether an LRSO could survive being pushed through water. If not, a submarine would have to come to the surface to launch a naval LRSO, or the naval LRSO might be restricted to use on surface ships (which are less survivable than submarines).

13. The use of the LRSO as a ground-launched cruise missile would violate the Intermediate Nuclear Forces Treaty if the range of the LRSO exceeds 500 km, which is highly likely. If New Strategic Arms Reduction Treaty (START) limits and counting rules remain in force indefinitely, then LRSO integration on fighters would cause those fighters to count against New START limits if LRSO, or an LRSO derivative for fighters, has a range exceeding 600 km. (The current AGM-86 Air-Launched Cruise Missile has a range of about 2,300 km, so it is likely that the planned bomber version of the LRSO has a range greatly exceeding 600 km, according to Gareth Jones, *Janes 360*, 10 April 2018, https://www.janes.com/article/79170/usaf-to-launch-lrso-and-b-52-integration-in-2019. Carriage by ships or submarines would not face any arms control issues but might be more technically challenging than usage on land or by fighters.)

14. The *Nuclear Posture Review* concluded that flexible US nuclear response options, including options beyond the current program of record, are essential for deterring adversaries from engaging in the limited first-use of nuclear weapons. However, additional analyses may be warranted on whether US advantages in conventional forces, possibly augmented by improved capabilities that are not yet in the program of record, could fill this deterrence role or whether US advantages in conventional forces and missile defense would merely incentivize enemy first-use of nuclear weapons.

15. For example, see *Approaches for Managing the Costs of U.S. Nuclear Forces, 2017 to 2046*, Congressional Budget Office, 31 October 2017, https://cbo.gov/publication/53211. This paper estimated that the LRSO accounts for 2 percent of planned nuclear expenditures in 2017–46.

16. For example, see Reif, "Overkill;" and Aaron Mehta, "Democrats Renew Attack on New Nuclear Cruise Missile," *Defense News*, 8 March 2017, https://www.defensenews.com/space/2017/03/08/democrats-renew-attack-on-new-nuclear-cruise-missile/.

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