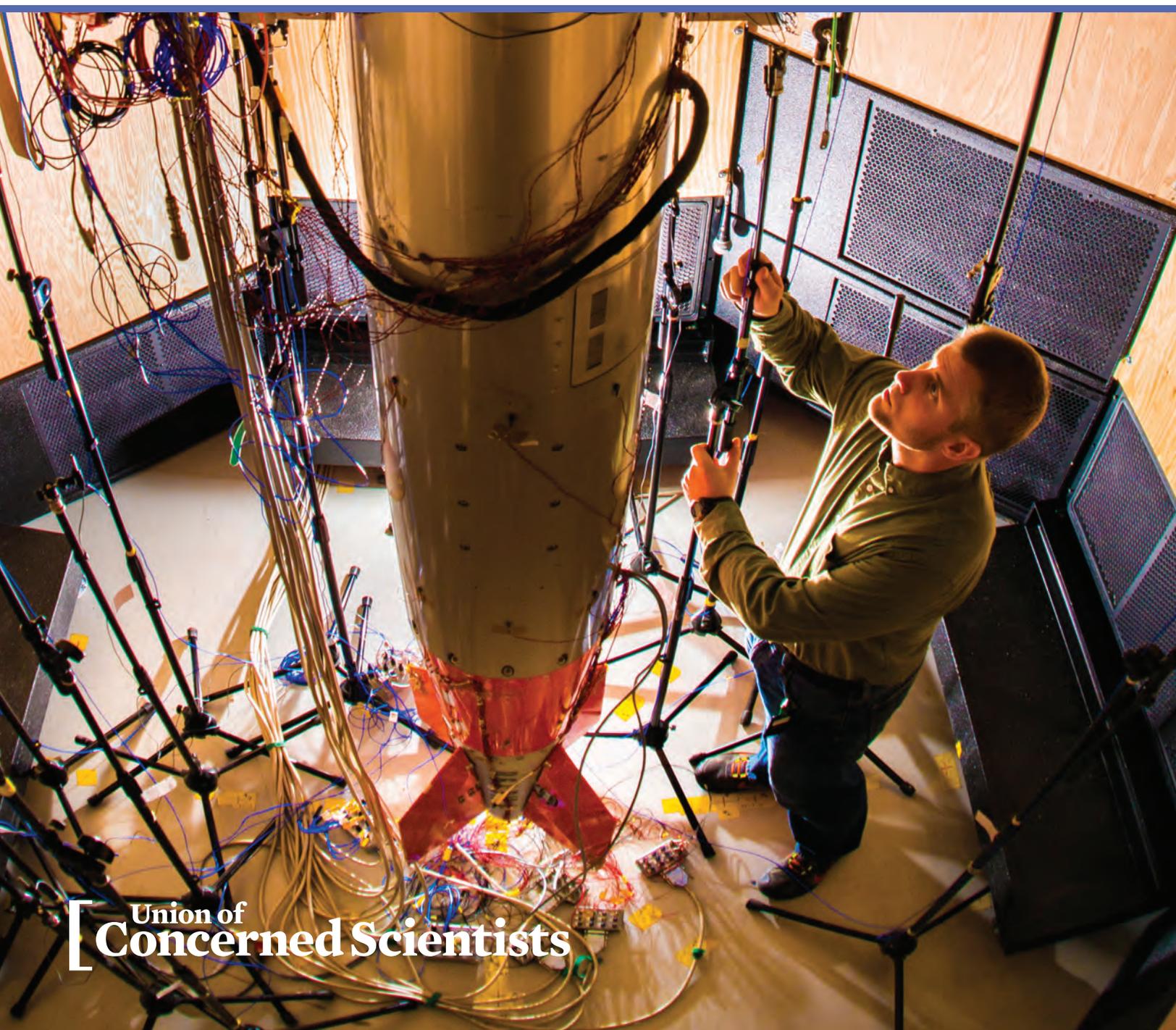


Bad Math on New Nuclear Weapons

The Costs of the 3+2 Plan Outweigh Its Benefits



Union of
Concerned Scientists

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At Sandia Labs, a mechanical engineer performs an acoustic test on a B61-12, a bomb that is part of the 3+2 plan.

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The United States has an ambitious plan for the future of its nuclear arsenal that entails building several new types of nuclear warheads for deployment on land- and submarine-based ballistic missiles.

When current nuclear warheads were built, the government assumed they would remain in the arsenal for roughly 20 to 30 years before being replaced by new designs. Since the United States began a moratorium on nuclear explosive testing in 1992, however, it has introduced no new warheads. Instead, it has been maintaining existing warheads.

Until two years ago, the United States planned for each warhead in the stockpile to undergo a “life extension program” to address any aging issues and, in some cases, modernize components or add new safety and security features. This endeavor would extend the life of the warhead by 20 to 30 years, at which point it would undergo another life extension program, and so on.

However, in June 2013, the Obama administration announced its new “3+2” plan for the future U.S. nuclear arsenal. The United States deploys four types of ballistic missile warheads: two on land-based intercontinental ballistic missiles (ICBMs) and two on submarine-launched ballistic missiles (SLBMs). Under the 3+2 plan, the United States would not extend the life of these four warheads. Instead, it would replace them with three new interoperable warheads (IWs) that could be deployed on both ICBMs and SLBMs. These three new IWs constitute the “3” in “3+2.” However, because each IW will have a land-based and a sea-based variant with common nuclear components but some different non-nuclear components, it may be more accurate to describe the plan as “6+2.”

In addition, the NNSA plans to refurbish two existing air-delivered weapons through life extension programs: a

bomb and an air-launched cruise missile (ALCM) warhead—which together constitute the “2” in “3+2.”

The Obama administration has expressed three main goals for the 3+2 plan: (1) reducing by up to 50 percent the size of the “hedge” force of nuclear weapons that are kept in reserve in addition to the weapons deployed; (2) reducing the cost of maintaining the stockpile of nuclear warheads; and (3) transitioning to an arsenal in which all weapons use insensitive high explosive (IHE) instead of conventional high explosive to initiate the nuclear explosion, thereby reducing the risk of dispersing plutonium in the event of an accident or act of terrorism.

Can the hoped-for benefits of the 3+2 plan be achieved? Would they outweigh the technical and political costs of the program? And what are the merits of the 3+2 plan compared to the alternative of extending the life of each of the four current ballistic missile warheads in addition to the two air-launched weapons?

Trimming the hedge. In addition to the roughly 1,900 strategic nuclear weapons the United States deploys, it currently maintains a hedge force of 2,400 such weapons in reserve for both technical and political reasons. If the deployed weapons of one type experienced a technical problem, the United States could replace them with another type of weapon from the hedge. It could also use the hedge to increase the deployed arsenal for political purposes. According to the administration, the 3+2 plan would allow the United States to reduce the number of weapons in the hedge for technical reasons by up to 50 percent.



Pantex production technicians prepare a B61 bomb for a surveillance test. Under the 3+2 plan, four B61 variants will be consolidated into one new bomb, the B61-12.

However, the current hedge of 2,400 strategic warheads is roughly twice the technical hedge required for an arsenal with existing warhead types that is compliant with the New Strategic Arms Reduction Treaty (New START). The United States should cut its strategic hedge in half once it gains confidence in the life-extended W76-1 SLBM warheads and can retire the excess W76-0 warheads. Thus, the United States can—and should—make a substantial reduction in the strategic hedge even without pursuing the 3+2 plan.

The 3+2 plan would allow a further reduction in the technical strategic hedge from 1,250 to 1,000 warheads for a New START-sized arsenal—a 20 percent reduction. Thus, the 3+2 plan would provide a modest reduction in the hedge for a New START-sized arsenal. However, if the arsenal is reduced below levels specified by New START, the 3+2 plan allows deeper reductions in the hedge. Nonetheless, the goal of reducing the hedge by 50 percent can be met only by eliminating the air-delivered bombs and cruise missiles.

But there is a significant catch: according to the administration, any reductions in the hedge under the 3+2 plan would need to await the completion of all three interoperable warheads—which would take at least three decades.

Moreover, the United States should reassess its current practice of maintaining a technical hedge as well as deploying two types of warheads per delivery system and two types of ballistic missile delivery systems; employing all three hedging strategies should not be necessary. It should also quantify the odds of a warhead failure to determine the need to guard against technological surprise in the first place. For example, Britain and France have a very different approach to their nuclear forces: neither country maintains a technical hedge nor deploys multiple types of ballistic missile warheads.

The United States can—and should—make a substantial reduction in the strategic hedge even without pursuing the 3+2 plan.

Even absent a resumption of nuclear testing, building new warhead types would send the wrong message to the rest of the world.

Reducing Costs. Based on the administration's own cost estimates, we find there is no reason to believe that 3+2 would be less expensive than refurbishing existing weapons; indeed, it may actually be a more expensive approach. In addition, there are other costs associated with the 3+2 plan that are not included in the administration's cost estimates. The administration should do a more comprehensive assessment of the full costs of pursuing 3+2 and of the alternative of refurbishing existing warheads.

Reducing risks. Three types of current U.S. warheads do not use insensitive high explosive. While IHE would not guard against plutonium dispersal from some types of terrorist attacks, nor would it be useful once warheads were deployed on SLBMs, transitioning to an all-IHE stockpile would reduce the risk of accidental plutonium dispersal and benefit the safety of the public as well as personnel who work with nuclear weapons. However, it is not possible to simply replace conventional high explosive with IHE because a greater volume of IHE is required to initiate the nuclear explosion; a transition to an all-IHE arsenal would require building new types of warheads.

Technical and political costs. Building the IWs would entail technical risks that are intertwined with political costs. Specifically, the warheads would use nuclear components that had never been tested together, and deploying such a warhead without nuclear explosive testing could increase uncertainty about the reliability of the warhead. Concern about warhead reliability may lead some political and military leaders to argue that nuclear "proof testing" is necessary to

demonstrate that weapons of such a new design will work as intended, and that therefore the United States needs to resume nuclear testing.

If the United States did resume nuclear testing, it could encourage a resumption of testing by other nuclear-armed nations, ending an international moratorium that benefits U.S. security. And because the non-nuclear weapon states that are a party to the Nuclear Non-Proliferation Treaty (NPT) have made the Comprehensive Nuclear Test-Ban Treaty (CTBT) a priority, resumed testing could undermine the NPT.

But even absent a resumption of nuclear testing, building new warhead types would send the wrong message to the rest of the world. The Obama administration acknowledges this but asserts that the IWs will not be "new." However, this claim is neither consistent with the common definition of the word "new" nor meaningful in a technical sense.

The non-nuclear weapon states have made the CTBT a priority because they believe it will restrict the ability of additional countries to develop nuclear weapons and the ability of existing nuclear states to develop new types of weapons. If the United States forgoes nuclear testing, but still develops new nuclear warheads, it would undermine a key rationale for the CTBT. This, in turn, could also undermine the Nuclear Non-Proliferation Treaty.

Finally, building new types of warheads is counter to the administration's own commitment to reduce the salience of nuclear weapons.

The bottom line. On balance, we assess that the costs of the 3+2 plan outweigh the benefits. Instead of pursuing the 3+2 plan and building new warheads, the United States should refurbish or retire existing weapons.

[INTRODUCTION]

The United States is proceeding with an ambitious 30-year plan to upgrade its aging nuclear warheads that includes retiring several warhead types and replacing them with new ones. U.S. nuclear weapons do not have expiration dates, but explosives, plastics, and lubricants can deteriorate with age, as can metals exposed to radiation for decades. When current nuclear weapons were built, the government assumed they would remain in the arsenal for roughly 20 to 30 years before being replaced by new designs. Since the United States declared a moratorium on nuclear explosive testing in 1992, however, it has introduced no new warheads. Instead, it has been maintaining existing warheads.

Until two years ago, the United States planned for each weapon that would remain in the stockpile to undergo a “life extension program” (LEP) to address any aging issues and, in some cases, modernize components or add new safety and security features. This would extend the life of the weapon by 20 to 30 years, at which point it would undergo another life extension program if it were to remain in the arsenal.

However, in June 2013, the National Nuclear Security Administration (NNSA)—a semi-autonomous agency of the Department of Energy (DOE) responsible for nuclear weapons—announced its new “3+2” plan for the future U.S. nuclear arsenal.¹ Under this plan, the United States would refurbish some of its warheads but retire its ballistic missile warheads and replace them with new ones.

The United States currently deploys four types of ballistic missile warheads: two on land-based intercontinental

ballistic missiles (ICBMs) and two on submarine-launched ballistic missiles (SLBMs). Under the 3+2 plan, the United States would not extend the life of these four warheads, but would instead replace them with three new interoperable warheads (IWs) that constitute the “3” in “3+2.” However, there would be two variants of each interoperable warhead—one for ICBMs and one for SLBMs—that would have common nuclear components but some different non-nuclear components. Thus, it might be more accurate to call the plan “6+2.”

In addition, the NNSA plans to refurbish two existing air-delivered weapons through life extension programs: a bomb and an air-launched cruise missile (ALCM) warhead²—which together constitute the “2” in “3+2.”

The Obama administration has discussed three main goals for the 3+2 plan: (1) substantially reducing—by up to 50 percent—the size of the “hedge” force of nuclear weapons that are kept in reserve in addition to the weapons deployed; (2) reducing the cost of maintaining the stockpile; and (3) transitioning to an arsenal in which all weapons use insensitive high explosive instead of conventional high explosive to initiate the nuclear explosion, thereby reducing the risk of dispersing plutonium in the event of an accident or act of terrorism.

However, there would be costs associated with building new warhead types, which would be controversial for both technical and political reasons.

First the technical reason: U.S. nuclear warheads have two stages—a primary stage and a secondary stage. The

¹ *The 3+2 plan is based on the framework laid out in a classified January 2013 memo by the Nuclear Weapons Council, a joint Department of Defense-DOE body that provides policy guidance and oversight of the nuclear weapons stockpile management process.*

² *In the FY2014 and FY2015 Stockpile Stewardship and Management Plans (SSMPs), the NNSA stated that its long term goal is to replace the bomb and the cruise missile warhead with two interoperable air-deliverable weapons, but this goal is not articulated in the FY2016 SSMP (NNSA 2013; NNSA 2014).*

primary stage is essentially an atomic bomb that produces energy through fission; this energy is used to ignite the secondary stage, which produces energy through fusion. Both stages are contained in the nuclear explosive package (NEP). Because these two nuclear components interact in complex ways, the NEPs of all deployed U.S. thermonuclear warhead designs have undergone explosive testing.

The new warheads proposed under the 3+2 plan would use a primary stage based on one from a previously tested warhead type and a secondary stage based on one from another previously tested warhead type, but the NEP as a whole would never have been explosively tested. The NNSA argues that its experimental and computational simulation capabilities have improved to the point that the United States should have sufficient confidence to deploy the new warheads without nuclear tests to confirm that they would work as intended. Nevertheless, deploying a new warhead design without such testing could raise questions about the reliability of the new weapons.

And that leads to a political reason the 3+2 plan is controversial: Ultimately, such uncertainty could lead some military and political leaders to argue that the United States needs to resume nuclear testing to “proof test” the new designs. If the United States did resume nuclear testing, it could encourage a resumption of testing by other nuclear-armed nations. And because the non-nuclear weapon states that are a party to the Nuclear Non-Proliferation Treaty (NPT) have made the Comprehensive Nuclear Test-Ban Treaty (CTBT) a priority, resumed testing could undermine the NPT.

Moreover, the Obama administration has pledged not to build new nuclear weapons. It actually maintains that these weapons will not be “new,” but this claim requires some creative wordsmithing (see box).

Why would the Obama administration want to claim that the United States will not design new warheads? It correctly assesses that building new weapon types would send the

Under this plan, the United States would refurbish some of its warheads but retire its ballistic missile warheads and replace them with new ones.

What’s New?

In its 2010 Nuclear Posture Review (NPR), the Obama administration states that “The United States will not develop new nuclear warheads. LEPs will use only nuclear components based on previously tested designs, and will not support new military missions or provide for new military capabilities” (DOD 2010a). While the first sentence may seem like a straightforward and unequivocal statement, it is not. When it comes to nuclear warheads, the administration has defined “new” in a specific way, one that is at odds with the normal definition of the word “new.”

In particular, the constraint that warheads will “use only nuclear components based on previously tested designs” does not preclude new nuclear warheads. As the NPR notes, the United States will give “strong preference” to “refurbishment of existing warheads” or the “reuse of nuclear components *from different warheads*” [emphasis added] (DOD 2010a). Yet warheads that use nuclear components from different designs in a new configuration will be of necessity a new design. Moreover, these components need not have been previously tested, but need only be *based* on previously tested designs. Such mix-and-match warheads will be “new” in any meaningful sense of the word.

For nuclear warheads, a more technically meaningful distinction between “new” and “not new” would be whether the NEP as a whole had been explosively tested. Thus, any weapon that used a NEP that had previously been tested would not be considered new, whereas a weapon that used a primary from one previously tested weapon and a secondary from another previously tested weapon would be considered new.

wrong message to the rest of the world. The non-nuclear weapon states have made the CTBT a priority because they believe it will restrict the ability of additional countries to develop nuclear weapons and the ability of existing nuclear states to develop new types of weapons. If the United States forgoes nuclear testing, but still develops new nuclear weapons, it would undermine a key rationale for the CTBT. This, in turn, could also undermine the NPT.

Can the hoped-for benefits of 3+2 be achieved? Would they outweigh the technical and political costs of the program? And what are the merits of the 3+2 plan compared to the alternative of extending the life of each of the four current ballistic missile warheads in addition to the two air-launched weapons?³

3 Another possibility is to retire some of the ballistic missile warheads rather than extending their life or replacing them, but we do not analyze this option here.

The 3+2 Plan

The current U.S. arsenal consists of seven types of weapons: four ballistic missile warheads, two for ICBMs (the W78 and W87) and two for SLBMs (the W76 and W88); two bombs (the B61, which has multiple versions, and the B83), and one ALCM warhead (the W80) (see Table 1). The B83 is slated for retirement after the B61 LEP is completed, which will leave six weapon types.⁴

The NNSA's projected timeline for the 3+2 program is shown in Figure 1. Note that the first interoperable warhead, IW-1, intended to replace the W78 ICBM warhead and half of the W88 SLBM warheads, began being developed in fiscal year 2014 (FY14). However, when Congress passed the FY14 budget in January 2014, it cut funding for the IW-1 and added language requiring more detailed analysis of the NNSA proposal. The NNSA's FY15 budget, released in March 2014, then deferred the IW-1 program by five years. The agency said its decision was based not just on budget constraints, but also on surveillance data showing “more graceful aging” of the W78 and W88 warheads, which means that they do not need to be replaced in the short term, letting the NNSA focus on more urgent needs (Jacobson 2014b). The NNSA also delayed the schedule for the IW-2 program by three years.

Life extension programs for both the W87 and one of the B61 variants (the B61-11 earth-penetrating bomb) are already completed. The W76 LEP, which will result in a warhead designated the W76-1, is being produced now. The remaining B61 variants (the B61-3, -4, -7, and -10) are next in line, and will be consolidated into one new bomb—the B61-12, which is still in the development phase (see Figure 1).

To date, modifications to weapons made as part of life extensions have been modest, although the B61 LEP will entail a more extensive overhaul. However, even the B61 LEP

TABLE 1. Current U.S. Nuclear Arsenal

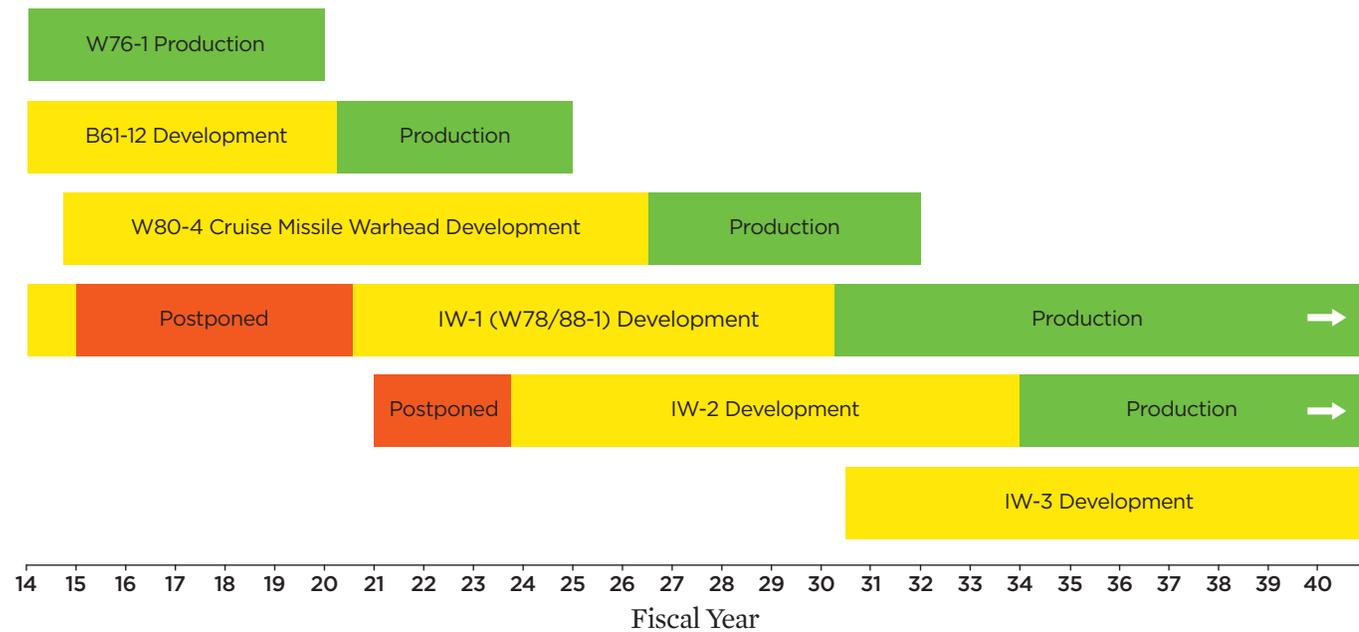
	Weapon Type	Deployed	Hedge
ICBM Warheads	W78	200	not publicly known
	W87	250	not publicly known
SLBM Warheads	W76	768	not publicly known
	W88	384	0
ALCM Warheads	W80	200	328
Bombs	B83	100	400
	Strategic B61 (B61-7, B61-11)		
	Tactical B61 (B61-3, B61-4, B61-10)	180	300
Total		2,100	2,700

The United States maintains weapons in the hedge to allow it to increase its deployed forces, and to replace one type of weapon that experiences a technical failure with other types from the hedge. The current strategic hedge is twice that required for a New START-sized force.

SOURCE: KRISTENSEN AND NORRIS 2015.

⁴ The administration has only recently begun linking the retirement of the B83 to the completion of the B61 LEP and deployment of the resulting B61-12.

FIGURE 1. Projected Timeline for the 3+2 Plan



The 3+2 plan will take more than 30 years to complete.

SOURCE: NNSA 2015.

will not include modifications to the nuclear explosive package. Initial agency plans did include modifying the NEP to add new safety features, but the Nuclear Weapons Council—a joint Department of Defense-DOE body that provides policy guidance and oversight of the programs to maintain the nuclear weapons stockpile—decided not to undertake that part of the life extension program. Despite scaling back the project, cost estimates for the B61 LEP have more than doubled from \$4 billion to \$10 billion.⁵

By contrast, the modifications the NNSA plans under 3+2 are much more aggressive than those in previous LEPs: they entail producing NEPs that will combine a primary based on one from a previously tested warhead type with a secondary from another previously tested warhead type.

In addition to the B61-12 bomb, the 3+2 plan includes an ALCM warhead. The NNSA recently decided to simply extend the life of the existing cruise missile warhead—the W80.

Interoperable Warheads

Interoperable warheads are key to 3+2. NNSA defines these as “warheads with a common NEP integrated with non-nuclear

systems that maximize the use of common and adaptable components” and “can be deployed on multiple delivery platforms” (NNSA 2013).

The current plan is for an ICBM and SLBM to deliver the same NEP but use different non-nuclear components. For example, the Air Force and Navy apparently have decided they would not use a common fuze (NNSA 2015). Thus, there would be two variants of each interoperable warhead—one for land-based ICBMs that would fit on the Mk21A reentry vehicle, and one for sea-based SLBMs that would fit on the Mk5 reentry vehicle.

The first interoperable warhead, the IW-1, would replace the W78 ICBM warhead and half of the W88 SLBM warheads, with the older W78 warhead first in line for replacement (NNSA 2015). As described above, the NNSA is pursuing a mix-and-match approach for the interoperable warheads that will combine a primary from one warhead with a secondary from another. For the IW-1, the NNSA plans to combine a primary based on the one in the W87 warhead with a secondary from another warhead (one report suggests the W80) (NNSA 2015; Collina 2014).

⁵ The NNSA’s original 2010 estimate for the B61 LEP was \$4 billion, while an updated 2012 cost estimate by the DOD’s Office of Cost Assessment and Program Evaluation was \$10 billion (Miller and Ho 2012; NNSA 2010b).

The NNSA is pursuing a mix-and-match approach for the interoperable warheads that will combine a primary from one warhead with a secondary from another.

While the Nuclear Weapons Council has not yet determined the plans for the second and third interoperable warheads, the NNSA's working assumption is that the IW-2 would replace the W87 ICBM warheads and the remaining W88 SLBM warheads, and sometime after 2040 the IW-3 would replace the W76-1 (the life-extended version of the W76, now in production) (NNSA 2015).⁶ We expect these warheads would also use a mix-and-match approach.

The push for interoperability is complicated by a lack of enthusiasm on the part of both the Navy and Air Force. The Navy—which has a history of pushing back on DOE proposals to alter warheads—has argued for delaying development of the IW-1 until at least the mid-2020s because of funding and other uncertainties (Undersecretary of the Navy 2012). Moreover, a Government Accountability Office (GAO) report notes the Navy's lack of preparation for participation in the IW program as a potentially significant problem (GAO 2013). The Air Force has been more supportive, but in April 2013 congressional testimony, one Air Force major general noted that interoperability “may not be feasible or affordable” and “we have to be ready to have some offramps” (Harencak 2013).

The Navy's attitude toward the 3+2 plan may also be affected by the upcoming Alt 370 alteration program for the W88 SLBM warhead, which will be completed only a few years before the production of the IW-1 is scheduled to begin (NNSA 2015). An alteration program is more modest than a life extension program, and entails replacing some

components with new ones in a way that does not change military operations, logistics, or maintenance requirements (DOD n.d.a).

In November 2014, the Nuclear Weapons Council expanded the scope of the W88 Alt 370 to include replacing the warhead's conventional high explosive with fresh explosive, which would allow it to be used through the late 2030s (NNSA 2015; Jacobson 2014c). Normally, the high explosive, which is contained in the nuclear explosive package, would be replaced as part of a full life extension program. However, the high explosive used in the W88 has a defined life expectancy and would need to be replaced as early as 2030. Since there is currently no planned LEP for the W88 and it would instead be replaced by IW-1 and IW-2 warheads, the Navy was concerned that if the IW-1 did not go ahead on schedule, time would run out to replace the W88's conventional high explosive.

Several months before the Nuclear Weapons Council decision, former Lawrence Livermore National Laboratory Director Parney Albright predicted that this Alt 370 update would expand to include some components of the nuclear explosive package itself. In his view, this expansion would mean that the Navy “will almost certainly argue” against an interoperable warhead “that costs too much money” instead of a simple refurbishment, as the NNSA did for the W76 life extension program (Jacobson 2014a).⁷ Once this happens, Albright argued, there would be less incentive for the Air Force to pursue interoperability for the W78 as well.

6 Don Cook, then NNSA's Deputy Administrator for Defense Programs, said the IW-1 would replace half of the W88s in the arsenal, while IW-2 would replace the other half (Cook 2013). The FY2014 Stockpile Stewardship and Management Plan (SSMP) states that the IW-2 and IW-3 are projected to replace the W87/88 and W76-1 respectively.

7 While nuclear warheads are in the NNSA budget, in recent years the DOD has contributed billions of dollars to the NNSA budget.

Deconstructing 3+2

Below, we investigate the NNSA's primary rationales for the 3+2 plan: trimming the hedge, cutting costs, and improving safety. We also discuss the claim that producing, as well as designing, new warheads is necessary to keep weapons designers engaged and to facilitate the hiring of new designers to replace those who retire.

Trimming the Hedge

The United States currently maintains a hedge force of nuclear weapons that are kept in reserve for both technical and political reasons. If the deployed weapons of one type experienced a technical problem (a system-wide failure), the United States could compensate by deploying another type of weapon from the hedge. It could also use the hedge to augment the deployed arsenal if it believes doing so is required by changes in the global political situation.

By trimming its hedge force of nuclear weapons and reducing its overall arsenal, the United States would take a step in the direction of eliminating nuclear weapons, as it is obligated to do under the Nuclear Non-Proliferation Treaty. Trimming the hedge would also allow the United States to reduce the costs of maintaining and storing its hedge warheads.

In a June 2013 report to Congress, the administration summarized the new U.S. nuclear employment strategy resulting from the 2010 Nuclear Posture Review. According to the report, “. . . the Departments of Defense and Energy examined their long-standing hedge approach and developed a more efficient strategy that allows the United States to maintain a robust hedge against technical or geopolitical risk with fewer nuclear weapons” (DOD 2013).

The report states: “A non-deployed hedge that is sized and ready to address these technical risks will also provide the United States the capability to upload additional weapons in response to geopolitical developments that alter our assessment of U.S. deployed force requirements” (DOD 2013). Thus, it appears that it is now the policy of the United States that a hedge that is adequate to respond to a technical failure is also adequate to respond to a political surprise. In other words, the “geopolitical hedge” would be equal to the “technical hedge.”

The United States currently has about 2,700 hedge warheads and bombs, compared to about 2,100 deployed weapons (see Table 1, p. 6), so the hedge force is now larger than the deployed force (Kristensen and Norris 2015). About 2,400 of the weapons in the hedge and 1,900 of those deployed are considered strategic since they would be delivered by long-range delivery systems. The remaining 500 weapons are tactical bombs, with about 200 deployed in Europe for delivery by short-range aircraft and 300 in storage as a hedge.

The W76 submarine-based warhead is in the middle of a life-extension program, although the United States plans to retire some of the warheads rather than extend their life. However, until the United States attains confidence in the updated model—the W76-1—it will keep some of the original W76 warheads—now renamed W76-0—slated for retirement in the hedge. It is not publicly known what the criteria are for being confident in the performance of the W76-1 or how long it might take to gain such confidence. But according to the new nuclear employment strategy articulated in 2013, the DOD will “maintain legacy weapons to hedge against the failure of weapons undergoing life-extension only until confidence in each LEP is attained” (DOD 2013).



NNSA

Pantex production technicians work on a W76 SLBM warhead. The W76 is undergoing a life extension program that entails modest modifications.

In addition, the new nuclear employment strategy discusses the preferred composition of the hedge. It states:

Where possible, the United States will provide intra-leg hedge options—i.e., uploading another warhead type from within a leg of the Triad in the event that a particular warhead fails. In instances where the current stockpile will not allow intra-leg hedging, the United States will be prepared to hedge adequately using inter-leg hedging—uploading additional warheads on another leg of the Triad to compensate for the failure of a given type of warhead (DOD 2013).⁸

In other words, if a submarine-based weapon failed, the DOD would prefer to compensate by deploying another type

of submarine-based weapon. Similarly, it would prefer to deploy another air-based weapon to compensate for the failure of an air-based weapon, and another land-based weapon to compensate for the failure of a land-based weapon.

However, it would not be possible for the United States to use intra-leg hedging if the W76 submarine-based warhead failed. The U.S. arsenal has a second type of submarine-based warhead—the W88, but almost all the W88s are deployed, leaving none as a backup in case of a problem with the W76.⁹ Thus, the United States would need to use inter-leg hedging to compensate for a problem with the W76 by deploying additional air- and land-based weapons. Since each Minuteman ICBM can accommodate up to three W78 warheads or one W87 warhead, the United States could deploy one or two

⁸ The United States deploys nuclear weapons on aircraft, on submarines, and on land—which are referred to as three legs of a triad.

⁹ The United States planned to produce several thousand W88 pits, but due to environmental problems, the Rocky Flats Plant (near Boulder, CO) that produced the pits stopped production in 1989 after completing only about 400.

additional W78s on each ICBM armed with a W78. It could also deploy additional B61 bombs and ACLMs. The net result would be fewer warheads deployed on SLBMs.

The FY 2016 Stockpile Stewardship and Management Plan (SSMP) states that, “Consolidation of the present four ballistic missile systems into three interoperable systems will enable an eventual reduction in the number of weapons retained as a hedge against technical failure” (NNSA 2015). It notes that “after consolidation,” there will be “up to 50 percent potential hedge reduction” (NNSA 2015).¹⁰

The SSMP goes on to state that the 3+2 plan can “remove the need for a significant part of the technical hedge, but only when fully implemented.” However, under current plans, production of the third interoperable weapon, the IW-3, would not even begin until after 2040. Thus, based on the NNSA’s timeline, any reduction in the hedge would take place no sooner than three decades from now. That is a long time before the proposed benefit would be realized.

What are the requirements for the technical hedge, assuming an arsenal of the size permitted under the New Strategic Arms Reduction Treaty (New START), which requires reductions to be completed by February 2018? In our analysis (see Appendix B, p. 21), we will also assume that the United States is confident in the performance of the W76-1 and has retired all remaining W76-0 warheads.

While the United States does not publish numbers of each type of warhead in its arsenal, it is possible to estimate the planned mixture under the New START agreement. New START allows for 700 deployed strategic nuclear delivery vehicles—ICBMs, SLBMs, and bombers—carrying a total of 1,550 countable warheads or bombs. However, under New START counting rules, each warhead on an ICBM or SLBM is counted individually, but all the bombs or cruise missiles associated with one bomber are counted as one weapon. Thus, the total number of deployed strategic warheads and bombs actually will exceed 1,550.

A reasonable assumption is that the deployed arsenal under New START will consist of roughly 1,750 warheads and bombs: 400 ICBM warheads (250 W87s and 150 W78s); 1,100 SLBM warheads (400 W88s and 700 W76s); 75 B61 bombs; and 175 W80 ALCM warheads.¹¹ (The United States deploys another

The United States could cut the hedge by almost a factor of two once it becomes confident in the W76-1 and B61-12. It would not need to wait for three decades until it had built and deployed three new types of warheads.

180 B61 bombs in Europe; although these will be the same as the B61-12 bombs that will be deployed in the United States, they are considered tactical weapons and thus are not accountable under New START. We do not consider them here.)

For a New START-sized arsenal with current warhead types, we find that the technical hedge would need to include 1,250 weapons to provide replacements if one type of weapon failed (see Appendix B, p. 21). To provide a hedge for the 700 deployed W76 warheads, the United States could add another two W78 ICBM warheads onto each of the 150 ICBMs armed with the W78, and deploy 150 additional B61 bombs and 250 additional W80 ALCMs. It is worth noting that if this hedge were deployed to replace the W76, the number of countable weapons would fall well below the New START limits.

How might implementation of the 3+2 plan change the requirements for the technical hedge, again assuming a New START-sized arsenal?

Deploying the first interoperable warhead (IW-1) to replace all the W78 ICBM warheads and half of the W88 SLBM warheads, as currently planned, would result in a technical hedge of either 1,050 or 1,300 warheads—depending on how the hedge is configured (see Appendix B, p. 21).

¹⁰ The NNSA’s assertion that the 3+2 plan will reduce the technical hedge by up to 50 percent is presumably based on the fact that a nuclear force with two warhead types that can substitute for each other will have a technical hedge equal to the size of the deployed force, whereas a force with three warhead types deployed in equal numbers will have a technical hedge equal to half of the deployed force (see Appendix A, p. 20). By building three warhead types for SLBMs and three for ICBMs, the technical hedge would be half of the deployed ICBM and SLBM warheads. However, this is not the relevant comparison, because the United States does not currently have two SLBM warhead types that can hedge for each other, and the required technical hedge is already much less than the deployed arsenal.

¹¹ In 2014, the United States released its planned force posture under New START: 400 ICBMs, 240 SLBMs, and 60 nuclear-capable bombers (American Forces Press Service 2014). The bomber force comprises 19 B-2 and 41 B-52 bombers (DOD n.d.b). Each B-2 can carry up to 16 nuclear bombs, for a total of 304 bombs, and each B-52 can carry up to 20 cruise missiles, for a total of 820. However, we assume that under New START, the United States will deploy 75 B61 bombs and 175 W80 air-launched cruise missile warheads, which is slightly less than the number of these weapons currently deployed. These would count as only 60 weapons under New START.

The United States should assess its need to guard against technological surprise in the first place.

A fully interoperable warhead would be able to serve as a hedge for both the W87 ICBM warhead and the W76 SLBM warhead, assuming that only one type would fail at any given time. However, the IW-1 will not be fully interoperable. Rather, it will have two variants—one for ICBMs and one for SLBMs—that will have different non-nuclear components (albeit with some identical parts). Only the NEP will be interoperable. Thus, the hedge could consist of IW-1 NEPs, non-nuclear components for the Navy warheads, and non-nuclear components for the Air Force warheads; the warheads would be assembled only if needed to replace a weapon in the deployed arsenal. Alternatively, the hedge could consist of fully assembled IW-1 warheads. This option would require building more IW-1 NEPs. In either case, the inter-leg hedge would be reduced from 700 to 300 warheads.

Adding a second interoperable warhead to replace the W87 and remaining W88 warheads would change the technical hedge to either 1,050 or 1,350 warheads—again depending on the way the hedge is configured (see Appendix B, p. 21). The hedge could include IW-1 and IW-2 NEPs, non-nuclear components for the Navy IW-1 and IW-2 warheads, and nonnuclear components for the Air Force IW-1 and IW-2 warheads; the warheads would be assembled only if needed to replace a weapon in the deployed arsenal. Alternatively, the hedge could include fully assembled Navy IW-1 and IW-2 warheads and Air Force IW-1 and IW-2 warheads,

with a total technical hedge of 1,350 weapons. In either case, there would only be intra-leg hedging.

If the United States replaced the W76 with a third interoperable warhead and deployed equal numbers of the three interoperable warheads, the technical hedge would be 1,000—whether or not the three IWs were truly interoperable (see Appendix B, p. 21). In this case, there would also only be intra-leg hedging.

In sum, if the United States maintains current warhead types by refurbishing existing weapons rather than pursuing the 3+2 plan, the total strategic technical hedge would be 1,250 warheads for a New START-sized arsenal. That technical hedge is much less than the current strategic hedge of 2,400 warheads, suggesting the United States could cut the hedge by almost a factor of two once it becomes confident in the W76-1 and B61-12. It would not need to wait for three decades until it had built and deployed three new types of warheads.

The technical hedge could be further reduced by a modest amount—to 1,050—by building one interoperable warhead, in the scenario where the hedge consists of NEPs and separate Navy and Air Force non-nuclear components that would only be assembled if needed. Under this scenario, adding a second interoperable warhead would not allow further reductions in the hedge, and adding a third interoperable warhead would allow an additional reduction to 1,000. Thus, if the goal is reducing the hedge, IW-2 and IW-3 are not very useful under this scenario.

Moreover, if the goal is also to create a hedge that does not rely on inter-leg hedging, adding a third interoperable warhead is unnecessary, since building two interoperable warheads would allow only intra-leg hedging. Therefore, it would make no sense to produce a third interoperable warhead rather than simply extend the life of the W76-1 under this scenario.

If the hedge instead included fully assembled ballistic missile warheads, then building IW-1 and IW-2 would increase

TABLE 2. Technical Hedge for Various Arsenal Sizes, under Refurbishment versus 3+2 Plan

	Deployed Warheads	Hedge under Refurbishment of Existing Warhead Types	Hedge under 3+2	Percent Reduction in Hedge under 3+2 Relative to Refurbishment
New START	1,750	1,250	1,000	20%
Half New START	900	775	525	32%
One-Third New START	600	600	350	42%

The reductions in the hedge allowed by the 3+2 plan will increase as the force size decreases, but a reduction of 50 percent would only be possible if the air-based weapons were eliminated.

the hedge. All three IWs would be needed to reduce the technical hedge to 1,000.

How would these numbers change if the United States makes further reductions in its arsenal below New START levels? The Pentagon has already determined that the United States can reduce its deployed weapons by a third relative to New START levels, independent of Russian reciprocity (White House 2013). A nominal strategic arsenal with deployed forces equal to half New START levels would have 900 deployed warheads (75 W78s, 125 W87s, 350 W76s, 200 W88s, 50 B61s, and 100 W80s) and a technical hedge of 775 weapons (see Appendix B, p. 21).

If the 3+2 plan were implemented and there were three warhead types for each of the ICBM and SLBM legs, for a deployed force of 900 strategic weapons, the technical hedge would be 525 weapons instead of 775—a one-third reduction (see Table 2).

If the United States made deeper reductions in its deployed forces to, for example, 600 weapons (50 W78s, 50 W87s, 200 W76s, 200 W88s, 50 B61s and 50 W80s), then the technical hedge would be 600 (see Appendix B, p. 21). Under the 3+2 plan, the technical hedge would be 350 rather than 600—a reduction of 42% (see Table 2). Thus, as the arsenal is reduced, the 3+2 plan allows deeper reductions in the hedge. However, because only two air-based weapons are planned, the goal of reducing the hedge by 50 percent can be met only if the air-based weapons are eliminated.

At a more fundamental level, the 3+2 plan or any other plan notwithstanding, the United States should reassess its hedge strategy.

For example, Britain and France take a very different approach to their nuclear arsenals. Britain has one type of nuclear weapon in its arsenal, a warhead similar to the U.S. W76 that is deployed on SLBMs. It deploys no more than 120 and has a total of no more than 225 (Fallon 2015; Norris and Kristensen 2013). It does not maintain a technical hedge. France currently has two warhead types for SLBMs, but only because it is currently replacing one warhead type with a new one; when finished, France will only deploy one warhead type on submarines. It also has one weapon type for aircraft delivery. It does not have a hedge force (Kristensen 2012).

Currently, the United States maintains a technical hedge as well as deploys two types of warheads per delivery system and two types of ballistic missile delivery systems. If one type of SLBM warhead failed, there would still be another warhead type deployed on SLBMs as well as two types deployed on ICBMs. The United States should reconsider its need to

maintain all three of these hedging strategies to deal with the potential for technical surprise. For example, a future ballistic missile force could consist of one deployed type of SLBM warhead, with a second type retained as a hedge.

The United States should also assess its need to guard against technological surprise in the first place. The failure of an entire class of weapons is unlikely—especially for existing weapon types, which have undergone nuclear explosive testing. The United States should quantify the odds of such a failure since a revision of this policy could obviate the need both for a technical hedge and for deploying two kinds of weapons per delivery system.

Cutting Costs

The NNSA has argued that reductions in the hedge and in the number of weapon types under the 3+2 plan would save money in the long term. Reducing the hedge would reduce the number of warheads to be produced and maintained, which would reduce the LEP production costs and maintenance costs, all else being equal. By reducing the number of ballistic missile warhead types by one, the 3+2 plan would require one fewer LEP, which would also result in savings, all else being equal.

However, all else may not be equal: the cost of LEP programs can vary greatly depending on the complexity of the modifications. For example, the cost of the straightforward W76 LEP is roughly \$4 billion, or \$2.5 million per warhead, whereas the NNSA's projected cost for the more complicated B61-12 LEP is \$7–10 billion, or \$14–20 million per bomb.¹²

Thus, developing and producing three new interoperable warheads may be more expensive than refurbishing the four existing ballistic missile warheads, depending on the relative

Developing and producing three new interoperable warheads may be more expensive than refurbishing the four existing ballistic missile warheads.

¹² The NNSA will produce an estimated 1,600 W76-1 warheads (Kristensen and Norris 2015). The NNSA plans to produce roughly 500 B61-12s (Kristensen 2015).

TABLE 3. Research, Development, and Production Costs for Different Warheads, as Estimated in the FY15 and FY16 Stockpile Stewardship and Management Plans

Program	FY15 SSMP Cost Estimate (FY15 dollars in billions)	FY16 SSMP Cost Estimate (FY15 dollars in billions)	Cost Difference
W76-1 LEP	4.1	4.4	+7%
B61-12 LEP	7.4 - 9.0	6.8 - 9.5	-8% to +6%
W88 Alt 370	2.4 - 2.8	2.7 - 3.7	+13% to +32%
W80-4 LEP	4.8 - 6.3	5.9 - 8.1	+23% to +29%
IW-1	7.9 - 9.8	9.8 - 14.8	+24% to +51%
IW-2	8.9 - 10.7	10.2 - 15.3	+15% to +43%
IW-3	10.0 - 12.7	9.6 - 14.2	-4% to +12%
Total	45.5 - 55.4	49.4 - 70.0	+9% to +26%

The NNSA's FY16 cost estimates for warhead life extension programs and interoperable warheads show a significant increase relative to its FY15 estimates.

complexity of the warheads.

Most of the NNSA's cost estimates in the FY16 stockpile plan are greater than those in the FY15 document (see Table 3, p. 14)—some by as much as 40 to 50 percent. The NNSA states the figures are higher in part because, for the first time, experts from the national weapons laboratories and nuclear weapons production facilities were involved in assessing the

Based on the NNSA's cost estimates, there is little reason to believe that the 3+2 plan would be less expensive than simply refurbishing existing weapons. Indeed, it may be more expensive.

complexity of each LEP and warhead program.

Moreover, according to the NNSA, the substantial increase in the cost estimates for the interoperable weapons is due to the assumption that there will be different fuzing mechanisms for the Air Force and Navy versions of the IW warheads (NNSA 2015). The increase in the cost estimate for the W88 Alt 370 program is due to the replacement of the conventional high explosive. There is no public information about the increase in the cost estimate for the W80-4 LEP.

The FY15 stockpile plan compared its estimated costs of building IW-1 and IW-2 with those of refurbishing the W78, W87, and W88. The analysis included the research, development and production costs, as well as the sustainment costs. Sustainment costs include those for maintenance, periodic replacement of limited-life components, and surveillance activities to assess the safety, security, and reliability of the weapons. (Note that the estimates in Table 3 do not include sustainment costs.) NNSA found that building the IW-1 and IW-2 rather than doing life extension programs for the W78, W87, and W88 would result in cost savings of \$3 billion to \$19 billion (in FY15 dollars).¹³

Unfortunately, the FY15 stockpile plan provides no information about the estimated costs of the W78, W87, and W88

¹³ The FY15 Stockpile Stewardship and Management Plan (SSMP) compared the costs for the 3+2 plan with those for the LEP strategy laid out in the FY 2011 stockpile plan, before the NNSA adopted the 3+2 plan. While Table 8-11, (page 8-18) of the FY15 SSMP indicates that savings would range from \$10.2 to \$28.6 billion for the first cycle of LEPs, it is comparing apples to oranges. The FY 2011 plan includes a LEP for the B83 bomb, where the 3+2 plan does not. As footnote 5 on page 8-17 indicates, the cancelled B83 LEP is responsible for \$7.5 to \$ 9.5 billion of these cost savings—leading to an actual net savings of only \$2.7 to \$19.1 billion. Leaving aside the B83 bomb, the FY2011 plan included the B61-12, W76-1, and W80 LEPs; the W88 Alt 370; and the W78, W87, and W88 LEPs. The 3+2 plan includes the B61-12, W76-1, W80, and B83 LEPs; the W88 Alt 370; and the IW-1 and IW-2 warheads. Neither the next W76 life extension program nor the IW-3 warhead was included in the NNSA analysis. In other words, the costs associated with conducting life extension programs for the W78, W87, and W88 warheads were compared with those associated with building the IW-1 and IW-2.



Los Alamos National Laboratory

Building interoperable warheads would require manufacturing new plutonium pits, which in turn requires establishing an enhanced pit-manufacturing capability, likely at the cost of several billion dollars. Here, a pit is being cast at Los Alamos National Laboratory.

LEPs, or the sustainment costs of any of these weapons, so it is difficult to assess the validity of the calculated cost savings. However, there are several things to note.

First, this is a wide range, which indicates that the uncertainty is large.

Second, the cited savings are likely to be overestimates since the cost comparison does not include either the IW-3 or the next W76 life extension program. The IW-3's research, development and production costs would almost certainly be greater than those of a straightforward W76 LEP, meaning that the nominal cost savings of pursuing the 3+2 plan would be reduced.

Third, the NNSA calculation of potential savings does not take into account additional costs that the Navy and Air Force would incur to conduct additional flight tests (beyond those they regularly conduct) of their reentry vehicles with the new interoperable warheads.

The NNSA did not repeat its calculation of cost savings in its FY16 stockpile plan, nor did it repeat its claim that the 3+2 plan will reduce costs. Moreover, while the FY16 plan includes updated cost estimates for the IW-1 and IW-2, it still does not include cost estimates for the W78, W87, or W88 LEPs.

However, if we assume that the cost estimates for the W78, W87, and W88 LEPs are the same as those used in the FY15 cost savings calculation, when the FY16 cost estimates are used for IW-1 and IW-2, the cost difference between the 3+2 plan and the refurbishment strategy ranges from a cost increase of \$7 billion to a cost savings of \$16 billion.¹⁴ Because the cost estimates for the other LEPs increased somewhat from the FY15 values (although not by as much as did those for the IW programs), it is likely that the cost estimates for the W78, W87, and W88 LEPs would have increased somewhat as well if the NNSA were to calculate them. Thus, the cost increase of \$7 billion may be a lower limit. On the other hand, as noted above, NNSA's savings estimates do not take into account other factors.

In short, based on the NNSA's cost estimates, there is little reason to believe that the 3+2 plan would be less expensive than simply refurbishing existing weapons. Indeed, it may be more expensive.

Finally, building the interoperable warheads would require manufacturing new plutonium pits (the fissile cores of thermonuclear weapons, contained in the primary stage), which in turn requires establishing an enhanced pit-manufacturing capability. For example, the IW-1 that will replace the W78 and W88 warheads will use a "W87-like" pit.

The Los Alamos National Laboratory currently can produce some 10 pits annually, but the NNSA plans to install new equipment and increase its annual capacity to 50–80 pits by 2030, when the IW-1 warhead is slated to begin production. The cost of doing so is uncertain, but will likely be several billion dollars. This cost should also be allocated to the 3+2 program.

Bottom line: Before work on the IW-1 begins in 2020, the NNSA should develop a better understanding of the full costs of the IW programs, and of the alternative of refurbishing the ballistic missile warheads. These cost estimates should be validated by independent experts.

Improving Safety

The NNSA says that its 3+2 plan would create a nuclear stockpile in which all warheads use insensitive high explosive (IHE) to initiate the nuclear explosion. IHE is more difficult to detonate than conventional high explosive and thus makes

¹⁴ The NNSA estimated that the FY15 costs savings for the 3+2 plan relative to LEPs ranged from \$2.7 to \$19.1 billion. The FY16 cost estimate of the IW-1 and IW-2 increased by \$3.2 to \$9.6 billion, so the minimum cost saving is now $-(2.7 - 9.6)$ billion = $-\$6.9$ billion. The maximum costs savings is $-(19.1 - 3.2)$ billion = $-\$15.9$ billion.

accidental detonation of the high explosive less likely.

U.S. nuclear weapons are designed so that the accidental detonation of a weapon's high explosive has a less than one-in-a-million chance of causing a nuclear detonation (DOD n.d.a). The real concern is that an accidental detonation of the high explosive—or a detonation caused by a terrorist attack—would disperse plutonium over a wide area. IHE, because it is more difficult to detonate than conventional high explosive, reduces this risk. IHE also would make handling the high explosives safer for workers and reduce the need for special equipment, facilities, and procedures at sites that work with them, potentially yielding cost savings.

However, the safety benefits of IHE are greater than its security benefits. In other words, IHE would be more effective in preventing an accidental detonation than in preventing a detonation caused by a terrorist attack. Even IHE could be detonated by the explosion of a nearby hand-grenade or by some types of bullets fired from some types of rifles at a distance of up to 150 meters.¹⁵

The safety benefits of using IHE are not as great for SLBM warheads as for ICBM warheads. The submarine-launched Trident II missile uses a solid propellant that has a low detonation threshold, and detonation of the propellant would detonate even IHE. Thus, once the warheads are mated to the SLBMs on the submarines, IHE has little advantage over conventional high explosive. However, IHE would provide safety benefits during SLBM warhead handling and transportation. (By contrast, land-based Minuteman III ICBMs use a propellant that is difficult to detonate.)

The United States developed IHE in the 1960s and 1970s, and nuclear weapons with IHE were added to the arsenal

starting in 1979. However, not all weapons introduced since 1979 use IHE. In particular, the W88 SLBM warhead, developed during the 1980s and first produced in 1988, uses conventional high explosive. IHE is somewhat less energetic than is conventional high explosive, so more of it is needed. The United States wanted to make the W88 warheads as small and light as possible so it could maximize the number placed on each SLBM and the range of the missile, and decided to forgo using IHE.

Currently the W87 ICBM warhead, the W80 ALCM warhead, and the B61 and B83 bombs all employ IHE. The remaining three warheads—the W78 ICBM warhead, and the W76 and W88 SLBM warheads—use conventional high explosive. The current W76 life extension program does not add IHE.

It is not possible to simply replace the conventional high explosive in a weapon with IHE because, as noted above, more IHE would be required. Moreover, the high explosive is part of the nuclear explosive package, so adding IHE would entail modifying the NEP.

Although there are warheads with IHE that would fit on the Mk12-A reentry vehicle that carries the W78 ICBM warhead, they are probably not viable candidates for replacing the W78. In particular, the W80 and W84 warheads are physically smaller than the W78 and would therefore fit on the Mk12-A reentry vehicle. However, these warheads were developed for delivery by cruise missiles, so may not be capable of handling the increased atmospheric stress they would experience on an intercontinental ballistic missile trajectory. (Intercontinental ballistic missiles travel at much greater speeds than do cruise missiles.) At a minimum, extensive flight testing would be required to certify that these cruise missile warheads would function after passing through a more demanding ICBM environment. Thus, replacing the W78 ICBM warheads with ones that use IHE would likely require producing a warhead of a new design.

It is not feasible to replace the W76 or W88 SLBM warheads with an existing warhead containing IHE. The limiting factor here is the size of the Trident II SLBM reentry vehicle. Both the Mk4 and Mk5 reentry vehicles are too small to carry the W87, W80, or W84 warheads. It would be possible to modify the third stage of the Trident missile so that it could accommodate a smaller number of larger warheads, but such modification could be costly. Without doing so, acquiring an all-IHE SLBM force would require producing new warhead designs.

At a minimum, extensive flight testing would be required to certify that these cruise-missile warheads would function after passing through a more demanding ICBM environment.

¹⁵ The minimum explosive charge required for detonation of IHE is greater than 4 ounces of TNT, whereas the minimum velocity required for detonation by a projectile is approximately 1,000 meters per second (Harvey and Michalowski 1994). In comparison, the U.S. MK3A2 hand grenade has an explosive power of 8 ounces of TNT (Department of the Army 2009). There are several rifle/bullet combinations that provide a bullet speed of greater than 1,000 meters per second at a distance of up to 150 meters (Hornady n.d.).

New designs could reduce technical confidence in the resulting weapons.

Despite the stated goal of acquiring an all-IHE SLBM force, the W76 LEP now under way is a straightforward refurbishment and the W76-1 will retain the conventional high explosive. The NNSA did not use the opportunity of the LEP to replace the W76 with a warhead containing IHE. Indeed, the Navy has expressed concerns that changing the design of a weapon to add IHE would introduce uncertainty about the weapon's reliability (GAO 2013).

The Problem of Mix-and-Match Warheads

The NNSA's 3+2 plan for the interoperable warheads is to build "mix and match" warheads, in which the primary would be from one previously tested warhead design, and the secondary would be from a different previously tested warhead design. The new combined warhead design, however, will not undergo nuclear explosive testing.

In this respect, the 3+2 program is reminiscent of the 2005 Reliable Replacement Warhead (RRW) program, which envisioned a future arsenal based on a suite of new warheads that would nominally be more reliable and would incorporate advanced safety and security features. The first RRW would have been based on a nuclear explosive package that had been tested but never deployed. However, another proposed design incorporated a primary from one warhead with a secondary from another. The NNSA argued that experimental and computational simulation capabilities had improved to the point that the NNSA would have sufficient confidence to deploy the new warheads without nuclear explosive tests to confirm that they would work as intended.

After providing low levels of funding for several years, Congress eventually saw the RRW program as overly ambitious and much more expensive than anticipated, and eliminated funding for it in 2009. The Obama administration canceled the

program in 2010. Part of the administration's rationale was that the RRW program would have created an "entirely different" warhead, and the administration did "not foresee any reason to have a new warhead" (DOD 2010b).

However, the administration has apparently changed its mind. While the NNSA plans to use only components that have previously undergone nuclear explosive testing, mixing and matching primaries and secondaries that have never been tested together would result in a design that would be "new" in anything but the narrowest semantic sense (see box on page 5).

New designs could also reduce technical confidence in the resulting weapons. As noted above, the Navy has expressed concerns that using newly-designed warheads would introduce uncertainty. Indeed, the JASON independent advisory group of scientists that advises the government on defense and other policy issues has long warned that the "... greatest care in the form of self-discipline will be required to avoid system modifications, even if aimed at 'improvements,' which may compromise reliability" (Drell et al. 1995).

Ultimately, such uncertainty could lead some to argue that the United States needs to "proof test" the new designs through underground nuclear explosive testing. If the United States did resume nuclear testing, it would encourage a resumption of testing by other nations and could lead to the collapse of the Nuclear Non-Proliferation Treaty.

Weapons Designers and the 3+2 Plan

Some have argued that extending the life of existing warhead types will not allow weapons designers to develop their skills and will make it more difficult to attract and retain high-caliber scientists as weapons designers (AAAS and UCS 2015). However, assuming such a problem exists, it could be addressed by having designers design new weapons even if the United States did not plan to build any new ones. While the United States has not produced a new weapon type in 25 years,¹⁶ during that time, designers have designed several new weapons, including two for the RRW program. They have also designed new weapons to allow the United States to better understand the nuclear weapons capabilities of other countries.

¹⁶ The newest weapon type is the W88, and it entered the arsenal in 1989.

Conclusion and Recommendations

The NNSA's 3+2 plan has three main goals: reducing the hedge, reducing costs, and transitioning to an all-IHE force.

Reducing the Hedge. One reason the NNSA wants to reduce the hedge is to achieve a smaller overall stockpile that would be more in line with U.S. international security obligations. We strongly endorse such an action. However, the United States can—and should—make a substantial reduction in the strategic hedge without pursuing the 3+2 plan.

The current strategic hedge of 2,400 warheads is twice the technical hedge required for a New START-sized arsenal with existing warhead types. The United States should cut its strategic hedge in half once it gains confidence in the W76-1 warhead and can retire the excess W76-0 warheads.

Pursuing the 3+2 plan would further reduce the required technical strategic hedge from 1,250 to 1,000 warheads for a New START-sized arsenal—a modest reduction of 20 percent.

The United States should cut its strategic hedge in half once it gains confidence in the W76-1 warhead and can retire the excess W76-0 warheads.

As the nuclear arsenal is reduced further, the 3+2 plan would allow deeper reductions in the hedge. However, the goal of reducing the hedge by 50 percent can be met only if the air-based weapons are eliminated.

Building the IW-1 and IW-2 would provide an intra-leg hedge for the W76 warhead; IW-3 is unnecessary to achieve this objective. Currently, if the W76 failed, the United States could upload ICBM warheads and deploy additional air-delivered cruise missiles and bombs. However, as the arsenal is reduced below New START levels, some W88s could be made available for the W76 hedge. More fundamentally, providing an intra-leg hedge for the W76 may be unimportant since the United States also deploys a second type of SLBM warhead and two types of ICBM warheads.

Indeed, the United States should reassess its current practice of maintaining a technical hedge as well as deploying two types of warheads per delivery system and two types of ballistic missile delivery systems; employing all three hedging strategies should not be necessary. It should also reconsider the need to guard against technological surprise in the first place. The failure of an entire class of weapons is highly unlikely—at least for existing weapons, which have undergone nuclear explosive testing. The United States should quantify the odds of such a failure since a revision of this policy could obviate the need for both a technical hedge and for deploying two kinds of weapons per delivery system.

Neither Britain nor France worries about technical failure. Britain deploys one type of nuclear weapon on submarines; France deploys one type on aircraft and is moving from one type of submarine-based warhead to another. Neither country maintains a hedge.

Instead of pursuing the 3+2 plan and building new warheads, the United States should refurbish or retire existing weapons.

Reducing Costs. The NNSA has said its plan will lead to cost savings by reducing the hedge and the number of warhead types that need to undergo life extension programs.

In its FY15 SSMP, the NNSA estimates that building IW-1 and IW-2 rather than extending the lives of the W78, W87, and W88 would result in savings of \$3 to \$19 billion. The NNSA did not do a cost comparison in its FY16 SSMP. However, the estimated costs for the 3+2 plan in the FY16 SSMP are significantly greater than those in the FY15 SSMP. Using these values, the cost of building the IW-1 and IW-2 could be as much as \$7 billion *greater* than that of conducting LEPs for the W78, W87, and W88.

Moreover, these savings are an overestimate for the 3+2 program since the cost comparison did not include the IW-3 and the next W76 LEP; designing and producing the IW-3 would almost certainly be more expensive than a refurbishment of the W76-1. Also, building interoperable warheads instead of refurbishing existing ones would necessitate additional flight testing, which is an additional expense that the Defense Department would have to cover.

Thus, there is no reason to believe that building new weapons under the 3+2 plan would be less expensive than

refurbishing existing weapons. In any event, the NNSA should do a thorough assessment of the full costs of pursuing the 3+2 plan and compare it to the costs of conducting life extension programs for the weapons remaining in the arsenal.

Adding Insensitive High Explosive. The NNSA's goal of reducing the risk of accidental plutonium dispersal by transitioning to an all-IHE stockpile is worthwhile. It would benefit the safety of the public as well as those who work with nuclear weapons. However, doing so would likely require building new mix-and-match warheads—as the NNSA plans to do as part of the 3+2 plan.

Technical and Political Costs. The 3+2 plan entails technical risks and political costs. Deploying new warhead types undermines the most fundamental goals of the stockpile stewardship program by increasing uncertainty about the reliability of the resulting warhead. That uncertainty could lead some political and military leaders to argue that nuclear “proof testing” is necessary to demonstrate that such weapons will work as intended, and that therefore the United States needs to resume nuclear testing.

Building new types of warheads also is contrary to one of the key goals of the Comprehensive Test-Ban Treaty, and undermines the Nuclear Non-Proliferation Treaty regime. Finally, it is counter to the administration's commitment, as expressed in its 2010 Nuclear Posture Review, to reducing the salience of nuclear weapons.

The Bottom Line. Instead of pursuing the 3+2 plan and building new warheads, the United States should refurbish or retire existing weapons.

[APPENDIX A]

A nuclear force with two warhead types that can substitute for each other will have a technical hedge equal to the size of the deployed force (see Table A-1), whereas a force with three warhead types deployed in equal numbers will have a technical hedge equal to half of the deployed force (see Table A-2). By building three warhead types for submarine-launched ballistic missiles (SLBMs) and three for inter-continental ballistic missiles (ICBMs), the technical

hedge would be half of the deployed ICBM and SLBM warheads.

If the deployed force had three warhead types, but they were not deployed in equal numbers, then the size of the technical hedge would be between 50 percent and 100 percent of the deployed force. For example, if the ratio of deployed forces is 1:2:3, the hedge will be two-thirds of the deployed force (see Table A-3).

TABLE A-1. Hypothetical Force with Two Warhead Types (Wa and Wb)

	Deployed Warheads	Technical Hedge
	100 Wa	100 Wb
	200 Wb	200 Wa
Total	300	300

For a force with two warhead types, the number of warheads in the hedge will equal the number deployed.

TABLE A-2. Hypothetical Force with Three Warhead Types (Wa, Wb, and Wc) Deployed in Equal Numbers

	Deployed Warheads	Technical Hedge	Notes
	100 Wa	50 Wb + 50 Wc	
	100 Wb	50 Wa + 50 Wc	
	100 Wc	50 Wa + 50 Wb	
Total	300	150 (50 Wa + 50 Wb + 50 Wc)	Since we assume that only one warhead type will fail at a time, the hedge needs to include only 50 each of Wa, Wb, and Wc.

For a force with three warhead types deployed in equal numbers, the number of warheads in the hedge will be half of the number deployed.

TABLE A-3. Hypothetical Force with Three Warhead Types (Wa, Wb, and Wc) Deployed in Unequal Numbers

	Deployed Warheads	Technical Hedge	Notes
	50 Wa	25 Wb + 25 Wc	
	100 Wb	50 Wa + 50 Wc	
	150 Wc	75 Wa + 75 Wb	
Total	300	200 (75 Wa + 75 Wb + 50 Wc)	Since we assume that only one warhead type will fail at a time, the hedge needs to include 75 each of Wa and Wb, and 50 Wc.

For a force with three warhead types deployed in unequal numbers, the number of warheads in the hedge will be less than the number of deployed warheads but greater than half of the deployed warheads. In the case shown here, there are 300 deployed warheads and a hedge of 200 warheads.

[APPENDIX B]

For a New Strategic Arms Reduction Treaty (New START)-sized arsenal with current warhead types, Table B-1 shows that the technical hedge would need to include 1,250 warheads to provide replacements if one type of warhead failed.

Note that the United States currently deploys 100 strategic B61 and B83 bombs and has a total of 500, so up to 400 additional bombs are in the hedge and available for deployment. However, the entire B-2 fleet of 19 aircraft can carry only 304 bombs, and the 16 aircraft on day-to-day deployment can carry only 256 bombs, leaving room for deployment of only an additional 156 to 204 bombs. Thus, we will assume that the United States will deploy 75 B61 bombs under New START, leaving room for an additional 175. These will serve as the hedge for the 175 W80 warheads.

Also note that the United States has a total of 500 cruise missiles and deploys 200, leaving up to 300 cruise missiles that could be deployed; the B-52 fleet can carry 820 cruise missiles, allowing deployment of the additional 300.

Thus, to provide a hedge for the 700 deployed W76 SLBM warheads, the United States could add another two

W78 inter-continental ballistic missile (ICBM) warheads onto each of the 150 ICBMs armed with the W78, and deploy 175 additional B61 bombs and 225 additional W80 ALCMs.

The inter-leg hedge would therefore consist of 700 warheads.

Deploying the first interoperable warhead (IW-1) to replace all the W78 ICBM warheads and half of the W88 SLBM warheads, as currently planned, would result in a technical hedge of either 1,050 or 1,300 warheads—depending on how the hedge is configured (see Table B-2, p. 22).

A fully interoperable warhead would be able to serve as a hedge for both the W87 ICBM warhead and the W76 SLBM warhead, assuming that only one type would fail at any given time. However, the IW-1 will not be fully interoperable. Rather, it will have two variants—one for ICBMs and one for SLBMs—that will have different non-nuclear components. Only the nuclear explosive package (NEP) will be interoperable. Thus, the hedge

TABLE B-1. Nominal Strategic Arsenal under New START with Current Warhead Types

	Deployed	Technical Hedge	Notes
	150 W78 (ICBM)	150 W87 (ICBM)	
	250 W87 (ICBM)	250 W78 (ICBM)	
	700 W76 (SLBM)	300 W78 (ICBM) + 225 W80 (ALCM) + 175 B61	If the W76 developed a problem, the U.S. could compensate by uploading an additional two W78 warheads on each of the 150 ICBMs armed with the W78 warhead, and deploying 175 more B61 bombs and 225 more W80 ALCMs
	400 W88 (SLBM)	400 W76 (SLBM)	
	75 B61	75 W80 (ALCM)	
	175 W80 (ALCM)	175 B61	
TOTAL	1,750	1,250 = 150 W87 + 300 W78 + 400 W76 + 225 W80 + 175 B61	To avoid double counting, note that the weapons in the W76 hedge are adequate to also serve as the hedge for the W87, W80, and B61.

The technical hedge required for a New START-sized arsenal is roughly half that of the current strategic hedge.

TABLE B-2. Nominal Strategic Arsenal under New START with IW-1 Replacing All W78 and Half of W88 Warheads

	Deployed	Technical Hedge	Notes
	150 IW-1 (ICBM)	150 W87 (ICBM)	
	250 W87 (ICBM)	250 IW-1 (ICBM)	
	700 W76 (SLBM)	400 IW-1 (SLBM) + 125 W80 + 175 B61	There are several ways to configure the W76 hedge. For example, the United States could build more IW-1s to allow a hedge of 700 IW-1s. Since fully implementing the 3+2 plan would entail building 750 IW-1s (see Table B-4), we assume a total of 750 IW-1s (350 deployed and 400 in the hedge) here as well.
	200 W88 (SLBM)	200 W76 (SLBM)	
	200 IW-1 (SLBM)	200 W76 (SLBM)	
	75 B61	75 W80	
	175 W80	175 B61	
TOTAL	1,750	1,050 = 150 W87 + 200 W76 + 400 IW-1 NEPs + 125 W80 + 175 B61 1,300 = 150 W87 + 200 W76 + 250 IW-1 (ICBM) + 400 IW-1 (SLBM) + 125 W80 + 175 B61	The IW-1 will have two variants—one for SLBMs and one for ICBMs. The hedge could consist of 400 IW-1 NEPs that would be assembled into warheads only if needed, or of 650 IW-1 warheads: 400 for SLBMs and 250 for ICBMs. In the former case, the hedge would be 1,050 warheads and NEPs; in the latter case, it would be 1,300 warheads.

Because the IWs are not truly interoperable, the size of the technical hedge will depend on how it is configured. The hedge will decrease only if it consists of separate NEPs and non-nuclear components that would only be assembled if needed.

could consist of 400 IW-1 NEPs, 400 Navy component sets, and 250 Air Force component sets; the warheads would be assembled only if needed to replace a weapon in the deployed arsenal. This scenario would require building a total of 750 IW-1 NEPs—350 for the deployed arsenal and 400 for the hedge. Alternatively, the hedge could consist of 650 IW-1 warheads: 400 SLBM versions and 250 ICBM versions. This case would entail building 1,000 IW-1s, and the hedge would be 1,300 weapons. In either case, the inter-leg hedge would be reduced to 300 warheads.

Adding a second interoperable warhead to replace the W87 and remaining W88 warheads would result in a technical hedge of either 1,050 or 1,350 warheads—again depending on the way the hedge is configured (see Table B-3). The hedge could include 350 IW-1 NEPs, 350 IW-2 NEPs, 350 Navy IW-1 component sets, 350 Navy IW-2 component sets, 200 Air Force IW-1 component sets, and 200 Air Force IW-2 component sets; the warheads would be assembled only if needed to replace a weapon in the deployed arsenal. This scenario would require building 750 IW-1 NEPs and 750 IW-2 NEPs—400 for the deployed arsenal and 350 for the hedge. Alternatively, the hedge could include 550 IW-1 and 550 IW-2

warheads, with 350 SLBM versions and 200 ICBM versions for IW-1 and for IW-2. This case would entail building 950 IW-1s and 950 IW-2s, and the total technical hedge would be 1,350 weapons. In either case, there would only be intra-leg hedging.

If the United States replaced the W76 with a third interoperable warhead and deployed equal numbers of the three interoperable warheads, the technical hedge would be 1,000—whether or not the three IWs were truly interoperable (see Table B-4).^{*} In this case, there would only be intra-leg hedging. This option would require building 750 of each interoperable warhead—550 for the SLBM leg, and 200 for the ICBM leg.

In sum, if the United States maintains current warhead types by refurbishing existing weapons rather than pursuing the 3+2 plan, the total strategic technical hedge would be 1,250 warheads for a New START-sized arsenal. The technical hedge could be further reduced by a modest amount—to 1,050—by building one interoperable warhead, in the scenario where the hedge consists of NEPs and separate Navy and Air Force component sets that would only be assembled if needed. Under this scenario, adding a second IW would not allow

^{*} *If the three warheads were not deployed in equal numbers, the hedge would be greater than 1,000 (see Appendix A, p. 20).*

TABLE B-3. Nominal Strategic Arsenal under New START with IW-1 and IW-2 Replacing All W78, W88, and W87 Warheads

	Deployed	Technical Hedge	Notes
	200 IW-1 (ICBM)	200 IW-2 (ICBM)	
	200 IW-2 (ICBM)	200 IW-1 (ICBM)	
	200 IW-1 (SLBM)	200 IW-2 (SLBM)	
	200 IW-2 (SLBM)	200 IW-1 (SLBM)	
	700 W76 (SLBM)	350 IW-1 (SLBM) + 350 IW-2 (SLBM)	
	75 B61	75 W80	
	175 W80	175 B61	
TOTAL	1,750	1,050 = 400 IW-1 NEPs + 400 IW-2 NEPs + 75 W80 + 175 B61 1,350 = 200 IW-1 (ICBM) + 200 IW-2 (ICBM) + 350 IW-1 (SLBM) + 350 IW-2 (SLBM) + 75 W80 + 175 B61	The IW-1 and IW-2 will each have two variants—one for SLBMs and one for ICBMs. The hedge could consist of 400 IW-1 and 400 IW-2 NEPs that would be assembled into warheads only if needed, or of 550 IW-1 warheads (350 for SLBMs and 200 for ICBMs) and 550 IW-2 warheads (350 for SLBMs and 200 for ICBMs). In the former case, the hedge would be 1,050 warheads and NEPs; in the latter case, it would be 1,350 warheads.

Because the IWs are not truly interoperable, the size of the technical hedge will depend on how it is configured. The hedge will decrease only if it consists of separate NEPs and non-nuclear components that would only be assembled if needed.

TABLE B-4. Nominal Strategic Arsenal under New START with IW-1, IW-2, and IW-3 Deployed in Equal Numbers

	Deployed	Technical Hedge
	135 IW-1 (ICBM)	67 IW-2 (ICBM) + 68 IW-3 (ICBM)
	135 IW-2 (ICBM)	67 IW-3 (ICBM) + 68 IW-1 (ICBM)
	135 IW-3 (ICBM)	67 IW-1 (ICBM) + 68 IW-2 (ICBM)
	365 IW-1 (SLBM)	183 IW-2 (SLBM) + 182 IW-3 (SLBM)
	365 IW-2 (SLBM)	183 IW-3 (SLBM) + 182 IW-1 (SLBM)
	365 IW-3 (SLBM)	183 IW-1 (SLBM) + 182 IW-2 (SLBM)
	75 B61	75 W80
	175 W80	175 B61
TOTAL	1,750	1,000 = 67 IW-1 (ICBM) + 183 IW-1 (SLBM) + 67 IW-2 (ICBM) + 183 IW-2 (SLBM) + 67 IW-3 (ICBM) + 183 IW-3 (SLBM) + 75 W80 + 175 B61

If all three IWs are deployed, the required technical hedge will be 1,000—20 percent lower than the hedge of 1,250 that would be required if the ballistic missile warheads instead undergo life extension programs.

TABLE B-5. Smaller Strategic Arsenal with Current Warhead Types

	Deployed	Technical Hedge	Notes
	75 W78 (ICBM)	75 W87 (ICBM)	
	125 W87 (ICBM)	125 W78 (ICBM)	
	350 W76 (SLBM)	200 W88 (SLBM) + 150 W78 (ICBM)	If the W76 developed a problem, the U.S. could compensate by uploading an additional two W78 warheads on each of the 75 ICBMs armed with the W78 warhead.
	200 W88 (SLBM)	200 W76 (SLBM)	
	50 B61	50 W80 (ALCM)	
	100 W80 (ALCM)	100 B61	
TOTAL	900	775 = 75 W87 + 150 W78 + 200 W88 + 200 W76 + 50 W80 + 100 B61	

In this scenario, deploying three IWs instead of extending the life of current warhead types would reduce the hedge from 775 to 525—a one-third reduction.

further reductions in the hedge, and a third IW would reduce it by only another 50 warheads. Thus, if the goal is reducing the hedge, IW-2 and IW-3 are not very useful under this scenario.

Moreover, if the goal is also to create a hedge that does not rely on inter-leg hedging, adding a third interoperable warhead is unnecessary, since building two interoperable warheads would allow only intra-leg hedging. Therefore, it would make no sense to produce a third interoperable warhead rather than simply extend the life of the W76-1.

If the hedge instead included fully assembled ballistic missile warheads, then all three IWs would be needed to reduce the technical hedge to 1,000.

How would these numbers change if the United States makes further reductions in its arsenal below New START levels? Table B-5 shows a nominal strategic arsenal with deployed forces equal to half New START levels. It has a technical hedge of 775 weapons. Because only 200 W88s are deployed, the remaining 200 can serve as a partial hedge for the W76, with the remaining hedge consisting of uploaded W78 ICBM warheads.

If the 3+2 plan were implemented and there were three warhead types for each of the ICBM and SLBM forces, for a deployed force of 900 strategic weapons, the technical hedge would be 525 weapons instead of 775—a one-third reduction.

If the United States made deeper reductions and cut the deployed SLBM force to 200 W76 and 200 W88 warheads, then there could be all intra-leg hedging. If, for example, the deployed force totaled 600 weapons (see Table B-6), then the

technical hedge would be 600. Under the 3+2 plan, the technical hedge would be 350 rather than 600—a reduction of 42%. Thus, as the arsenal is reduced, the 3+2 plan allows deeper reductions in the hedge. However, because there would be only two types of air-based weapons, the goal of reducing the hedge by 50 percent can be met only if the air-based weapons are eliminated.

TABLE B-6. Even Smaller Strategic Arsenal with Current Warhead Types

	Deployed	Technical Hedge
	50 W78 (ICBM)	50 W87 (ICBM)
	50 W87 (ICBM)	50 W78 (ICBM)
	200 W76 (SLBM)	200 W88 (SLBM)
	200 W88 (SLBM)	200 W76 (SLBM)
	50 B61	50 W80 (ALCM)
	50 W80 (ALCM)	50 B61
Total	600	600

In this scenario, deploying three IWs instead of extending the life of current warhead types would reduce the hedge from 600 to 350—a reduction of 42 percent.

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Bad Math on New Nuclear Weapons

The Costs of the 3+2 Plan Outweigh Its Benefits

Instead of pursuing the 3+2 plan and building new warheads, the United States should refurbish or retire existing weapons.

The United States has an ambitious plan—dubbed “3+2”—for the future of its nuclear arsenal that entails building several new types of nuclear warheads for deployment on land- and submarine-based ballistic missiles.

The Obama administration has several goals for its 3+2 plan: (1) reducing by up to 50 percent the size of the “hedge” force of nuclear weapons that are kept in reserve in addition to the weapons deployed; (2) reducing the cost of maintaining the stockpile of nuclear warheads; and (3) improving the safety of the warheads.

We find that the United States can—and should—reduce its strategic hedge by a factor of two even without pursuing the 3+2 plan. For a New START-sized arsenal, the 3+2 plan would allow a further reduction of 20 percent, but only after several decades. The 3+2 plan would offer some safety benefits by reducing the risk of accidental plutonium dispersal for some weapons. However, there is no reason to believe that 3+2 would be less expensive than refurbishing existing weapons; indeed, it may actually be a more expensive approach.

Moreover, pursuing the 3+2 plan would entail technical risks and political costs. The new warheads would use nuclear components that had never been tested together, and deploying such a warhead without nuclear explosive testing could increase uncertainty about the reliability of the warhead.

Concern about warhead reliability may lead some political and military leaders to argue that the United States needs to resume nuclear testing to demonstrate that the weapons would work as intended. If the United States did resume testing, it could encourage a resumption of testing by other nuclear-armed nations, ending an international moratorium that benefits U.S. security. But even absent a resumption of nuclear testing, building new warhead types could send the wrong message to the rest of the world.

On balance, we assess that the costs of the 3+2 plan outweigh the benefits. Instead of pursuing the 3+2 plan and building new warheads, the United States should refurbish or retire existing weapons.

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