Summary Report: Workshop on the Future of the U.S. Nuclear Arsenal

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AAAS

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Introduction

On September 12, 2014, the Center for Science, Technology, and Security Policy at the American Association for the Advancement of Science (AAAS) and the Union of Concerned Scientists (UCS) hosted a workshop to discuss the future of the U.S. nuclear arsenal. The meeting was unclassified and off the record. To allow free discussion, it was carried out under the Chatham House Rule under which statements made during the meeting (such as those reported here) can be cited but not attributed to individual speakers.

In addition to those from the sponsoring organizations, workshop participants included active and retired scientists and engineers from Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories; representatives from the National Nuclear Security Administration (NNSA), the Department of Defense (DOD), and the Office of Management and Budget; independent scientists who are members of the JASON panel that advises the government on nuclear weapons and other security issues; and experts from non-governmental organizations and academia.

While this report sometimes characterizes views as being held by groups of participants for the sake of simplicity and to avoid identifying individual speakers, participants' opinions did not fall into simple, easily separable categories.

Key Findings

- There was broad agreement among participants that more work must be done to assess the financial costs of the Department of Energy's (DOE) 3+2 warhead plan and the alternatives. Some participants believed that eventual savings were likely, some believed that savings were possible under certain circumstances, and others believed savings were unlikely ever to be realized. However, the consensus was that better understanding of the potential costs requires a more detailed assessment that takes into account both DOE and DOD expenditures.
- There was agreement that using insensitive high explosives (IHE) in U.S. nuclear weapons would be beneficial, but not on how great a benefit it would convey.
- There was agreement that reducing the hedge would be beneficial, but not on the need for 3+2 to make hedge reductions.
- The current arsenal does not allow intra-leg hedging for the W76 submarine-based warhead. If a problem arose with this warhead, there are no other submarine-launched ballistic missile (SLBM) warheads in the hedge to replace it, as the W88s are fully deployed. To compensate, the United States could upload additional inter-continental ballistic missile (ICBM) warheads, and deploy more bombs and air-launched cruise missiles. This situation would change if the 3+2 plan was implemented. Under 3+2, the United States would build equal numbers of three different warheads for SLBMs, which would allow intra-leg hedging for the SLBMs. However, there was no agreement on the value of moving from inter-leg to intra-leg hedging.
- There was no agreement on either the technical risks or political downsides of designing and producing warheads with components that had not previously been explosively tested together.
- The specific requirements for the existence and size of a technical hedge are not publicly understood, and were debated by the participants. For example, there was disagreement over the likelihood of the failure of one warhead type, as well as whether the technical

> hedge needs to provide replacement warheads that meet all the targeting criteria of currently deployed warheads. There was a suggestion that a technical analysis of this issue would be useful, and could be conducted by experts from the weapons labs.

Background

U.S. national strategic policy for nuclear weapons has been clearly formulated. According to President Obama's 2009 Prague speech, the United States "will take concrete steps towards a world without nuclear weapons," but also, for "[a]s long as these weapons exist, the United States will maintain a safe, secure, and effective arsenal to deter any adversary, and guarantee that defense to our allies…"

National Security Presidential Directive 28, issued in June 2003, states that the United States will:

> Conduct research and development on a broad range of safety, security, reliability, and control methods and devices for nuclear warheads and weapon systems, including use control, and delay and denial capabilities. As a long-term goal, pursue technologies that render the unauthorized use of U.S. nuclear weapons impossible without their remanufacture.

According to the NNSA, this directive requires the adoption of such technologies when they are identified, although this obligation is subject to cost and practicality as well. The NNSA's primary focus in response to this directive is on transitioning to a stockpile in which all weapons use insensitive high explosive (IHE), which is less likely to explode as a result of an accident or an attack than is the conventional high explosive (CHE) used in several current weapons types.

The 3+2 Plan

The NNSA's 3+2 proposal is the plan of record for the future of the U.S. nuclear stockpile. The plan calls for three interoperable ballistic missile warheads deployed (with some modifications) on both the submarine-launched ballistic missile (SLBM) and intercontinental ballistic missile (ICBM) legs of the triad, and two interoperable air-delivered warheads or bombs. Hence "3+2." These would replace the existing seven (twelve accounting for five B61 variants) types of warheads in the current stockpile. The 3+2 plan will not be fully realized for at least 40 to 50 years.

REDUCING THE HEDGE

One of the benefits the NNSA cites for 3+2 is a reduction in the "hedge"—the reserve stockpile of warheads the United States maintains in addition to the deployed arsenal. These hedge warheads can be uploaded relatively quickly in response to a problem with existing warheads (technical surprise) or changes in the international security situation (geopolitical surprise). The number of warheads in the U.S. hedge is classified, and it is not publicly known how the size of the hedge is derived.

According to the June 2013 U.S. Nuclear Employment Strategy,[1] "a non-deployed hedge that is sized and ready to address…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." However, there was disagreement among participants about whether this was applicable to the current hedge or would apply only after the 3+2 plan is fully implemented.

Public estimates put the current number of hedge warheads at roughly 2,400, compared to about 2,300 deployed warheads. If these numbers are correct, the hedge appears slightly larger than needed if the goal is to be able to replace all deployed warheads on a 1-to-1 basis.

According to the NNSA, the current ratio of warheads in the technical hedge to deployed warheads is greater than 1:1. Some participants stated that the United States is extending the life of only half the W76 warheads, and that the remaining W76 warheads will be kept in the hedge until the Navy gains confi-

[1] Available at http://www.defense.gov/pubs/ReporttoCongressonUSNuclearEmploymentStrategy_Section491.pdf

dence in the life-extended version, known as the W76-1. Only then will the original excess W76 warheads be retired and the technical hedge reduced.

If that is the case, once the excess W76 warheads are retired, the number of warheads in the technical hedge will be less than the number of deployed warheads because there are no other SLBM warheads to hedge for the W76. Instead, if there was a technical problem with the W76 warhead, the United States could upload warheads on ICBMs and/or add air-launched cruise missiles and bombs to substitute for the W76 warheads.

Some participants argued that such inter-leg hedging, between two legs of the triad, was less than ideal because it did not allow holding all the same targets at risk. They believed that the goal should be intra-leg hedging, in which there would be enough reserve warheads within each leg of the triad to hedge for deployed warheads within that same leg. Others disputed the idea that it was necessary to have a perfect replacement within the same leg for each deployed warhead, arguing that this has not been the case for the last several decades, and there is no reason to believe it is necessary now.

The NNSA also states that interoperability, when fully implemented, could lead to up to a 50 percent reduction in the size of the technical hedge. (Recall that the 3+2 stockpile would not be fully in place for 40-50 years.) There was significant debate among participants on this point. Some noted that although the 3+2 plan could eventually allow the technical hedge to shrink substantially, this was due not to interoperability, but to the fact that the plan calls for three warheads each on the land- and sea-based legs of the triad.[2] Whether or not these warheads were interoperable would be irrelevant to the ability to decrease the size of the hedge.

Some participants also pointed out that the only truly interoperable component of the planned warheads will be the nuclear explosive package (NEP). In the FY 2014 Stockpile Stewardship and Management Plan, the NNSA describes the plan as "three interoperable nuclear explosive packages with adaptable non-nuclear components." Outside of the NEP, the ICBM and SLBM warheads would have substantial overlap in components, but it would not be possible to simply put an ICBM warhead on an SLBM or vice versa, so the warheads as a whole would not truly be interoperable. In other words, the ICBM and SLBM legs of the triad would each have three warhead types. Therefore, in terms of the number of weapon types in the stockpile, it would be more accurate to call the NNSA's plan "6+2" (or "6+4," depending on whether the bomb and cruise missile warheads were truly interoperable).

Most participants agreed that a clear explanation of how the 3+2 plan would affect the hedge and the timelines for that change would be beneficial in deciding the overall value of the approach.

REDUCING THE NUMBER OF WEAPON TYPES

The NNSA states that, when completed, the 3+2 plan will reduce the number of warhead types in the U.S. arsenal from 12 (five of which are variants of the B61 bomb) to five.

When the B61-12 life extension program is completed and the B61-11 earth penetrator weapon is eventually retired, the number of warhead types in the arsenal will drop from 12 to seven. Retiring the B83 bomb, a move that has long been planned but more recently has been linked to the completion of the B61-12, will reduce the number of types to six.

The first interoperable warhead (IW-1) is planned to replace only half of the W88 SLBM warheads currently in the arsenal, so its deployment will not further reduce the number of warhead types. (If reducing the number of warhead types in the arsenal more quickly were a priority, all W88s could be replaced by the IW-1, reducing the number of types to five.) The second interoperable warhead (IW-2), which would replace the remaining W88 warheads, would reduce the number of warhead types in the arsenal to five. The third interoperable warhead (IW-3), howev-

[2] For any triad leg, if there are two warhead types then the size of the technical hedge will equal that of the deployed arsenal (assuming enough warheads are available for the hedge; otherwise the technical hedge will be less than the deployed arsenal). If there are equal numbers of three warhead types, then the technical hedge will be half of the deployed arsenal.

er, would simply replace the W76-1, and therefore would not lead to a further reduction in the number of warhead types.

However, if 3+2 is really 6+2 (or 6+4), then the number of warhead types will ultimately be eight (or ten), not five.

REDUCING COSTS

There was substantial debate among participants about the effect that the 3+2 plan would have on costs.[3] The 3+2 plan would reduce the number of warhead types remaining in the stockpile and thus the number of life extension programs that would need to be carried out, and it would reduce the number of weapons in the hedge and thus the number of weapons that would need to be life-extended.

The participants discussed the cost estimates for the plan from the NNSA's FY 2014 and FY 2015 Stockpile Stewardship and Management Plans (SSMP). Estimates for several of the 3+2 elements in the FY 2015 SSMP are significantly lower than estimates for the same elements in the FY 2014 plan. The FY 2015 SSMP states that the lower estimates are primarily due to unspecified "improvements in the cost models for future life extensions." The FY 2015 SSMP also states that, compared with the previous plan described in the FY 2011 SSMP, 3+2 would reduce costs by between $11 billion and $28 billion (in FY 2014 dollars) over the next 25 years. However, some participants pointed out that the FY 2011 SSMP includes the cost of a life extension program for the B83 bomb, estimating it at $7.5 to $9.5 billion. The FY 2015 SSMP does not include the cost of a B83 life extension program (LEP) because that weapon will be retired. When the B83 LEP cost is eliminated from the FY 2011 SSMP numbers, the net savings for 3+2, according to the FY 2015 SSMP numbers, would be between $2 billion and $21 billion. However, 3+2 would result in a cost increase if the costs given in the FY 2014 SSMP were used instead of those in the FY 2015 SSMP.

Moreover, none of the NNSA estimates takes into account additional costs for the 3+2 program that would be borne by the DOD, such as costs for systems integration and flight testing, which could be substantial.

Participants disagreed over whether the 3+2 plan would ultimately be more or less expensive than continuing to carry out life extension programs on existing weapons. Some participants suggested that publicly available data on previous life extension programs and budget estimates does not support the claim that 3+2 will lower costs. The W76 LEP was a straightforward refurbishment program that encountered a significant technical problem when it was initially unable to produce a material known as "Fogbank" that was used in the original weapons. Despite delays and cost increases associated with resolving this problem, the cost for the W76 LEP will be roughly $4.5 billion. If 1,600 warheads are updated, that cost would be $2 million per warhead. Estimates for the B61 LEP, a more ambitious program that has not yet begun production, are in the range of $8-10 billion for 400 bombs, or $20-25 million per warhead—a ten-fold increase even before production has begun.

Since interoperable warheads may be even more technically difficult to produce than the B61 LEP, some participants argued that they would inevitably be more expensive. However, others felt that it could be technically less demanding to build a new interoperable warhead using a relatively simple design rather than to continue trying to recreate existing warheads, which may have more complex designs or require materials that are difficult to replicate. If so, interoperable warheads may actually be cheaper to build. However, one participant noted that a recent DOD study of interoperability in complex systems found that if the requirements for the systems did not match to at least 85 percent, then interoperability makes the systems more expensive and sometimes significantly so.

Some participants argued that the DOD costs of conducting flight tests on two different reentry vehicles could overwhelm any savings from a reduced number of warhead types. Others argued that this

[3] In its FY 2015 Stockpile Stewardship and Management Plan, the NNSA states that the plan would decrease costs to maintain the stockpile in the long run. However, the FY 2016 Stockpile Stewardship and Management Plan, released in March 2015, does not claim that the 3+2 plan would decrease long-term costs.

might not be true, because a large portion of the cost comes from the design and development of the warhead itself, and it is not clear that two completely separate sets of flight tests would be needed, even if a warhead was to be used with both land-based and submarine-launched ballistic missiles. For example, some flight tests could simulate the extremes of both stockpile-to-target sequences at once, so they would not need to be duplicated. The question was raised, however, whether the military services would accept these results rather than doing their own testing for the factors they were most concerned about.

Participants also disagreed about whether it would be necessary to produce additional pits, and at what level. Some argued that if the United States simply continued to refurbish existing warheads as has happened to date, no pit production would be needed. Others disagreed, saying that eventually all pits would need to be replaced because of concerns about aging. Current U.S. policy is to assume that pits have a lifetime of 85 years, so there is a need to begin replacing them soon given expected production rates of no more than 50-80 pits per year.

However, plutonium aging experiments as of several years ago found that pits had a *minimum* lifetime of 85 years, and further research could show that the minimum lifetime is greater than this. One participant noted that the plutonium aging experiments at Los Alamos are no longer being funded.

Finally, some participants noted that potential future reductions in the size of the arsenal should also be taken into account when assessing long-term costs. Other participants argued that even if the arsenal shrank, 80 percent of the cost of a program is for research and development. In this case, building fewer weapons of any given type would not do much to reduce costs; in this notional example, building half the planned number of weapons would save only 10%. The only way to significantly reduce costs would be to have fewer types of weapons. However, in the budgets presented in NNSA's annual SSMP, the cost for the first weapon in a class is roughly 50 percent of the total program cost, not 80 percent. Thus, building half as many weapons of one type would result in a 25 percent cost savings.

Participants agreed that there was not enough information available to determine whether 3+2 would result in cost savings or cost increases, and that it would be useful to have a full study of the DOD and DOE expenditures associated with the 3+2 plan.

ENHANCING SAFETY

The NNSA's primary approach for enhancing safety throughout the stockpile is to move to a stockpile in which all weapons use insensitive high explosive. Currently both the W88 and W76 submarine-based warheads and the W78 land-based warhead use conventional high explosive.

Although IHE has clear benefits over conventional high explosive in terms of reducing risks, especially of plutonium release (or dispersal) in the event of a fire or accident, its value varies depending on the situation. For SLBM warheads, the benefits of IHE would be negligible while the warheads were on submarines at sea, because SLBMs use a propellant that has a low threshold for detonation, and detonation of the propellant would detonate even IHE. (ICBMs, in contrast, use a non-detonable propellant for the first two stages.) There are also fewer opportunities for anything to happen to an SLBM warhead while at sea. There are still benefits to using IHE on SLBM warheads because it would reduce risks during handling and transport. To date, however, the Navy has resisted making this change, presumably due to risk or some other perceived disadvantage.

For ICBMs, the benefits of IHE are clearer, but it is still not obvious that the proposed interoperable warheads are the simplest way to incorporate IHE into these weapons.

The current plan to achieve an all-IHE stockpile calls for "mix-and-match" warheads—new warheads that would use a primary from one weapon type with a secondary from another. Participants differed on whether this approach would raise more reliability issues than alternative proposals to base the future stockpile on existing weapon types that already incorporate IHE. Some stated that some types of "mix-and-match" warheads might be easier to certify than those based on refurbishment or reuse.

Reliability and Quantification of Margins and Uncertainty

Quantification of Margins and Uncertainty (QMU) is a process by which designers determine how confident they are that a weapon will operate as planned, and quantify this information to help them decide whether there is a sufficient performance margin. It is a method that is routinely used in many fields of engineering, but was only adopted relatively recently in reference to the nuclear explosive package. Previously, the NEP was always assigned a reliability of one—meaning it was assumed that, if the NEP was properly triggered, the probability of a nuclear explosion with the desired yield was always 100 percent. Even when the United States conducted nuclear explosive tests, it did not carry out enough tests to provide statistically significant information about reliability.

Participants with knowledge of the methodology agreed that QMU's expansion has been beneficial, especially in increasing discipline among designers in laying out the criteria for confidence in reliability. They emphasized, however, that although QMU is a valuable tool in understanding key problems in warhead maintenance and reliability, it cannot provide a final answer to these questions. As has been the case since the beginning of the nuclear weapons program, the expert judgment of weapon designers will remain a key factor in assessing confidence in a weapon's reliability.

There was some disagreement among participants over whether developing new interoperable warheads with a high margin would allow for sufficient confidence in the performance of these warheads if uncertainty also increased. Some believed that it was possible to increase margin such that there would be enough to deal with new uncertainties that arose, while others argued that even if the margin was increased substantially, uncertainty might also increase substantially with a new design, so the ratio of margin to uncertainty might not improve.

It was noted that the reliability of a design for an interoperable warhead might prove to be too uncertain to certify without resuming nuclear explosive testing. In such a case, it was stated, the United States would not pursue the design.

More generally, participants discussed the technical risks of designing and producing weapons that use a nuclear explosive package that has not undergone nuclear explosive testing. Some asked why confidence in weapon reliability was not better maintained by remanufacturing stockpiled warheads within established tolerances for serial production, recognizing the importance of the manufacturing process. In response, other participants stated that some change will be required regardless of whether 1) the weapon is refurbished; 2) components are reused by mating a primary from one existing design to a secondary from another existing design; or 3) the primary or secondary is replaced using a component "based on" a tested design. Another questioner asked why new sources for materials could not be identified if changes were needed due to currently unavailable materials, or why a "national security" exemption could not be used if changes were needed to comply with new health regulations.

There was also some discussion of the potential political costs of building weapons that use a nuclear explosive package that has not undergone nuclear explosive testing. In particular, some suggested that proceeding down this path could lead to resumed U.S. nuclear explosive testing—not because the weapons labs would support doing so, but because Congress might require it to gain political confidence in the new weapons. Others rejected this possibility. Some also argued that these designs, even if they used existing components, would be considered "new" by outside observers.

It was noted that weapons could be made more secure by external means, such as using transport vehicles with enhanced features. This would also support increased safety.

Participants agreed overall that QMU is valuable, and its use should be expanded. There was a sense that this would require carrying out more (non-nuclear) experiments and tests to improve the process, however, and the cost of such experiments would require additional resources.

There was no agreement on either the technical risks or political downsides of designing and producing warheads with components that had not previously been explosively tested together.

Maintaining Weapons Expertise

Some argued that maintaining nuclear weapons design expertise would be essential even if the United States had no nuclear weapons, because it would be necessary to understand latency and proliferation issues in the future, and to interpret intelligence on other nations' weapons. There was some discussion of what was needed to maintain such expertise at the U.S. labs, with some arguing that the labs would end up with second-rate people if there was not challenging work for designers to do—and that "make-work" would not be adequate. Some asserted that the downside of refurbishing existing nuclear weapons rather than designing new ones was that the labs would lose the best people.

Delivery Systems

While much of the discussion during the workshop focused on 3+2 and plans for future warheads, participants noted that delivery systems are an important part of the equation as well, especially in terms of cost and testing requirements. Moreover, the decisions that are made now about the future structure of the nuclear forces will shape the strategic landscape for decades to come.

In the 2010 Nuclear Posture Review, the Obama administration committed the United States to maintaining a nuclear triad. However, the administration is now struggling with fulfilling that commitment, as projected costs have increased and the government faces a severe budget crunch. One way to get significant savings in the nuclear weapons program is by eliminating a leg of the triad, a possibility that some participants advocated revisiting.

Alternatively, under current budget restrictions, the only way to replace the triad will be to take money from conventional forces. To date, very hard choices have not been required, but the current budget situation is compelling both public and internal debate over what is necessary, and there is intense competition among programs. The period of greatest concern is in the 2020s, when the "bow wave" of programs that may need updates hits both the NNSA and DOD.

In a June 2013 speech in Berlin, President Obama said that the United States can meet its needs for its nuclear arsenal with a one-third reduction from current force levels. The administration clarified that this meant a one-third reduction in warheads and a one-third reduction in delivery systems relative to the New START limits. The question is what mixture of forces would best meet this requirement. One possibility is to maintain ten ballistic missile submarines with 16 missiles each while reducing the number of ICBMs from 450 to 250; another possibility is to maintain eight submarines and 300 ICBMs. There was some debate among participants about whether a smaller force will have enough flexibility, but the fact that the United States has already decided it can meet requirements at lower numbers means that this outcome has already been accepted. Part of the problem, some participants noted, is that an updated discussion of targeting requirements has been missing from the discussion about force modernization and future force structure.

Some participants questioned the need for two weapons on the air-based leg of the triad. Others reemphasized the idea that eliminating one leg of the triad, such as the ICBMs, would give the most significant savings. It was suggested that the United States should consider letting the Minuteman III "age gracefully," leading to its eventual elimination after 2035, when the current plan calls for a replacement missile. Other participants raised concerns about whether the SLBM force would remain relatively invulnerable for decades, and therefore whether eliminating ICBMs might endanger the U.S. deterrent in the long run.