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Implementing the Hedge Strategy in the 2018 Nuclear Posture Review

Aaron R. Miles

Fellow, Center for Global Security Research

Lawrence Livermore National Laboratory

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Disclaimer

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Abstract

The stability of nuclear deterrence is threatened when potential shifts in the technology and security environments can compromise key force attributes, such as the ability of nuclear forces to survive an adversary's first strike. Strategies for hedging against uncertainty seek to preserve effective deterrence when technical problems arise or when adversaries develop new military capabilities and forms of aggression. The latest U.S. nuclear weapons policy continues and expands upon previous efforts to maintain sufficient flexibility in U.S. nuclear force structure to sustain key force attributes in the face of technological or geopolitical challenges. An attribute-based approach to hedge planning allows for analysis and comparison of various nuclear force structure alternatives. This analytic approach supports the Trump Administration's finding that measured enhancement, rather than an expansive program to develop new weapon types, is sufficient to shore up the flexibility of U.S. deterrent forces.

Introduction

Maintaining stable and effective deterrence requires nuclear forces that are structured and postured to respond to potential futures challenges as well as deter today's adversaries under present circumstances. The 2018 Nuclear Posture Review (NPR) continues and expands upon previous U.S. efforts to hedge against uncertainty in the technology and security environments. It incorporates major elements from prior reviews, such as an emphasis on increased flexibility and determination to maintain diversity in the deployed force. Unlike prior reviews, the new policy identifies hedging against uncertainty as one of the roles that nuclear weapons play in U.S. security strategy. [1] It lays out a more thoughtful strategy for to accomplish this objective.

The 2018 NPR establishes a strategy for hedging against uncertainty that prioritizes the ability to sustain five key force attributes[2] in the face of technological or geopolitical challenges: survivability, ability to penetrate adversary defenses, prompt response capability, visibility, and range of warhead yields. In this paper, I use these key attributes to analyze the current and planned U.S. nuclear force structures, as well as various alternatives that have or may be proposed. This analysis is based on the ability of force structures to *provide* key attributes and combinations of attributes, and their ability to *preserve* those attributes and combinations when potential challenges arise.

Previous U.S. administrations understood the importance of many key attribute combinations and worked to preserve them. In parallel with its work to reduce the role of nuclear weapons in

U.S. security strategy, the Obama Administration laid the groundwork for a nuclear modernization plan that provides all but one important attribute combination. The Obama Administration then rejected calls to scale the plan back in ways that would increase the difficulty of preserving these attributes in the face of adversary challenges or technical problems.

The Trump Administration's NPR added two "modest supplements" to the Obama modernization plan, in part to fill the one single gap in the ability of existing U.S. forces to provide key attribute combinations. First, the United States will rapidly modify a small number of submarine-launched ballistic missiles (SLBMs) to give them lower yields like those it currently possesses only on more vulnerable aircraft-carried weapons. A low-yield SLBM would strengthen U.S. deterrence posture by providing a more assured ability to penetrate adversary defenses now and into the future. Second, and in part to further assure the ability to penetrate adversary defenses, the United States might later reinstate a nuclear-armed sea-launched cruise missile (SLCM) capability.

These two supplements, together with other elements of the modernization plan, significantly strengthen the U.S. ability to hedge against uncertainty. Following through on this plan will leave the United States better prepared to address technological and geopolitical challenges that are most likely to arise, and those that are less likely but would hold particularly grave consequences for the U.S. ability to deter nuclear attacks against the United States and its allies.

In the balance of this paper, I begin with a brief historical overview of U.S. hedging strategy as it has evolved through the post-Cold War period. This is followed by a discussion of how flexibility in nuclear force structure underwrites hedge strategy in a way that is critical to maintaining effective deterrence. Next, I describe an analytic approach to gauging and comparing the ability of various nuclear force structures to implement the U.S. hedge strategy. Finally, I analyze the ability of various force structure alternatives to meet these hedging criteria.

Evolution of U.S. strategy for hedging against uncertainty

Every nuclear posture review has recognized the importance of hedging against uncertainty. The challenge and urgency increased with each successive review, however, as force modernization and infrastructure renewal were repeatedly delayed. Meanwhile, continuing advancement and diffusion of technology increased the aperture of potential threats to U.S. deterrence.

The 1994 NPR adopted a "lead and hedge" strategy[3] under which the United States would lead in nuclear reductions while retaining the ability to regenerate those capabilities if Russia reversed course on democratization and returned to a more threatening posture. The 2001 NPR[4] determined that the United States would retain a nondeployed hedge force and build a responsive infrastructure in order to sustain the roles of U.S. nuclear weapons "in an era of uncertainty and WMD proliferation." The 2010 NPR[5] recognized three forms of uncertainty – technological, geopolitical, and operational. It developed a hedging strategy, described in the 2013 Report to Congress on U.S. Nuclear Employment Strategy,[6] that sought to guard against technological risk by "maintain[ing] a sufficient number of non-deployed weapons to hedge against the technical failure of any single weapon type or delivery system at a time." The 2010 NPR set a goal of shifting over time away from a large stockpile of nondeployed hedge weapons to a more responsive infrastructure that could instead produce new weapons if needed, but recognized that this would take a long time.

In order to preserve warhead attributes where possible, the 2013 employment guidance described a preference for hedge options within the same leg of the triad as the technical failure. Hedging in this way decreases the likelihood that a single technical failure could leave the force unable to execute the employment plans developed under Presidential guidance. However, the 2013 hedge strategy allowed that "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."[7]

While recognizing the potential for geopolitical and operational as well as technological uncertainty, the Obama Administration's hedge strategy planned only to address technological risk. It determined, without reference to any supporting analysis, that "[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."[8] Furthermore, this planning accounted only for technological risk associated with technical problems in the U.S. stockpile. It did not explicitly account for technological risk associated with adversaries' technical breakthroughs that might challenge the effectiveness of U.S. deterrent capabilities.

The 2018 NPR went further in three ways. First, it sought a greater emphasis on the critical importance of hedging against uncertainty. This was due partly to its assessment of a wide range of plausible future challenges, and partly to the slow progress towards a minimally sufficient infrastructure, let alone one that is truly responsive. The 2018 NPR elevated hedging to a role of nuclear weapons in U.S. security strategy, along with deterrence, assurance, and providing a meaningful response if deterrence fails.

Second, the 2018 NPR recognized and elaborated to a much greater extent on four types of risk: geopolitical, operational, technological, and programmatic. It describes technological risk as including both technical failures ("breakdown") and adversaries' technological breakthroughs. It adds programmatic risk as a fourth principal type of challenge. This addition reflected a sense that the United States is currently in a delicate place at the cusp of a once-in-a-generation nuclear modernization program that cannot be further delayed without critical elements of U.S. deterrence capabilities aging into obsolescence.

Third, the 2018 NPR directed that nuclear hedge planning deliberately account for geopolitical as well as technological challenges and that it focus on preserving critical force attributes rather than preserving numbers in the deployed stockpile. Under the new policy, "DoD will prioritize its nuclear hedge planning to sustain specific force attributes in the event of a technological or geopolitical challenge that threatens an element of U.S. nuclear forces."[9] This approach implicitly connects hedge planning to sustaining nuclear employment options.

Flexible range of nuclear options provides and preserves key force attributes

The 2018 NPR contends that possessing a flexible range of nuclear options strengthens deterrence and also improves the likelihood of avoiding the worst possible outcomes if deterrence fails. "Nuclear options" can refer to different ways of striking a target—bombs, ballistic missiles, etc.—as well as weapons with different yield or other design characteristics. Nuclear options can also include the ability to employ a single weapon or many, or the ability to strike different kinds of targets, from military forces in the field to hardened missile silos deep in enemy territory.

The new NPR emphasizes that greater flexibility can help "ensure that potential adversaries perceive no possible advantage in limited nuclear escalation," and "[preserve] credible deterrence against regional aggression."[10] There is good reason to focus on regional conflict scenarios. An adversary bent on aggression might gamble that the United States will back down in the face of limited nuclear use rather than risk defending a faraway ally on the adversary's doorstep. To deter such thinking, the United States needs credible responses to deliberate nuclear escalation. This should include options sufficiently removed from the level of massive nuclear exchange so that the enemy will fear that the United States would actually follow through. More escalatory options may be more frightening but also appear less rational and therefore less credible.

Ideally, nuclear options should provide the flexibility to make whatever threat will do the best job of deterring any given adversary from acts of nuclear aggression. One way to operationalize this is to identify particular attributes that help make deterrence effective and stable, and then prepare a range of response options that can preserve these attributes as adversaries' capabilities advance and technical problems arise within the U.S. arsenal.[11] This approach supports the NPR finding that measured enhancement, rather than an expansive program to develop new weapon types, is sufficient to shore up U.S. options.

The 2018 NPR directs that DoD prioritize U.S. nuclear hedge planning to sustain five key attributes:[12] **Survivability** ensures that adversaries cannot preemptively destroy U.S. forces. **Ability to penetrate** adversary defenses ensures that they cannot destroy U.S. weapons in flight. **Prompt response** is the ability to act fast enough to discourage adversaries from seeking advantage through surprise or by using fleeting assets. **Visibility** enables movement of forces in ways that reduce the likelihood of unintended escalation in crisis. **Range of warhead yields** includes lower yields that bolster the credibility of U.S. deterrence strategy and commitments to allies.

The 2018 identifies other force attributes elsewhere in the document, but these are generally derivative of the five listed above. For example, "diversity of trajectories"[13] is one way of helping to sustain the ability of U.S. forces to penetrate adversary defenses.

Analytic approach to hedge strategy implementation

Using the key attributes identified in the 2018 NPR (listed in Table 1 along with shorthand references), one can analyze the current and planned U.S. nuclear force structures, along with various alternatives that have been or may be proposed. This analysis includes the ability of force structures to *provide* key attributes and combinations, and their ability to *preserve* those attributes and combinations when potential challenges arise.

First, I identify those attribute combinations that should be preserved together within elements of the force, and exclude combinations that are unnecessary. Second, I specify a set of potential technological and geopolitical challenges, and divide them into two categories based on how likely they are to arise. Third, I specify a set of hedging criteria to govern how these potential challenges should be allowed to impact U.S. forces. Finally, I analyze the ability of various force structure alternatives to meet these hedging criteria.

Table 1. Five Key Attributes.

Attribute	Shorthand
Survivability	S
Ability to penetrate	P
Prompt response	F
Visibility	V
Range of warhead yields	Y

Each step in this analysis includes a significant degree of subjectivity. Others may reasonably disagree on whether a given challenge is more likely or less likely to arise, and even whether it is worth considering at all. While this paper suggests one reasonable set of hedging criteria for implementing the strategy, others are also possible. In any case, this analysis provides a framework that can be easily adjusted to incorporate alternative judgements.

There is some subjectivity even in interpreting the key attributes. In particular, there are two different meanings of survivability. Comprehensive survivability is the ability to carry out a large-scale second strike. Component survivability is the invulnerability of any given force component prior to employment. In this analysis, "S" denotes comprehensive survivability. Therefore, only weapons that might meaningfully contribute to a large-scale second strike are considered to possess the attribute of survivability. Component survivability is also important and could be considered separately, but can be a little tricky in some cases. For forward deployed nonstrategic weapons that play a political role in extended deterrence, some degree of vulnerability can be an element of strategy as well as a liability. "Range of warhead yields" is also subjective, and this analysis treats it as possession of some range of yields that includes low-yield options.

Important combinations of attributes

Many combinations of the key attributes are also important. For example, it would make little sense to deploy a force with one half that is survivable but cannot penetrate, and another that can penetrate but is not survivable. This would weaken deterrence because an adversary could strike one portion on the ground and the other in the air. Some other combinations are not necessary, and in particular there no need for every force element to possess or sustain all five attributes.

Seven attribute pairs are important and should be preserved (see Table 2). Survivable penetrating forces are the core of an assured response capability. The prospect of a prompt second strike may enhance deterrence, so SF is also important. Prompt and low-yield capabilities are not useful if they are not also penetrating. The ability to penetrate is so critical to these other attributes that it makes sense to replace promptness (F) and range of yields (Y), respectively, with FP and YP.

Furthermore, it turns out that these replacements do not change the subsequent analysis. For example, any of the potential challenges considered below that impact promptness (F) also impact prompt penetrating capabilities (FP) in the same way.

The combination of prompt and low-yield allows the possibility of a rapid response that might in some cases be more credible that higher-yield alternatives. It also provides a means for the President to reduce collateral damage in scenarios where a limited rapid response is deemed necessary. Finally, while assets used for deterrence signaling need not possess all attributes of the force, they should be credible. This requires that they can penetrate adversary defenses and that they include low-yield options. This latter requirement is not restricting because all U.S. air-carried weapons are variable-yield designs.

Table 2. Important Attribute Pairs.

SP	Survivable + Penetrating = Core of assured response capability
SF	Survivable + Prompt
FP	Penetrating + Prompt (Subsumes F)
YP	Penetrating + Low yield (Subsumes Y)
FY	Prompt + Low yield
PV	Penetrating + Visible => Signaling with credible asset
YV	Visible + Low yield => Signaling with credible asset

The other three pair combinations are not necessary (see Table 3). The combination SY is unnecessary because the second-strike force does not need to include low-yield weapons in order to deter a disarming first strike. Visible elements of U.S. forces can be used for deterrence signaling whether or not they themselves are critical to U.S. second strike, and whether or not they provide prompt strike capability. In fact, the "slow" nature of the bomber leg, including the ability to recall a strike, is part of its signaling utility.

Table 3. Unnecessary Attribute Pairs.

SY	Low-yield not required for large-scale second strike
SV	Primary second-strike assets not necessarily visible. Other elements of the force can be used for signaling.
FV	Prompt strike capability not required (and not necessarily desirable) for signaling platforms.

Excluding three pair combinations limits the number of possible triple combinations, or trigraphs, and higher-order combinations. Only three attribute trigraphs are important (see Table 4), and no quadruple combinations are necessary. Like F and Y, the pairs SF and FY are only viable if they are also penetrating. SPF and PFY can replace these pairs without impacting any of the subsequent analysis. Similarly, it turns out that PYV fully represents a credible signaling asset, and can replace PV, YV, and V. This means that in the analysis that follows, any challenge that impacts PYV would also impact V, PV, and YV in the same way. The full list of important attributes and combinations is collected in Table 5.

Table 4. Important Attribute Trigraphs.

SPF	Prompt Survivable Second Strike (Subsumes SF)
PFY	Prompt Low yield Penetrating (Subsumes FY)
PYV	Penetrating + Low yield + Visible => Signaling with credible asset (Subsumes V, PV, and YV)

Table 5. Important Attributes and Contributions. Square brackets indicate when other combinations are also included.

S	Survivable
P	Able to penetrate
SP	Survivable + Penetrating = Core of assured response capability
SPF [SF]	Prompt Survivable Second strike
FP [F]	Prompt + Penetrating
YP [Y]	Low yield + Penetrating
FYP [FY]	Prompt + Low yield +Penetrating
VYP [PV, YV, V]	Visible + Penetrating + Low yield => Signaling with credible asset

Potential challenges to key attributes

The next step is to identify potential technological and geopolitical challenges, which I then divide into two categories based on whether each is more likely and less likely to arise. In the category of more likely challenges, I include failure of a single warhead type; an adversary's

limited defense against U.S. intercontinental ballistic missiles (ICBMs); an adversary ability to detect U.S. stealth aircraft; adversary ability to target U.S. aircraft at standoff ranges (i.e., ranges at which U.S. bombers might employ air-launched cruise missiles); adversary ability to detect the Air-Launched Cruise Missile (but not its planned replacement); and a Russian decision to break out from the New START Treaty. In this analysis, I assume that a SLCM would use a variant of the W80 warhead that is currently planned for the replacement of the existing ALCM, while acknowledge that as yet no warhead decision has been made. Since the low-yield ballistic missile (LYBM) is described in the NPR as a limited response capability, I treat an adversary's capability for limited ballistic missile defense as negating the LYBM.

Less likely challenges include failure of a U.S. platform; an adversary ability to defend against large-scale ballistic missile attack; adversary ability to detect stealthy cruise missiles (which this analysis assumes would imply an ability to also detect larger stealthy bombers); advanced anti-submarine warfare (ASW) capabilities that can detect U.S. ballistic missile submarines; and a military alliance between the United States' two most capable potential adversaries, Russia and China. I will also consider the simultaneous occurrence of any two "more likely" challenges as comparable to a "less likely" challenge. In this analysis, I assume that a SLCM could be carried on multiple platforms (though I am aware of no such decision), and therefore cannot be threatened by any single platform failure other than the missile itself.

Table 7. Potential Technological and Geopolitical Challenges to Key Force Attributes.

More Likely Challenges	Less Likely Challenges
Warhead failure (Assume W80 for SLCM)	Platform failure (Assume multiple SLCM platforms)
Limited BMD (Treat as negating LYBM)	Large-scale BMD
Detect stealth aircraft	Detect stealth cruise missiles (Implies stealth bomber detection as well)
Target aircraft at standoff range	Advanced ASW
Detect ALCM (prior to replacement by LRSO)	Military alliance between Russia and China
Russian breakout from New START Treaty	Treat two simultaneous "more likely" challenges (including simultaneous failure of two warheads) as comparable to a single "less likely" challenge.

This analysis treats warhead failures as more likely than platform failures because nuclear warheads are not tested to the same extent as platforms, and therefore it might be more difficult to identify and address technical problems before they can seriously degrade the system

reliability. Simultaneous failures might be more likely when warheads share common components, but such details are not included in this illustrative analysis.

Finally, neither of the two geopolitical challenges included would have a clear impact on preserving any of the key attributes or combinations. Consequently, they are omitted them from the discussion of results below, and it does not matter whether these are placed in the "more likely" or "less likely" column. This would seem to support the 2010 NPR determination that requirements for the technical hedge are more determinative than those for the geopolitical hedge. However, sustaining the key attributes is not necessarily the only consideration in hedge planning. For example, both the Obama and Trump Administrations expressed a preference for maintaining rough numerical parity with Russia's deployed strategic force, even when deviations from rough parity might not pose a serious threat to survivability or other key attributes of U.S. forces. Future analysis could account for this by including a sixth key attribute related to warhead upload capacity or some aspect of infrastructure responsiveness, such as excess warhead production capacity.

Establishing hedge criteria

This analysis adopts three illustrative hedge criteria. These are based in part on the idea that not all key force criteria are equally important. In particular, those at the core of the U.S. assured response capability warrant special protection.

Criterion #1. No likely challenge or platform failure. No single event in the category or "more likely" challenges, and no single platform failure, should threaten any key attribute or combination. Since warhead failures are considered "more likely" challenges, this criterion subsumes the Obama Administration strategy for hedging against a single warhead or platform failure.

Criterion #2. No single challenge to assured response. For assured response capability (SP, together with S and P), no single challenge or pair of "more likely" events can threaten the U.S. assured response capability. This means that an adversary must solve more than one "hard problem" in order to threaten the U.S. capacity for assured second strike.

Criterion #3. Do not present multiple attack vectors. For any attribute combination that is not at the core of U.S. assured response capability, the collection of plausible "less likely challenges" and pairs of "more likely challenges" should not include multiple attack vectors. Attack vectors are ways that adversaries can deliberately challenge U.S. deterrent capabilities. Presenting adversaries with multiple ways of potentially negating a U.S. capability makes it more likely that they will seriously undertake the attempt. It is important to note that some combinations of "more likely" challenges constitute an attack vector (e.g., counter stealth plus targeting aircraft at standoff range), while others do not (e.g., Counter stealth plus a warhead failure).

Several limitations of this hedge planning analysis warrant mention. First, this analysis accounts for the attributes that various systems contribute, but does not attempt to fold in other important considerations related to warhead numbers. For example, it does not address the established need to rebalance warheads in the SSBN leg of the triad. Numbers do, however, figure in implicitly

through our interpretation of survivability as an attribute involving the ability to carry out a large-scale second strike. Second, the list of attribute contributions in Table 6 does not account for the relative contribution of different force elements that provide the same attribute. For example, both SLBMs and ICBMs are responsive, but ICBMs are the most responsive force element. Similarly, ICBMs contribute survivability when on alert but are generally considered less survivable than SLBMs. Fourth, this analysis does not include all operational considerations, such as more limited forward basing options for aircraft compared to naval assets. Finally, the list of potential challenges is not necessarily all inclusive, but the analysis could easily be expanded.

Attributes of current and planned U.S. systems

Current and future U.S. nuclear systems provide key attributes and combinations, as indicated in Table 6. Submarine-launched ballistic missiles (SLBMs) are survivable, prompt, and penetrating. ICBMs are all also prompt and penetrating, and contribute survivability when on alert and capable of launching under attack. Air-carried systems are visible, penetrating, and provide low-yield options. Bombers armed with cruise missiles contribute survivability as long as bombers can be dispersed and placed on alert. This analysis does not consider gravity bombs as significant contributors to overall survivability because the need for bombers to overfly each individual target substantially decreases their flexibility and their ability to substitute for ballistic missiles in larger-scale strikes. The LYBM would add a prompt low-yield capability that is also penetrating but does not contribute to survivability because only a small number of SLBMs will be modified. The SLCM would provide another low-yield, penetrating option. If sufficient numbers are deployed, it could in principle contribute to survivability in the same way that the ALCM/LRSO does. I also treat the SLCM as a contributor to visibility because of the potential for naval vessels to participate in signaling activities. Ballistic missile submarines (SSBNs) are not treated in this way because each one is too valuable an asset to serve routinely in this capacity.

Table 6. Attributes of current and planned U.S. systems.

System	Warhead	Attributes
ICBM	W78, W87	SPF
SLBM	W76, W88	SPF
B52/Cruise missile	W80	SPYV
B2	B61, B83	PYV
B21/LRSO	W80	SPYV
B21	B61	PYV
LYBM	W76	PFY
SLCM	Assume W80	SPYV

The list of systems in Table 6, which I use for subsequent analysis, does not differentiate between the various strategic and non-strategic variants of the B61 gravity bomb, including the earth-penetrating B61-11. Simplifying in this way has a limited effect because the life-extended B61-12 will soon replace the other variants (except for the B61-11). In the meantime, it means that any B61 failure in this analysis is a worst-case scenario in which all variants are similarly degraded. Similarly, this analysis treats the W76-0 and the life-extended W76-1 as a single warhead type. Finally, I do not extend the analysis to include existing or planned dual-capable fighter bombers that can also deliver B61 gravity bombs. This simplification is equivalent to assuming that an adversary ability to target a stealth bomber corresponds to an ability to also target these other aircraft. The omission does not otherwise impact the analysis because failure of a stealth bomber platform never results in loss of a key attribute or combination.

Analysis of alternative U.S. nuclear force structures

The current U.S. nuclear force includes all systems listed in Table 6 except for the B21 bomber, the LRSO, the LYBM, and SLCM. Existing U.S. forces provide all five key attributes and all but one important combination. Because they are all aircraft-carried, existing low-yield options do not provide a prompt capability and therefore cannot threaten time-sensitive targets.

The 2010 NPR and 2013 Presidential nuclear employment guidance led to nuclear modernization plan that would modernize the current force (including replacement of the ALCM with the LRSO), add the B21 bomber, and retire the B83 strategic bomb. I will refer to this force structure as the 2010 modernization plan. The 2010 modernization plan does not address the prompt low-yield gap in existing U.S. forces.

The 2018 NPR found that Russia's focus on battlefield nuclear weapons, coupled with "Russian strategy and doctrine [that emphasizes] the potential coercive and military uses of nuclear weapons," might reflect a gap in U.S. deterrence options. Closing this gap does not, however, require that the United States "match or mimic Russia's more expansive arsenal."

Instead, the NPR found that two "modest supplements" will sufficiently shore up America's nuclear options. The 2018 NPR thus adds the low-yield ballistic missile (LYBM) and SLCM, and also reverses the commitment to retire the B83 gravity bomb. I refer to this as the 2018 modernization plan. Adding the LYBM fills the one gap in the ability of the existing U.S. force to provide the key attributes combinations.

Figure 1 graphically demonstrates the ability of the existing U.S. nuclear force and each of the two modernization plans to provide and preserve the key attributes and combinations. The vertical axis on each plot shows the number of ways that potential challenges may negate each attribute combination. In these and subsequent plots, a bar that extends to the top of the plot indicates an attribute combination that is not present in the given force structure. In Figure 1 and subsequent plots, this only ever applies to the combination FYP.

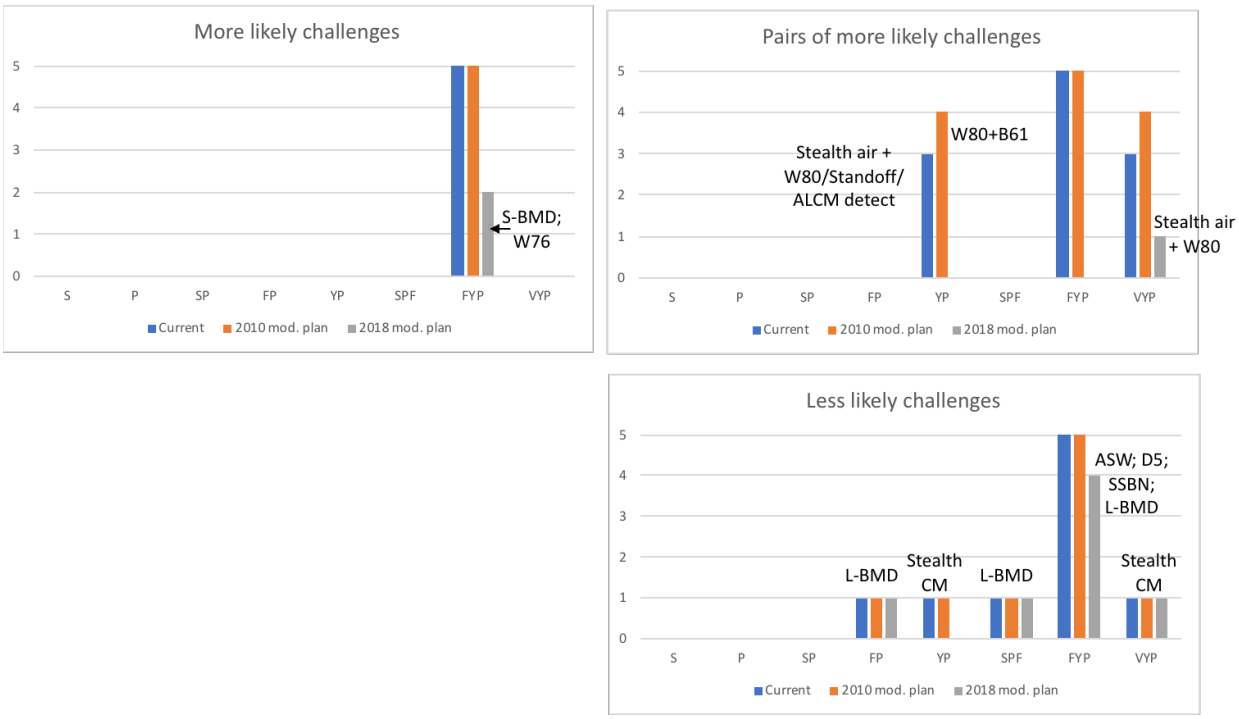

Figure 1. Ability of existing U.S. nuclear force and modernization plans to provide and preserve key attributes. A fully extended bar indicates an attribute combination that is not present in that force structure.

In addition to leaving the FYP gap unaddressed, the 2010 modernization plan actually reduces slightly the hedge strength of the force. This greater vulnerability of the combinations YP and VYP results from retirement of the B83, leaving only two variable-yield warheads in the stockpile. The force is then susceptible to an (albeit unlikely) simultaneous failure of the B61 and W80. The 2010 modernization plan meets the first two illustrative hedging criteria (except that FYP is absent), but fails the third criterion for all combinations involving Y.

The NPR supplements under the 2018 modernization plan result in a force that meets the illustrative hedging criteria, except that FYP comes from a unique capability that is therefore susceptible to two of the "more likely" challenges: single warhead failure and small-scale missile defense. The combination VYP (and therefore also V, VP, and YV) is vulnerable to one "more likely" challenge and one pair of "more likely" challenges. It still meets the third hedging criterion, though, because one of these includes a warhead failure and therefore does not constitute an attack vector.

Thus, the NPR supplements significantly strengthen the ability to preserve key attributes into the future. Advancements in adversary air defenses pose the greatest risk to preserving signaling and low-yield options that are also penetrating. Maintaining the ability to forward deploy nuclear-capable aircraft and developing the Long-Range Standoff Cruise Missile (LRSO) to replace the aging Air-Launched Cruise Missile[14] are important parts of sustaining these combined attributes. Reliance on air-delivered systems is limiting, though, because they must remain undetected to

avoid being shot down. The low-yield ballistic missile[15] and sea-launched cruise missile[16] offer a hedge against potential advances in detecting stealth airframes and targeting aircraft at long distances (using, for example, hypersonic weapons[17]).

Preserving the other key attributes does not currently require new capabilities. The United States can avoid the danger of losing prompt response capability by continuing to reject calls to de-alert the ICBM force.[18] According to the NPR, "there are no known, near-term credible threats to the survivability of the [strategic submarine] force."[19] Nevertheless, the U.S. Navy conducts a vigorous program to guard against a technological revolution in anti-submarine capability. The United States also maintains a degree of survivability in other legs of the triad, in particular the ability to disperse bombers armed with cruise missiles. The prospect of defending against large-scale ballistic missile attacks remains far off, and defense against even a single advanced missile is difficult. To help prevent future threats to the penetration ability of its ballistic missiles, the United States can build flexibility into the replacement programs for Cold War era systems.

Although the 2010 modernization plan did not formally seek to hedge against loss of the attribute set identified in the 2018 review, our analysis illustrates considerations that were very present when the Obama Administration considered alternative force structures and postures. At various times, the Obama Administration rejected calls to (1) cancel the LRSO and allow the ALCM to age out of the force, (2) eliminate the ICBM leg of the triad, (3) de-alert the ICBM force, (4) cancel the B61-12 and eliminate gravity bombs, and (5) cancel the B21 bomber or develop it a conventional-only bomber. In each case, proponents of these changes argued that the existing force provides unnecessary redundancy that need not be sustained. For example, some argued that the cruise missile is unnecessary if the United States possesses gravity bombs. Others concluded that the SLBM force makes ICBMs redundant, or at least removes any need to maintain ICBMs on alert.

Figure 2 shows the effect that each of these changes would have on the ability to hedge, relative to the 2010 modernization plan. In this analysis, I assume that a decision to cancel the B21 (or opt against giving it any nuclear capability) also results in loss of a nuclear-capable B2, since that system must eventually age out or lose its ability to reliably penetrate advanced air defenses.

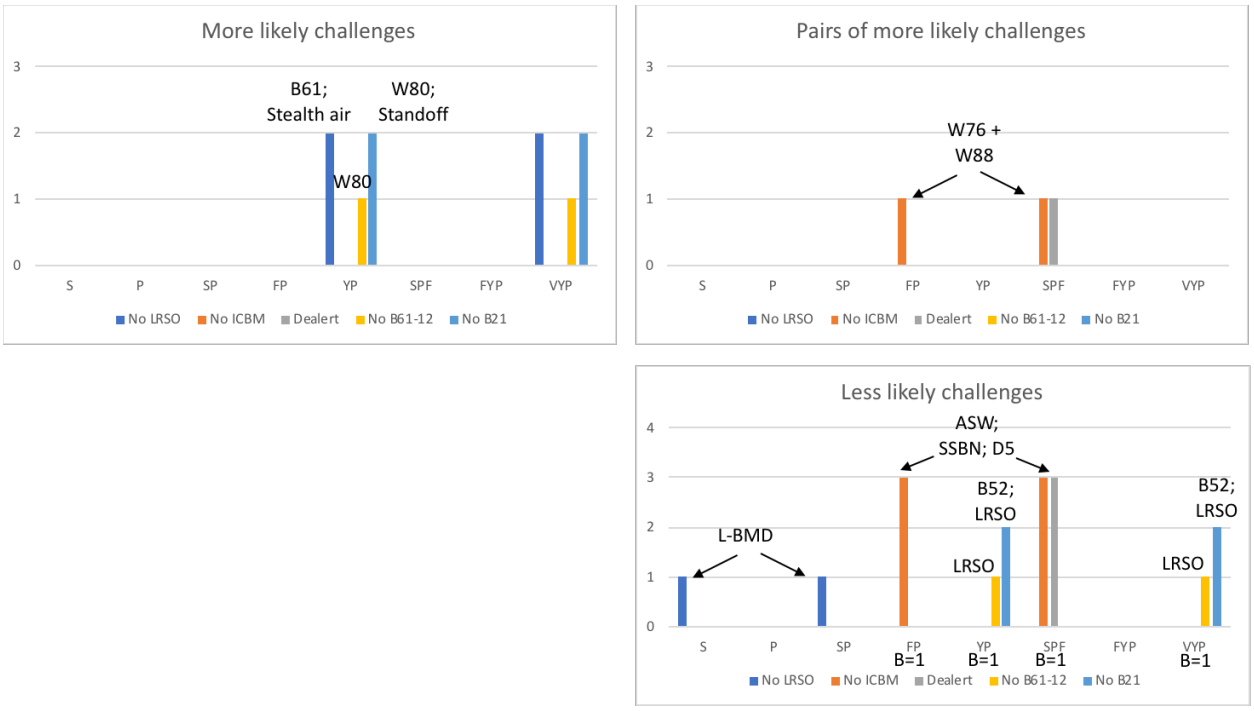

Figure 2. The impact on hedge strength of deviations in the 2010 modernization plan. Columns show the additional number of ways that potential challenges may negate each attribute combination, relative to the baseline 2010 modernization plan. In cases where the baseline 2010 plan also had some susceptibility, baseline numerical values are included and denoted by "B".

The columns in Figure 2 show the additional number of ways that potential challenges may negate each attribute combination, relative to the baseline 2010 modernization plan. For example, Figure 1 shows that the 2010 modernization plan leaves one potential "less likely" challenge to the attribute combination YP, namely, an ability to detect stealthy cruise missiles. Figure 2 shows that eliminating the B61 would result in one additional way to challenge YP, namely, a technical failure of the LRSO missile.

Proponents of the 2010 modernization plan argued that the ability to reliably preserve low-yield employment options depends on retaining a gravity bomb, a penetrating bomber, and an air-launched cruise missile. As shown in Figure 2, eliminating any one of these results in one or two "more likely" potential challenges to YP and VYP, where under the 2010 plan there were none. Canceling the B61-12 or the stealth bomber also introduces one or two potential "less likely" challenges to these same attribute combinations. Canceling the LRSO adds additional risk by eliminating the ability of the bomber force to hedge against an adversary's development of large-scale ballistic missile defense. Without LRSO, all three of our illustrative hedging criteria are violated, including the assured response criterion.

Proponents of the 2010 modernization plan also argued against de-alerting or canceling the ICBM force. They argued that these changes would add undesirable risk to the U.S. ability to

preserve a prompt response capability. In Figure 2, this effect is shown as significantly increased risk to FP and SFP, and a corresponding new inability to meet our third hedging criterion.

The proposed additions under the 2018 modernization plan have raised similar questions about the potential for needless redundancy, and no doubt will continue to do so. For example, what benefit could a SLCM provide over that already provided by ALCM/LRSO? Does addition of the SLCM eliminate any need to also retain gravity bombs?

Figure 3 shows the impact on hedge strength of several possible deviations from the 2018 plan. As noted previously, the LYBM contributes a unique prompt low-yield capability that is otherwise absent in the force. It also helps preserve low-yield capability in some threat scenarios. The SLCM helps ensure a credible signaling mode (VYP) that is not vulnerable to an adversary's development of both the ability to detect stealth aircraft and the ability to target aircraft at standoff range. The stealth bomber and gravity bombs are important for addressing what would otherwise be a vulnerability to potential failure of the W80 cruise missile warhead.

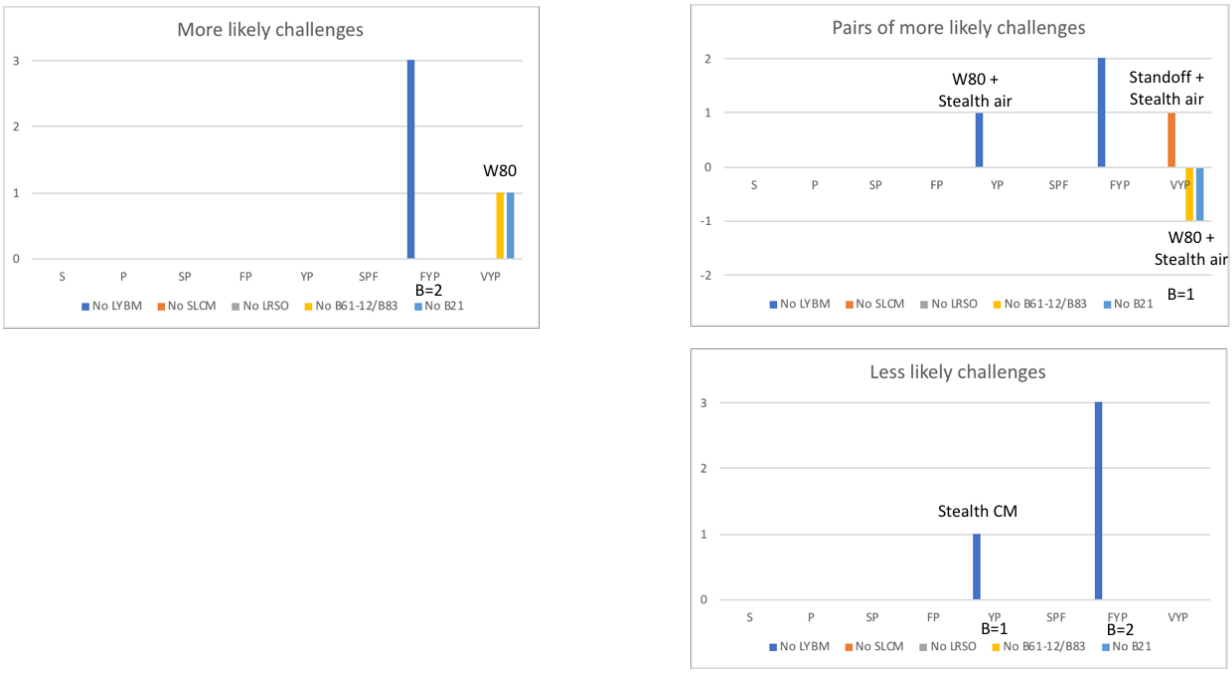

Figure 3. The impact on hedge strength of deviations in the 2018 modernization plan. Columns show the additional number of ways that potential challenges may negate each attribute combination, relative to the baseline 2018 modernization plan. In cases where the baseline 2018 plan also had some susceptibility, those baseline numerical values are included and denoted by "B". A fully extended bar indicates an attribute combination that is not present in that force structure.

Eliminating either the stealth bomber or the gravity bombs would convert a failure mode involving a pair of simultaneous "more likely" challenges into a failure mode that requires only a

single such challenge. This vulnerability could be lessened, however, if the B61 or some other warhead design could be used for the SLCM. Figure 3 also suggests that LRSO is less important in terms of hedge strength than is the SLCM. LRSO shares the same aircraft vulnerabilities as other available signaling modes, while the SLCM provides greater resilience through platform diversity.

Conclusions

The 2018 NPR continues and expands upon previous U.S. efforts to hedge against uncertainty in the technology and security environments. It incorporates major elements from prior reviews, such as an emphasis on increased flexibility and determination to maintain diversity in the deployed force. Like its predecessors, the 2018 review also faces the unfortunate reality that previous administrations have not done enough to implement their own hedge strategies. In response, it seeks to further emphasize the importance of hedging against uncertainty by elevating it to a role of nuclear weapons in U.S. national security strategy.

The new NPR also takes a somewhat different approach to hedging. It directs planners to prioritize key force attributes that help make nuclear deterrence effective and stable. The Defense and Energy Departments can implement this strategy by ensuring that the deployed and non-deployed force together sustain a sufficient range of nuclear employment options to provide these key attributes and preserve them as adversary capabilities advance and if technical problems arise within elements of the U.S. force.

While the new NPR is the first to formalize hedge planning to preserve these force attributes, previous administrations understood their importance as well. The Obama Administration laid the groundwork for a nuclear modernization plan that provides all but one important attribute combination, and rejected calls to scale the plan back in ways that would increase the difficulty of preserving these attributes in the face of adversary challenges or technical problems.

Adding the supplemental capabilities in the 2018 NPR fills the one gap in the ability of existing U.S. forces to provide key attribute combinations. Together with other elements of the nuclear modernization program, the LYBM and SLCM also significantly strengthen the ability to hedge against uncertainty. Following through on this modernization plan will leave the United States better prepared to address those challenges that are most likely to arise, and those that are less likely but would hold particularly grave consequences for the U.S. ability to deter the highest forms of aggression against the United States and its allies.

Notes

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