CARNEGIE
ENDOWMENT FOR
INTERNATIONAL PEACE

WORKING PAPER

FEBRUARY 2020

Toward Accountable Nuclear Deterrents: How Much is Too Much?

George Perkovich

Toward Accountable Nuclear Deterrents: How Much is Too Much?

George Perkovich

This paper was made possible by support from the Foreign Ministry of Sweden, the MacArthur Foundation, and the Edgerton Foundation.

Carnegie Endowment for International Peace
Publications Department
1779 Massachusetts Avenue NW
Washington, DC 20036
P: + 1 202 483 7600
F: + 1 202 483 1840
CarnegieEndowment.org

This publication can be downloaded at no cost at CarnegieEndowment.org.

CONTENTS

Executive Summary 1

Introduction 3

Premises: Zero is a Diversion, and the Operative Question Should Be How Much is Too Much? 5

Ask Different Questions to Get Better Answers: Two Initiatives to Constructively Guide International Nuclear Politics 11

Conclusion 20

Appendix: Exploring the Case for Physically Bounding Escalation 24

About the Author 31

Notes 31

Executive Summary

For decades, policy debates in nuclear-armed states and alliances have centered on the question, "How much is enough?" What size and type of arsenal, and what doctrine, are enough to credibly deter given adversaries? This paper argues that the more urgent question today is, "How much is too much?" What size and type of arsenal, and what doctrine, are too likely to produce humanitarian and environmental catastrophe that would be strategically and legally indefensible?

Two international initiatives could help answer this question. One would involve nuclear-armed states, perhaps with others, commissioning suitable scientific experts to conduct new studies on the probable climatic and environmental consequences of nuclear war. Such studies would benefit from recent advances in modeling, data, and computing power. They should explore what changes in numbers, yields, and targets of nuclear weapons would significantly reduce the probability of nuclear winter. If some nuclear arsenals and operational plans are especially likely to threaten the global environment and food supply, nuclear-armed states as well as non-nuclear-weapon states would benefit from actions to physically reduce such risks. The paper suggests possible modalities for international debate on these issues.

The second initiative would query all nuclear-armed states whether they plan to adhere to international humanitarian law in deciding if and when to detonate nuclear weapons, and if so, how their arsenals and operational plans affirm their intentions (or not). The United Kingdom and the United States have committed, in the words of the 2018 U.S. Nuclear Posture Review, to "adhere to the law of armed conflict" in any "initiation and conduct of nuclear operations." But other nuclear-armed states have been more reticent, and the practical meaning of such declarations needs to be clarified through international discussion.

The two proposed initiatives would help states and civil society experts to better reconcile the (perceived) need for nuclear deterrence with the strategic, legal, and physical imperatives of reducing the probability that a war escalates to catastrophic proportions. The concern is not only for the well-being of belligerent populations, but also for those in nations not involved in the posited conflict. Traditional security studies and the policies of some nuclear-armed states have ignored these imperatives. Accountable deterrents—in terms of international law and human survival—would be those that met the security and moral needs of all nations, not just one or two.

These purposes may be too modest for states and activists that prefer the immediate prohibition and abolition of nuclear weapons. Conversely, advocates of escalation dominance in the United States and Russia—and perhaps in Pakistan and India—will find the force reductions and doctrinal changes implied by them too demanding. Yet, the positions of both of these polarized groups are unrealis-

tic and/or unacceptable to a plurality of attentive states and experts. To blunt efforts to stifle further analysis and debate of these issues, the appendix of this paper heuristically rebuts leading arguments against accountable deterrents.

Middle powers and civil society have successfully put new issues on the global agenda and created political pressure on major powers to change policies. Yet, cooperation from at least one major nuclear power is necessary to achieve the changes in nuclear deterrent postures and policies explored here. In today's circumstances, China may be the pivotal player. The conclusion suggests ways in which China could extend the traditional restraint in its nuclear force posture and doctrine into a new approach to nuclear arms control and disarmament with the United States and Russia that could win the support of middle powers and international civil society.

If the looming breakdown in the global nuclear order is to be averted, and the dangers of nuclear war to be lessened, new ideas and political coalitions need to gain ascendance. The initiatives proposed here intended to stimulate the sort of analysis and debate from which such ideas and coalitions can emerge.

Introduction

In an interview for the television film World Order 2018*, Russian President Vladimir Putin explained that if Russia's warning systems detected an enemy attack with nuclear-armed missiles he would order "reciprocal" nuclear strikes. "If there is this decision to destroy Russia then we have a legal right to respond," Putin said. "Yes," he acknowledged, "this would be a global catastrophe for humanity but I, as a citizen of Russia and the head of the Russian state, would like to ask you this—what do we need a world for if there is no Russia in it?"*[1]

For decades, policy debates in nuclear-armed states and alliances have centered on the question, "How much is enough?"[2] What size and type of arsenal, and what doctrine, are credibly threatening enough to deter given adversaries? Game theory and historical models of deterrence and conflict escalation have animated these debates. (Domestic political-economic interests also determine the size and features of nuclear arsenals, of course.)[3] The more urgent question today is, "How much is too much?" What size and type of arsenal, and what doctrine, are too likely to produce humanitarian and environmental catastrophe that would be strategically and legally indefensible?

Most governments and civil society organizations insist that any number greater than zero is too much.[4] Prohibition should be the order of the day. Conversely, in Russia and the United States, influential actors want to increase capabilities to dominate potential escalatory contests (or at least to deny such capabilities to adversaries). Similar dynamics appear on smaller scales in China, India, and Pakistan. Yet prohibitionists and escalation dominators both divert the debate from the most urgent and achievable imperative, which is to "lessen the danger of nuclear war," as called for in the 2010 Nuclear Non-Proliferation Treaty (NPT) Review Conference.[5] This imperative requires governments to 1) physically reduce the probability that use of nuclear weapons would lead to humanitarian and environmental catastrophe, not only in belligerent states but also in states uninvolved in such conflict, while 2) not increasing the risks of aggression that nuclear weapons could plausibly be necessary to defeat.

This paper proposes two initiatives to help mobilize pursuit of these twin objectives.

One would involve nuclear-armed states, perhaps with others, commissioning suitable scientific experts to conduct new studies and international debates on the probable climatic and environmental consequences of nuclear war. Such studies would benefit from recent advances in modeling, data, and computing power. They should explore what changes in numbers, yields, and targets of nuclear weapons would significantly reduce the probability of nuclear winter.

The second initiative would query all nuclear-armed states whether they plan to adhere to the law of armed conflict in deciding if and when to detonate nuclear weapons, and if so, how their arsenals and operational plans affirm their intentions (or not)? The United Kingdom and the United States have committed, in the words of the 2018 Nuclear Posture Review, to "adhere to the law of armed conflict" in any "initiation and conduct of nuclear operations."[6] But other nuclear-armed states have been more reticent, and the practical meaning of such declarations needs to be clarified through international discussion.

The initiatives discussed below should be difficult to resist on their merits. The destructive capacity that Putin invoked is too much for anyone to have. Much less is necessary to deter rational actors;[7] it is impossible to know if more would be sufficient to deter irrational ones.

The initiatives proposed here are meant to appeal to more influential states than do the agendas of prohibitionists or escalation dominators; the notion is that those states could then attract and/or press one or more nuclear-armed states to join them. The most likely candidates would be the United Kingdom and China. They doubt the wisdom or practicality of pursuing escalation dominance and want to reinforce the global nonproliferation regime. China could be most important. Its power is growing. Its nuclear posture has always been relatively restrained but could change. It could gain much needed international soft power by leading an effort to significantly lessen the danger of nuclear war.[8] However, Chinese leaders would be unlikely to overcome their traditional reticence on these issues without international encouragement. This could be provided by middle powers in Europe and Asia that support the agenda proposed here.

Expertise is another problem. At the inaugural U.S. State Department conference on "Creating an Environment for Nuclear Disarmament," in July 2019, a number of officials from various governments noted that, as valuable as those discussions were, their governments do not have the human and financial resources to attend additional such gatherings. Given the yearly burdens of staffing NPT Preparatory Committee meetings, Conference on Disarmament sessions, United Nations (UN) First Committee sessions, and others, the teams that most governments devote to such work are too small and underfunded to do much more.

A related challenge is that international discussions on nuclear policy tend to be staffed by foreign ministry representatives. Yet, in actual nuclear policy making, inputs from military and technical experts are necessary (for political and bureaucratic reasons, as well as others). The fact that no government has mobilized human and financial resources to model in detail how global nuclear disarmament should be defined, verified, and enforced indicates the need for projects and forums that will stimulate thinking about these challenges. The Treaty on the Prohibition of Nuclear Weapons (TPNW) elided this set of issues, leaving them to individual nuclear-armed states to resolve

if and when they seek to join the treaty. The initiatives proposed here could mobilize at least some states to begin building the capabilities that more ambitious projects such as multilateral arms reduction and disarmament treaties will require.

This paper begins by summarizing some major premises about the prospects of nuclear disarmament, the risks of nuclear war, and the implications that can be drawn from variations among nuclear-armed states' arsenals and approaches to nuclear deterrence and war. These premises suggest that states and civil society organizations should focus on, first, avoiding conflicts that would most readily escalate to nuclear war, and second, limiting the potential destructiveness of nuclear arsenals. These objectives combine desirability and feasibility better than prohibition and escalation dominance do. The next part describes the two initiatives that could guide states toward defining how much is too much. The concluding section addresses additional political factors that would likely determine their effectiveness. The Appendix explores the leading assertions and arguments that would likely be made against moving away from escalation dominance to "accountable" deterrents.

Most of the discussion here operates in the dominant framework of national security and deterrence discourse, with the addition of legal and environmental considerations that traditional studies have neglected.[9] Due to space constraints and a desire not to distract from the main arguments, adequate attention is not given to domestic political, economic, and psychological factors that also influence governments' determinations of what instruments and policies are "necessary" to deter or defeat threats. These domestic drivers are especially prevalent in the United States and Russia.

Premises: Zero is a Diversion, and the Operative Question Should Be How Much is Too Much?

The following premises explain why the initiatives proposed below combine desirability and feasibility better than the near-term priorities of escalation dominators and prohibitionists do.

1. The five nuclear-weapon states have "unequivocal[ly] undertaken to accomplish the total elimination of their arsenals." They did this at the first NPT Review Conference (in 2000) reflecting the bargain in which non-nuclear-weapon states agreed in 1995 to indefinitely extend the NPT. However, the nuclear-weapon states are not now demonstrating serious intentions to fulfill this commitment. Moreover, Israel, India, and Pakistan possess nuclear weapons, never signed the NPT, and have not made disarmament commitments.
2. States with nuclear weapons cannot be forced to disarm. That is, they can't be coerced without running the risks of nuclear war, which is the risk that disarmers seek to eliminate in the first place. Therefore, these states will have to be persuaded to eliminate their nuclear arsenals.

3. Most, if not all, nuclear-armed states believe that nuclear deterrence works, and these governments are unpersuaded by arguments to the contrary.

Putin expressed this view in a June 2019 interview with the *Financial Times*: "You know, the entire history of mankind has always been full of military conflicts, but since the appearance of nuclear weapons the risk of global conflicts has decreased due to the potential global tragic consequences for the entire population of the planet in case such a conflict happens between two nuclear states."[10] The 2018 U.S. Nuclear Posture Review makes the same point in similar words.[11]

It is nearly impossible to prove that nuclear deterrence has or has not been effective.[12] As long as governments believe that nuclear weapons spare them from devastating aggression, they and their citizens will be reluctant to gamble that deterrence will persist without those weapons.[13] Of course, some governments and societies also value nuclear weapons for prestige and general national power, though they make deterrence the explicit rationale.

4. Threats of major *non-nuclear aggression* from more powerful adversaries drive some states' retention of nuclear weapons.

Even if all other states were willing to eliminate their nuclear arsenals, some perceive non-nuclear threats that they fear they cannot confidently deter or defeat without nuclear weapons. Leaders in Russia, some North Atlantic Treaty Organization (NATO) states, Pakistan, and China's eastern neighbors evince this view.[14]

5. The key nuclear problem is escalation: No one knows whether escalation of nuclear war after first use would be kept limited.

"Disarmers say escalation can't be controlled," notes Linton Brooks, the lead negotiator of the Strategic Arms Reduction Treaty (START) and former administrator of the United States National Nuclear Security Administration. "I say I don't know if it can be."[15] There are no data. The only time nuclear weapons were used, by the United States in 1945, the opponent did not have a countervailing nuclear capability. As Michael Quinlan concluded after decades of policymaking practice and study, "Anyone, however eminent, who tells us that escalation is a certainty, or who purports to put a tidy picture of percentage probability upon it is talking through his hat."[16]

The challenges of escalation are most consequential in contests between roughly evenly matched militaries and nuclear forces that are poised to conduct sequential nuclear counterforce operations.[17] The United States and Russia, and India and Pakistan are the two dyads most relevant today.

Keir Lieber and Daryl Press offer a succinct description of how the United States has pursued escalation dominance (or damage limitation):

> The United States is intentionally pursuing 'strategic primacy'—meaning that Washington seeks the ability to defeat enemy nuclear forces (as well as other [weapons of mass destruction])—but that U.S. nuclear weapons are but one dimension of that effort. In fact, the effort to neutralize adversary strategic forces—that is, achieve strategic primacy—spans nearly every realm of warfare: for example, ballistic missile defense, antisubmarine warfare, intelligence, surveillance-and-reconnaissance systems, offensive cyber warfare, conventional precision strike, and long-range precision strike, in addition to nuclear strike capabilities.[18]

Russian military strategists pursue similar objectives. In the words of Dave Johnson, a NATO expert on Russian military thinking:

> The opening of direct military conflict would represent the failure of Russia's primary theory of victory: to achieve its aims below the threshold for war. This would open operations in line with Russia's second theory of victory, which relies on calibrated damage and escalation control to compel adversary capitulation.[19]

Such escalation—which U.S. planners also envision—would likely begin with non-nuclear instruments and operations.[20] If those failed to produce the desired gains, including de-escalation, then nuclear weapons could be used, initially in ways limited enough to avoid triggering massive escalation. In the words of a 2016 Russian publication,

> The limited nature of a first nuclear strike, [would be] designed not to harden, but rather to sober up an aggressor, to force it to halt its attack and move to negotiations. In the absence of the desired reaction, provision is made for increasing the mass of nuclear weapons brought to bear, both in quantitative terms as well as their energy emission (that is, destructive power). Therefore . . . a nuclear first strike by the Russian Federation could have a limited character.[21]

Of course, as Dave Johnson concludes, "It is uncertain if the untested theory of . . . escalation control, would hold up under the stress of war."[22]

The larger the arsenals, the more tempting it becomes for strategists and operators to pursue escalatory doctrines. And, the larger the arsenals—in numbers and explosive yields—the more catastrophic escalation can be. (Circularity often obtains here: escalatory strategies may call for the production of larger arsenals; when large arsenals exist, they may invite escalatory planning. Factors

beyond deterrence theory and international security calculations influence states' decisions regarding numbers and types of nuclear weapons and delivery systems to develop and deploy. Military service rivalries, bureaucratic politics, military-industrial complex lobbying, and factional political competitions are among other factors that have influenced such decisions.)

The proclivity of large arsenals and attendant operational doctrines to produce escalation was vividly recounted by the commander of U.S. Strategic Command in July 2018. Speaking to a sizable audience, General John Hyten described a "big exercise" that his command conducted that February. "I just want you to ask in your own head, how do you think it ends? It ends the same way every time. It does. It ends bad. . . . Meaning it ends with global nuclear war," Hyten said.[23] Hyten continued by describing how the chairman of the Joint Chiefs of Staff at that time, General Joseph Dunford, and the entire Joint Staff observed the exercise from the National Airborne Operations Center. "As soon as the NAOC landed after the exercise was over," Hyten recalled, Dunford

> called me, like within seconds. And I'll just say General Dunford wasn't happy with the way the exercise went. He said we should provide the President more options, not fewer options. And the way the process was driving down, we were providing very few options. . . . So the goal is to provide more options to the President to give him options to de-escalate a conflict, not just escalate a conflict. To get us off that escalation ladder. . . . I don't know how many times I've said I don't want on the escalation ladder, I want off the escalation ladder. That's the point. And for whatever reason, the whole structure of the command was about the escalation ladder.

Among the many remarkable things in General Hyten's candid description is the fact that the predilection/drive for escalation remains after decades of reported efforts to fix it.[24] Nuclear weapons have not been detonated in war since 1945, and war games in the United States and perhaps elsewhere have shown that political leaders are reluctant to initiate nuclear use.[25] But, as the experience recounted by Hyten indicates, once nuclear deterrence has failed, escalation is extremely difficult to contain. [26]

6. Even if escalation dominance could strengthen deterrence, its pursuit leads to costly and destabilizing arms racing.

Escalation dominators seek to develop and deploy combinations of offensive and defensive weapons that could enable them, at least conceivably, to win exchanges at each potential level of contestation, or at least to disabuse adversaries from thinking that *they* could win such contests. Ideally, one's adversaries will perceive this dominance and then be deterred from starting a conflict and/or escalating.

In practice, however, adversaries often contest each other's attempts at dominance. This contestation certainly occurs through arms racing, as seen between the United States and the Soviet Union/Russia, and India and Pakistan. Each competitor seeks to achieve a breakthrough in offensive or defensive technologies that its opponents cannot effectively counter (at least for some time). And, when conflict occurs, military leaders in these states say they will seek to win escalatory competition.

However, such scenarios entail major gambles.[27] A crisis or conflict could occur in the midst of the arms race, before either side has achieved an effective advantage. The mindsets and capabilities then in place could lead to escalation that would leave one or both competitors worse off than if they had pursued more restrained policies. Or, the state(s) that began the quest for escalation dominance assuming it had superior, or at least adequate resources, could find that its population tires of the risks and expenditure involved and turns against the leaders that authored the strategy.

7. The probability and consequences of escalation vary with the sizes and qualities of states' nuclear arsenals and approaches to first use; the abnormality of the U.S. and Russian arsenals and approaches deserves more attention.

The large nuclear forces and ambitious operational and targeting plans of the United States and Russia are abnormal. Russia now stockpiles roughly 4,490 total nuclear weapons and the United States 3,800. The two possess 92 percent of the world's nuclear weapons. The next largest arsenal—France's—contains 300, followed closely by China's. It is noteworthy that the seven states with much smaller arsenals have not faced aggression of the scale and danger that has brought them close to needing to launch nuclear weapons. Among other things, this suggests that the United States and Russia could deter each other (and additional adversaries) with much less if they were unencumbered by the nuclear baggage accumulated during the Cold War. There is no historical evidence that deterring major aggression and the escalatory use of nuclear weapons requires the theoretical capacity to *win* a nuclear war.[28] The threat of being *in* nuclear war has been enough thus far to deter the type of aggression that would necessitate use of nuclear weapons by any state.

Nuclear-armed states also vary in their thinking, planning, and rhetoric regarding the first use of nuclear weapons and the viability of limiting nuclear war. Setting aside important nuance for the purposes of brevity and illustration, China, India, and Israel have conveyed that they would not be the first to introduce or use nuclear weapons in a conflict.[29] The United Kingdom and France do not specify whether and under what circumstances they would be the first to use nuclear weapons in a conflict.

The United States, Russia, and Pakistan are the only states that profess the viability of limiting nuclear war (escalation) as a central element of their nuclear doctrines.[30] French presidents, probably like others, have envisioned the possibility that "demonstration" detonations of one or a few nuclear weapons could signal resolve that would deter adversaries (probably Russia) from escalating a war and existentially threatening France.

Chinese leaders have perceived diminishing returns in arsenals beyond a minimum survivable force. They have eschewed quests to match, let alone to achieve nuclear escalation dominance over the United States (and Russia). Chinese leaders reject notions that nuclear war can be limited or successfully undertaken through finely calibrated nuclear counterforce escalation. This does not mean that China eschews strategic military competition or development of survivable nuclear and non-nuclear capabilities to deter and defeat the United States and other adversaries. Rather, the point is that China treats nuclear weapons differently than the United States and Russia do.

International concerns and politics arguably would be much different if no one had enormous arsenals and operational plans for using them in escalatory competition that would produce global humanitarian catastrophe. If no one had more than, say, 300 relatively low-yield nuclear weapons, would the rest of the world be better off and become more willing to cooperate in preventing proliferation and use of any weapons of mass destruction?[31] (See the contours of likely debates below and in the Appendix.) The simple point here is that Russia's and the United States' large arsenals and escalatory capabilities and plans are abnormal, and there are interests that should be considered beyond those that strategists of escalation dominance normally address. These interests are more likely to be addressed if international debate focuses on how much is too much.

In sum, complete nuclear disarmament appears infeasible at present. Focusing on this objective creates a straw man that advocates of escalation dominance attack to divert attention from the dangers of the status quo and the imperative of preventing escalatory warfare. International security and equity would benefit from the physical bounding of the destructiveness of escalatory nuclear war. The greatest threat of such escalatory war stems from the policies and forces of the United States and Russia. The policies and forces of other nuclear-armed states indicate alternative possibilities to maintain nuclear deterrence with significantly less risk. Indeed, U.S. policymakers for decades have sought to prevent Iran and North Korea from obtaining or retaining even a handful of nuclear weapons in part because such weapons could deter the United States from contesting their aggression (or removing their regimes). This indicates the basic deterrent effect of much less destructive nuclear arsenals.

Ask Different Questions to Get Better Answers: Two Initiatives to Constructively Guide International Nuclear Politics

The following two initiatives would foster analysis and debate on the question, How much is too much? These initiatives address important, legitimate concerns about humanitarian and environmental effects of nuclear war. These concerns have been raised by non-nuclear-weapon states and civil society. They have been largely ignored by nuclear-armed states and the security studies literature.[32] Conceptualizing, analyzing, and debating "accountable" nuclear deterrents could be done without undermining any other national and international security interests or disarmament commitments. Accountable deterrents would be those that can be justified in strategic, legal, and environmental terms to all populations -- not just one's own population -- more persuasively than escalation dominance or near-term prohibition can be.

The initiatives proposed here could be undertaken by a collection of states, by the United Nations, and/or by civil society. The scale and ambition could be as large as the Intergovernmental Panel on Climate Change, or as modest as the Conferences on the Humanitarian Impact of Nuclear Weapons. Both have been impactful, even if they have been insufficient to motivate the range of actors and actions necessary to "solve" the problems they address. This is the reality of international politics. Progress is usually incremental and is often followed by stasis and regress, and then, hopefully, progress again. If at least some nuclear-armed states agree to pursue these initiatives, they would create an opportunity for non-nuclear-weapon states to demonstrate that they are willing to continue engaging in the give-and-take that progress in international politics always requires.

1. **What changes in the numbers, yields, and targets of nuclear weapons would significantly reduce the probability that nuclear war would produce severe climatic change—nuclear winter?**

Summary: Data and models to assess the potential climatic effects of various scenarios of nuclear war have improved enormously since the prospect of "nuclear winter" first emerged in the 1980s. Potential effects could severely harm not only the populations of belligerent states but also nations far from the conflicts. The material interests of all nations would be served by a better understanding of the factors that would make catastrophic environmental and agricultural consequences of nuclear use more or less probable. Such assessments could then inform judgments about what levels of nuclear weapons—numbers and explosive yields—and targeting plans are "too much" for even "winners" of nuclear war to tolerate. Nuclear-armed states and others should be encouraged to conduct new studies to address these issues, and to participate in international dialogues on the merits and implications of these studies.

Concerns about the environmental consequences of nuclear war have ebbed and flowed since the 1950s. Then president Dwight Eisenhower, in 1955, warned Soviet officials that fallout from detonations of "two hundred H-bombs . . . might destroy entire nations." [33] His counterparts agreed, leading the historian John Lewis Gaddis to conclude, "There had emerged, then, by early 1956, an impressive international consensus on the *ecological* consequences of a nuclear war: the entire northern hemisphere might well become unliveable (sic). . . . The next step, one might think, would have been cooperation, as the highest priority, to remove the danger."[34]

It took decades more. In 1982–83, two U.S. research groups and one Soviet group published studies positing that exchanges involving the then-deployed nuclear forces of both countries would cause devastating fires, particularly in urban areas.[35] The intensity of such fires could produce sufficient heat to loft soot into the stratosphere in ways that could block sunlight and lower temperatures and precipitation over wide swaths of the globe.[36] Global agricultural productivity could be severely reduced.

These assessments engendered fierce debate among atmospheric scientists, nuclear weapon establishments, and international civil society.[37] Then president Ronald Reagan and general secretary Mikhail Gorbachev both cited concern about environmental risks as motivations for agreeing to eliminate intermediate-range nuclear weapons from Europe in the 1987 Intermediate Nuclear Forces (INF) Treaty. The Cold War ended shortly thereafter. Significant reductions in U.S., Soviet, French, and UK nuclear arsenals ensued. Attention to the climatic consequences of nuclear war dissipated.

Twenty years later, improvements in computing power and climate modeling and the intensifying nuclear arms competition between India and Pakistan gave renewed impetus to analyzing possible climatic consequences of nuclear war. A study by Alan Robock et al. and another by Owen B. Toon et al., both published in 2007, calculated that a nuclear conflict between India and Pakistan involving fifty detonations of Hiroshima-yield weapons in urban areas in each country could produce fires of a scale and intensity to cause global-wintering effects.[38] Decrease in global average temperatures would significantly shorten growing seasons, while diminished precipitation would impair growth of food crops. Subsequent simulations by additional researchers predicted 20 percent reductions of soybean and corn production in the midwestern United States, and of rice in China for several years, and 10 percent for up to a decade.[39] Such declines in agricultural production could profoundly harm both producers and consumers of food worldwide, especially those who could least afford the scarcity prices that would result.[40]

Proponents of nuclear weapons and other observers counter that the risks of nuclear winter are much less certain than the extant studies claim.[41] Scientific uncertainty would suggest that nuclear war "could" cause nuclear winter; disarmers often assert that it "would." While that semantic correction is

important, uncertainty does not negate the need to understand how variations in nuclear forces and targeting could raise or lower probabilities of climatic catastrophe.

Nuclear policy makers generally have ignored these issues even as the salience and scientific understanding of climatic change have grown.[42] As Linton Brooks, an arms control negotiator and former administrator of the U.S. nuclear complex, notes:

> Nuclear winter has not come up in the circles in which I move. . . . In policy terms, I don't dismiss it. I believe it's real. But I don't feel any more or less worried about nuclear exchanges when I read about nuclear winter. . . . The notion of the global food supply being badly disrupted is important. But once again, I already know that nuclear war would be horribly harmful. . . . The Southern Hemisphere would feel the burden. I could see that, but not how it mattered to the deterrence mission we were working on. . . . It doesn't alter my policy view that deterrence through the threat of nuclear retaliation is a horribly flawed strategy, but it's the best one we've got.[43]

Citing Russian and U.S. studies from the 1980s, Russian military experts have invoked the possibility of "nuclear winter" or "nuclear night" as reason to exclude "full scale" nuclear operations against (presumably) the United States. But, like counterparts in the United States, they postulate that "strictly limited" nuclear strikes with low-yield weapons on a small number of targets could be viable.[44]

Chinese scholars and scientists took cognizance of the mid-1980s U.S. and Russian nuclear winter studies and published several reports and studies that summarized the issues involved.[45] However, there is little public record that considerations of climatic effects have influenced Chinese nuclear force and operational planning.

In India and Pakistan, no serious study or attention has been paid to these issues, at least in publications and official discourse. "There has been very little thinking and talking in India about the consequences of nuclear weapons use, especially now," according to the veteran Indian national security journalist Manoj Joshi. "No one has picked up on the Robock studies and talked about them."[46]

In general, states engaged in what appear to be existential conflicts with militarily stronger adversaries will be unlikely to fear the potential risks of nuclear winter more than the immediate consequences of holding their nuclear fire and accepting defeat. This perspective is especially likely in states suffering nuclear attack while defending their own territory.[47]

Many escalation dominators and others resist addressing the possibility of nuclear winter because they think it could undermine deterrence. As Franklin Miller, a longtime U.S. nuclear policy maker puts it, "no one has defined what the threshold of numbers, yields, targets would be that would cause nuclear winter. And there's a risk also of Putin playing bully boy and saying, 'go ahead, you go ahead and cause nuclear winter,' and then we are self-deterred."[48]

Nuclear prohibitionists are less likely to oppose international scientific study and discussion of climatic effects of nuclear war. But they will be tempted to argue that prohibition of all nuclear weapons must be the priority, and that seeking less environmentally threatening nuclear postures would still wrongly preserve reliance on nuclear deterrence.

Both groups of skeptics do not adequately address two important facts: whether or not complete nuclear disarmament is desirable and feasible, it will take decades to implement and verify. In the meantime, some form of nuclear deterrence will remain. Reducing the threats that nuclear arsenals pose to the global environment and food supply would recognize the interests of nonbelligerent nations in ways that nuclear states have not done to date. A new appreciation of these interests could occur if studies demonstrated that the United States, China, and Russia could be severely harmed by climatic effect of nuclear war between India and Pakistan, for example, especially if these antagonists attack each other's cities. Thus, rather than ignore or deflect concern about the possibility of nuclear winter, and how nuclear arsenals and policies could be adjusted to reduce it, why not address these issues? After all, if weapons and plans for escalation dominance could limit the damage an adversary could inflict directly on a state, but would still cause agricultural crisis in its society or that of its neighbors, then even a winning counterforce "damage limitation" strategy would be self-defeating.

The "greatest uncertainty" in computing the climate after nuclear war "is how many weapons would be used, what yields would be employed, and which targets would be chosen," according to the authors of a 2019 study of the subject. [49] Thus, as Raymond Jeanloz, a University of California, Berkeley professor of earth sciences suggests, new studies should specifically consider scenarios that vary "the individual locations and sizes of nuclear explosions relative to fuel loading" of targets.[50]

Assessing the environmental implications of various arsenals and policies could be done in any number of ways. The basic idea is merely sketched here.

Nuclear-armed states could volunteer (or be requested by the NPT Review Conference or UN General Assembly) to enlist world-recognized scientists with relevant expertise to model likely climatic effects of nuclear-use scenarios that these states think are relatively plausible. If nuclear-armed states are reluctant to proffer such scenarios, the United Nations Office for Disarmament Research or the United Nations Institute for Disarmament Research (UNIDIR) could enlist

international experts to pose scenarios that could be feasible given publicly available descriptions of the arsenals and doctrines of the United States/NATO and Russia; the United States and China; India and Pakistan; and North Korea and the United States. In each postulated nuclear conflict, scenarios should range from low to medium to high in terms of the numbers and yields of weapons used, and the extent of fires likely to be produced as a function of the environments in which detonations occur (such as, urban versus remote; forested versus oceanic or desert). Whatever scenarios are studied, at least some version of the results should be made available for public review and analysis. Nuclear-armed states should be pressed to agree to deploy relevant experts to participate in international forums to discuss these studies.

Nuclear-armed states will naturally question studies conducted by others, much as advocates of nuclear disarmament will doubt studies done by nuclear weapons establishments. This is why at least some versions of studies undertaken by nuclear weapons establishments should be made public, and why conductors of such studies and their potential scientific critics should commit to participate in forums to discuss and debate them. Nuclear-armed states should be requested to fund studies by their national academies of science, weapons laboratories, and other relevant researchers. Other governments and philanthropies would be asked to fund reviews of these studies and/or the conduct of competing studies, as well as international meetings to debate them.

If models of climatic effects of plausible nuclear-war scenarios indicate little risk of agricultural or other catastrophe, then nuclear-armed states will have a stronger basis for retaining weapons and policies that could produce those scenarios. (Other arguments for reductions still could be validly made.) Conversely, if multiple scientific studies, openly debated by governments and independent scientists, identify scenarios of detonations that would likely produce severe environmental and agricultural harm beyond the populations of the belligerent states, then it should be more difficult for states to justify retaining arsenals of the size, destructiveness, and targeting guidance that are likely to produce such harm. (For example, Alan Robock and Owen B. Toon, leading atmospheric scientists, suggest that reduction of U.S. and Russian arsenals "to about 200 weapons each," eschewing targeting of "cities and industrial areas, would allow both countries to maintain their nuclear deterrence and would prevent the possibility of killing the majority of humanity through nuclear winter."[51] Other qualified experts can challenge their scenarios, assumptions, and conclusions.)

Ultimately, a person's tolerance of uncertainty about the climatic effects—and fallout—of nuclear war may depend on where they live and whether their country is the one facing the threat that cannot be defeated without use of nuclear weapons, or if their nation does not benefit from nuclear deterrence but could be severely harmed by environmental effects of nuclear war.[52] For example, if high quality studies conclude that a plausible nuclear war between India and Pakistan would severely

decrease U.S. production of vital crops such as corn and wheat, U.S. officials and citizens might feel greater urgency in trying to create conditions to reduce the probability of such an outcome. Indeed, the nuclear policies and arsenals of the United States, Russia, and China affect and are affected by each other. China's capabilities and perceived intentions, in turn, affect the policies and capabilities of India and Pakistan. Thus, these five states affect each other's vulnerability to potential climatic consequences of nuclear war. Reducing this vulnerability will require efforts by all of them.

Nuclear-armed states to date have based their policies and arsenals largely on how much they think is enough to deter given adversaries. They have not adequately accounted for how the environmental effects of their forces and plans could harm their own populations and, less justifiably, the populations of nonbelligerent states. Prevention (or minimization) of nuclear climatic catastrophe can become a physical standard for determining how much is too much.[53]

2. Do nuclear-armed states (and allies) plan to adhere to international humanitarian law (IHL) if and when they detonate nuclear weapons? If so, how do various arsenals and operational plans reflect their intentions?

Summary: Nuclear-armed states insist that they are responsible stewards of these weapons which they retain only for legitimate defensive purposes. Thus, it is fair to ask them to explain whether and how they plan to adhere to IHL (also known as the law of armed conflict, LOAC) in the potential conduct of nuclear operations. Further, they should be requested to engage in international dialogue on whether and how variations in explosive yields and numbers of weapons and their targets increase or decrease the probability that use of nuclear weapons would comport with IHL, including environmental considerations.

Norway and Mexico organized international conferences on "The Humanitarian Impact of Nuclear Weapons" in March 2013 and February 2014. Most nuclear-armed states chose not to attend. India and Pakistan sent observers. The third such conference was held in Vienna, in December 2014, and was attended by officials from the United States and the United Kingdom, with India and Pakistan (and perhaps China) sending observers.[54] The nonengagement of nuclear-armed states, arguably, eased the way for non-nuclear-weapon states to negotiate the TPNW, which declares that no use of nuclear weapons could comport with international humanitarian law.

Notwithstanding the TPNW, the legal and political issues surrounding the potential use of nuclear weapons remains unsettled. The United States, for example, in the 2013 Defense Department report on nuclear weapons employment policy and in the 2018 Nuclear Posture Review, affirmed, in the words of the Trump administration posture review, the commitment to "adhere to the law of armed conflict [in any] initiation and conduct of nuclear operations."[55] The United Kingdom similarly

insists that its "nuclear deterrent is entirely consistent with international law."[56] Some other nuclear-armed states do not speak to these issues. Drawing nuclear-armed states (and allies) into serious discussions of what such declarations and commitments mean is vitally important for several reasons.

First, in the current confrontational international environment it would benefit the cause of peace and security if influential states reminded themselves and the world why international humanitarian law is important. This body of law was created because war is often hell, and no one wants to live in hell. More narrowly, military personnel who could be ordered to conduct nuclear attacks—and their families—do not want to live with the horror of being involved in actions they will regret if they survive. The prospect of the most hellish types of war produces widespread anxieties and allocations of resources that undermine everyone psychologically, morally, economically, and politically. These costs come from measures to defend against such wars, and from fears of the widespread catastrophic consequences if deterrence and defense fail. Thus, states—especially since World War II—have determined it would be better to have some norms, rules, or laws that could limit destructiveness, even at the expense of reassuring their potential adversaries too.

Of course, obtaining compliance with and enforcement of international norms and laws is always challenging. Winners of conflicts are particularly difficult to hold to account for violations of such norms and laws.[57] Yet, even if effective prosecution and enforcement of judgments are unlikely, sustained airing of legal considerations can influence nuclear policy debates *before and during initial stages* of conflicts that have clear potential to escalate to the use of nuclear weapons. This restraining function, however modest it may be, is a second reason for pursuing this initiative.

Third, clarifying which states publicly commit to follow international humanitarian law would help focus domestic and international attention on those nuclear-armed states that either ignore the question or reject the applicability of LOAC. Of course, some relevant governments do not allow domestic mobilization and debate on such issues. Yet, this does not mean that these governments are immune from domestic spillovers of international pressure.[58] Greater international attention to these issues would attune media and others to respond more intensely and knowledgeably when officials threaten to use nuclear weapons. Such debates could educate current or future leaders who are unaware of the requirements of international law and the rationale behind them.[59]

Fourth, elucidating legal considerations—and the difficulties of actually enforcing post facto judgments—can help focus international politics on the underlying imperative of preventing aggression in the first place, especially aggression of the type that could make use of nuclear weapons appear necessary and proportionate. If it is doubtful that nuclear weapons would be used in ways that comport with the LOAC, then the imperative becomes clearer to prevent such aggression. "The

central aim must remain prevention," the longtime British defense official Michael Quinlan reminded. "That is, preventing the whole process of [major] war from ever starting."[60] This would entail greater attention to resolving underlying disputes, strengthening non-nuclear defenses, and identifying off-ramps to de-escalate conflicts.[61]

Fifth, arsenals and policies that would be more likely to comport with the law of armed conflict would provide more credible and therefore more effective deterrence. And, if deterrence failed, understanding whether and how variations in numbers, yields, and targets of nuclear weapons could change the probable humanitarian (and environmental) effects of nuclear-weapons use could save lives. Detonations in urban areas of even "low-yield" nuclear weapons would still be so enormously destructive as to inhibit any sane and informed leader; the point is that current arsenals are excessive in all dimensions. (The justices who issued the International Court of Justice's 1996 opinion on the legality of the threat or use of nuclear weapons said they lacked "a sufficient basis" for determining whether limited uses of "low yield, tactical nuclear weapons" would or "would not tend to escalate into the all-out use of high yield nuclear weapons."[62] The drafters of the TPNW decided not to ask the question.)

To put this another way, engagement on the questions related to international humanitarian law, paired with considerations of climatic effects of various nuclear-use scenarios, could establish new, relatively widely supported criteria for sizing, targeting, and using nuclear forces. The law of armed conflict already informs some states' selection of targets. This criterion could be complemented by the need to reduce climatic effects from fires. Both of these imperatives could alter the level of certainty that nuclear war planners "require" for destroying targets. Requirements of near certainty often raise the number and explosive yields of weapons sought by military planners, though strong arguments could be made that general deterrence would be effective with less demanding requirements.[63] In moral, legal, environmental, and strategic terms, yields of weapons should be the minimal necessary to make adversary leaders conclude that targeted objects are likely to be destroyed if they (the adversaries) commit aggression or persist in one that is already under way. Conventional weapons should be the first choice, as Jeffrey Lewis and Scott Sagan have reminded.[64] But, if conventional weapons are insufficient, then the lowest possible nuclear yield should be used.

Many weapons in today's arsenals are more destructive than they need to be because they were produced and deployed before improvements in accuracies of delivery systems were achieved. To be sure, replacing them would entail significant cost and political controversy. Many will argue that lower-yield weapons would "lower the threshold" for their use and make nuclear war more likely. This neglects the fact that even "low-yield" nuclear weapons, say 5 kilotons, would cause unprecedentedly immediate and massive destruction of urban environments.[65] Moreover, critics

would not morally and legally argue in principle for higher-yield weapons. If deterrers favor lower-yield weapons because they believe such weapons will make war less likely, including nuclear war, this should not be an argument against reducing yields.

One can also imagine that if, say, the United States transitioned to an arsenal comprised mainly of lower-yield weapons, but Russia did not, escalation dominators would decry a "yield gap." Arms control has been pursued to attenuate or close such gaps in the past. But, it would probably be impossible to verify yields of deployed nuclear weapons.[66] Nevertheless, the interests served by IHL and reducing risks of nuclear winter should outweigh the imagined benefits of excessively destructive warhead yields. This is a debate worth having.

(The imperative of physically bounding the destructiveness of nuclear conflict is explored further in the Appendix, with arguments for and against two alternative approaches: recessed deterrence based on dismantled arsenals, and "accountable" deterrence based heuristically on roughly 300 total weapons.)

States could explore the legal implications of various scenarios for nuclear operations in several ways. One obvious approach would be for parties to the NPT to call for the conduct of a series of international conferences to clarify whether and how states are prepared to apply international humanitarian law to the potential use of nuclear weapons, as discussed above. NPT review conferences and preparatory committees do not provide the time and necessary military, national security, and legal expertise to conduct such dialogue. But these meetings could put a suitable process in motion.

With or without the imprimatur of NPT parties, the Conference on Disarmament (CD) could establish a program of work along these lines. The consensus rule in CD decisionmaking would be an obstacle insofar as a single state could block such an initiative. If this obstacle could be overcome, the CD could invite states to provide the types of experts needed. CD members would then define the program of work.

Collections of diverse states, such as the Nonproliferation and Disarmament Initiative (NPDI), could offer to organize a forum to carry out the proposed dialogue. The NPDI's membership does not include most of the nuclear-armed states, so the participants in NPDI would need to be willing to invite others to participate in the process it would conduct. Such an effort would be more ambitious than the initiatives undertaken to date.

The United Nations could commission UNIDIR to produce one or a series of studies on these issues, which could be based on dialogues with representatives of nuclear-armed states and civil society experts.

Whether or not broader international forums could be established, parliaments in one or more states could organize meetings to which official and/or unofficial experts from relevant states could be invited to address these issues. Such meetings would not be as inclusive or systematic as the processes that the CD or UNIDIR might conduct, for example, but they could nonetheless generate interest in these issues and create pressure on nuclear-armed states to address them more fully.

If none of these modalities are feasible, philanthropists and governments could commission one or more suitable nongovernmental organizations to conduct studies of the issues presented here. Such studies should necessarily involve extensive interviews with relevant officials and experts in as many nuclear-armed states as possible, and international workshops in which participants with diverging views would participate. Such research and dialogue would then enrich the resulting publications.

All of this may appear quixotic. Yet, it is difficult to see how the current alarming impasse in international nuclear politics will be surmounted if greater clarity is not reached around criteria for sizing and wielding nuclear arsenals during the interim between today and complete nuclear disarmament. If some arsenals or doctrines are more likely than others to reflect the spirit and the always debatable letter of IHL, then states and experts should clarify this. States that do not want to be known as willing violators of IHL should make efforts to modify their forces and policies to better accord with such legal prescriptions. Negotiating agreement among the United States, Russia, China, India, Pakistan, the UK, and France to actually reduce and/or balance their military forces to this end is quixotic today, but there is no reason why analysis and debate necessary to conceptualize such a collective shift could not begin now.

Conclusion

Today's political dynamics thwart efforts to reinvigorate or reinvent global nuclear order. To be more precise, policymakers, defense contractors, and other influential actors in some governments are attenuating the physical restraints and political compromises on which nuclear order depends. Meanwhile, resisting these trends, prohibitionists are questioning the value of compromising too. The status quo is intolerable to both groups: escalation dominance is too much for one, and disarmament is too much for the other. Progress out of this deadlock may require initiative from other actors.

In 2009, knowledgeable practitioners and analysts concluded that the most feasible yet still ambitious agenda for reconciling nuclear deterrence and disarmament was "minimization," in the words of the International Commission on Nuclear Nonproliferation and Disarmament (ICNND). This commission involved representatives from fifteen countries including the five NPT nuclear-weapon states and India and Pakistan. It posited that "minimization" should entail *by 2025* the "general delegitimation of nuclear weapons," reductions to "low numbers" totaling "no more than 2,000 warheads" worldwide, adoption of no-first-use doctrines by all nuclear-armed states, and corresponding de-alerting measures.[67]

Eight years later, in a more fractious political environment, the veteran U.S. NPT diplomat Lewis Dunn called similarly for a "redefined global nuclear-disarmament agenda."[68] Dunn suggested that 2045 could be an ambitious-yet-realistic timeframe to achieve the "strategic elimination of nuclear weapons."[69] This envisions that "the use of nuclear weapons would have been ruled out as a policy option by all of the world's current (and any future)" nuclear-armed states. The numbers of nuclear weapons in this 2045 world "could range from the low tens to the very low hundreds," but none would be operationally deployed.[70] Most missile and aircraft delivery systems dedicated to delivery of nuclear weapons would have been eliminated or taken off alert and mothballed.

The ICNND and Dunn analyses and recommendations were penetrating. Yet, neither provided objectives or standards to guide the reduction process. What level of weaponry is too much, from the standpoint of physically containing the danger of catastrophe not only to belligerents but also to nonbelligerent nations? How can nuclear arsenals and doctrines be made more consonant with international law?

While prohibitionists insist that no threat or use of nuclear weapons is legally tolerable, states will retain nuclear weapons for the foreseeable future and will claim to be responsible stewards of them. In return for toleration of that reality, nuclear-armed states and allies at least ought to be willing to explore publicly what they could do to reduce the consequences of their potential use of these weapons. The issue is not only catastrophic harm to the warring nations, but also, or even more, to nonbelligerent nations. President Vladimir Putin, in the statement quoted at the beginning of this paper, invoked the right of defense. This suggests that legitimacy is important. But then he so cynically dismissed the rights of the rest of the world as to invite global demand for the types of measures highlighted in this paper, if not immediate prohibition.

A good friend who favors prohibition and disarmament read a draft of this paper and welcomed the questions it highlights. But, in the end he criticized me (nicely) for playing "Goldilocks." "You have to choose," he said, "either these weapons are okay or they are not."

Goldilocks may indeed represent the approach recommended here. Some nuclear policies and arsenals are too hard. Their proclivity to produce globally catastrophic escalation and destruction is too great. Such destructiveness is also demonstrably unnecessary, as other possessors of less destructive arsenals show. Conversely, nuclear "zero" is too soft for some states facing more powerful adversaries. This feeling is especially strong in states whose identity, institutions, and contending political leaders have become "nuclearized." History, personal interviews, and intuition tell me that even the seemingly most aggressive strongmen recognize that they can't overcome the power of nuclear weapons. Their constituents see this too. The supposedly strong leader and his devotees can say, "we would have gone to war and destroyed the enemy, but, you see, they have nuclear weapons. We are not crazy. We will have to be cleverer and find better ways to defeat them." Until Russia, China, the United States, India, Pakistan, Israel, and North Korea become much less militarized and threatening to each other and their neighbors, nuclear weapons will appear necessary to restrain their leaders from acting on their worst impulses. In the meantime, Goldilocks' interest in finding a mattress—an arsenal—that is not too hard nor too soft seems reasonable.

Of course, libraries are full of NPT Review Conference action plans and think tank policy papers recommending arms control and disarmament policies and treaties that could significantly improve international security. If political power is not mobilized behind them, and the United States and Russia continue to resist them, no progress will occur.

Under what conditions could the initiatives proposed here (or something like them) gain traction? First, a plurality of influential states—including in Europe and East Asia—and civil society actors would need to embrace one or more of them. In doing so, they would stake a position between the status quo and the imagined world of the TPNW. Leaders of such a grouping could then seek to persuade counterparts in one or more nuclear-armed states to join them as a way to prevent further disinvestment in the nuclear order. At that point, the plurality of supportive states and civil society actors would be larger than the number of populous states that prefer either nuclear escalation dominance or prohibition. With such a plurality—including at least one nuclear-armed state, and civil society organizations from other nuclear-armed states—the studies and debates proposed here could be launched.

China is pivotal. As discussed above, China's restraint in building its nuclear arsenal and in adhering to a doctrine of no-first-use has reflected sensitivity to the question, How much is too much? China has urged the United States and Russia to reduce their vastly greater nuclear arsenals. These calls have been ignored for decades. However, the Trump administration's demand for China to join the nuclear arms control process could create a new dynamic. The end of the INF Treaty and the prospective end of the New START open the field.

China could respond to invitations to join an extended New START, or a successor agreement, by inviting the United States and Russia to reduce their operationally deployed strategic nuclear forces to China's level. According to New START counting rules, this would require a seven to eight-fold reduction of U.S. and Russian forces.[71] Or, China could offer to subject itself to the New START limits, which would allow it a massive build up. Obviously, neither option would be remotely tolerable to Washington or Moscow. Thus, the more practical approach would be for the three countries to negotiate a follow-on START that would cover all INF-range land-based missiles, as well as land- and sea-based ballistic missile launchers, and bombers and air-launched cruise missiles now covered by New START. Prospective boost-glide missiles above this range also would be covered. Such delivery systems would be limited whether they carry nuclear or non-nuclear warheads, as with INF and New START. As the Chinese scholar Tong Zhao has noted, the three countries currently possess roughly 600 launchers of these types.[72] This rough parity creates a political basis for these three states to negotiate with each other.

Analyzing the merits and operational exigencies of such an arrangement and negotiating it would take significant effort and time, and is beyond the scope of this paper. The point here is that considerations of climatic effects of escalatory nuclear war and of international humanitarian law highlight the need to greatly reduce the number and potential destructiveness of Russia and U.S. nuclear forces, and to prevent China's from growing. Both sets of considerations underline the especial problems of high-yield weapons and targeting of urban environments. The latter may appear particularly challenging to China whose relatively small long-range nuclear arsenal reportedly focuses on urban targets. However, a trilateral negotiation that covers conventionally armed as well as nuclear-armed weapons would present an opportunity for Beijing to highlight that it deploys much less long-range megatonnage than do the United States and Russia. Moreover, addressing this broader set of delivery systems together could mitigate a danger that U.S. and Russian critics of minimal deterrents emphasize—that small nuclear forces could be vulnerable to strikes by precision conventional forces (discussed in the Appendix below). China would be careful not to alienate Russia, but Moscow's own recent calls for extending New START and reinvigorating nuclear arms control seem to provide space for Beijing to welcome such an approach.

China need not lead discussions of the issues proffered here. If other influential states and civil society organizations take the initiative, China could gain significant soft power merely by welcoming and participating in such studies and dialogues. At a time when Asian and European middle powers express growing concern over China's increasing military power, many could welcome China's contribution to a wider international effort to physically limit the physical destructiveness of nuclear war.[73] This should give further impetus for others to create such an opening for Chinese leadership, and for Beijing to take it.

The willingness of the United States to participate in the proposed initiatives will not be ascertainable until after the 2020 presidential election. If momentum behind one or more of these initiatives were apparent in 2021, then the possibility of U.S. cooperation would grow. Russian leaders could find incentives not to be left out. All of this remains uncertain of course. What is knowable is that new practical initiatives are needed to mobilize concerned states and civil society organizations to lessen the dangers that nuclear weapons will pose in the years or decades before verifiable nuclear disarmament can be achieved.

Appendix: Exploring the Case for Physically Bounding Escalation

The greatest risks of escalatory nuclear warfare exist primarily in the U.S.-Russia competition, and perhaps in the India-Pakistan competition on a much smaller scale. The former involves thousands of weapons with high yields, guided by doctrines and operational plans that envision massive nuclear strikes and counterstrikes. The latter involves today a total of perhaps 300 weapons with unknown yields, and a growing tendency of military planners on each side to seek capabilities to attack the other's nuclear forces before they can be used.[74]

To conceptualize how to reduce risks of catastrophic escalation it is necessary to reconcile (as much as possible) two competing imperatives. One is to deter massive aggression, including adversaries' use of nuclear weapons. The other imperative—if deterrence fails—is to foreclose as much as possible those uses of nuclear weapons that would most likely produce humanitarian and environmental catastrophe. Reconciliation of these imperatives need not be perfect in order to be practically useful. Rather, alternative nuclear forces, doctrines, and operational plans need only satisfy these imperatives better than current forces, doctrines, and plans do.

Two alternative approaches to counterforce escalation dominance illustrate the analysis and debate called for in this paper: recessed deterrence based on dismantled "small" arsenals, and what I call "accountable" deterrence based heuristically on roughly 300 weapons with the lowest necessary yields.[75] The adequacy of deterrents cannot be determined by numbers of weapons alone.[76] A thorough analysis of these alternatives must assess specific threat scenarios, overall nuclear and non-nuclear force balances (including missile defenses), and other factors that enhance or undermine stability, as well as probable consequences if deterrence failed and nuclear weapons were used. It would need to address how transitions might occur from the status quo to less potentially destructive arsenals, and how to address heightened vulnerability to adversaries' cheating as one's own forces shrink.[77]

Rather than attempt such an ambitious and necessary analysis here, the discussion that follows merely clears the underbrush by challenging common arguments against less destructive forces. If some number of nuclear-armed states, plus a plurality of other influential states, conclude that this debate could lead to more welcome and practical policies than the preferences of the United States and Russia on one hand, and prohibitionists on the other hand, then power could be mobilized to make this agenda central to the nuclear order.

Jonathan Schell made the most famous argument for recessed nuclear deterrence. In his books *The Abolition* and *The Gift of Time*, Schell argued that even with zero assembled nuclear weapons, the "capacity for rebuilding them" would remain and serve as a deterrent.[78] States facing threats of massive aggression—especially genocide—that could not be defeated by other means could rebuild enough nuclear weapons to inflict unacceptable damage on the putative aggressor.[79] Rather than see last-resort reliance on nuclear deterrence as a killer argument against disarmament, Schell and others argue that residual deterrence is an answer to the charge that nuclear disarmament would invite the sort of aggression that could not be deterred or defeated by other means.

Analysts thinking from today's perspective retort that nuclear deterrents based on recessed capabilities would, in political crises, precipitate destabilizing races to reconstitute arsenals.[80] Another worry is that deterrence-through-reconstitution would be unsafe due to the difficulty of retaining experienced and talented personnel to manage reconstitution. The most capable scientists and engineers may be unlikely to pursue careers maintaining reconstitution capabilities compared to more intellectually stimulating work.[81]

Harald Muller, the German disarmament scholar, incisively challenges some of these assumptions. "It is inconceivable that governments would move beyond minimum nuclear deterrence when they believe a war probable enough to make their security ultimately contingent on having nuclear weapons (if not immediately available, then at least quickly reconstitutable)," Muller writes.[82] Governments will only move in this direction via steps that improve, or at least do not diminish their security. Such steps would necessarily include strengthened transparency and verification arrangements. If, as Thomas Schelling and others assume, states wanted robust reconstitution capabilities, the requisite facilities and cadres of technicians and security personnel would most probably be detectable by the national and international verification system that would have to be established before states would have agreed to dismantle their weapons in the first place. Moreover, a state pursuing break out from such an international regime would not be confident that it could succeed and use, or threaten to use, reconstituted weapons before a competitor was able to mount preemptive or reprisal attacks on it. The basic considerations that have militated against nuclear first use since 1949 would obtain in the circumstances that had led states to agree to dismantle their weapons.[83]

In weighing trade-offs between the risks posed by large counterforce nuclear arsenals and those of disassembled forces, the former commander of U.S. Strategic Command, retired General Lee Butler, has argued that the latter would bring underappreciated gains:

> A world free of nuclear weapons but burdened with the knowledge of their possibility is far more tolerable than a world wherein an indeterminate number of actors maintain or seek to acquire these weapons under capricious and arbitrary circumstances. The former is effectively a condition of existential deterrence wherein all nations are marginally anxious but free from the fear of imminent nuclear threats. The latter is a continuing nightmare of proliferation, crises spun out of control and the dreaded headline announcing a city vaporized in a thermo-nuclear cloud.[84]

From the perspective of international humanitarian law and avoiding potential environmental disaster, there is little doubt that recessed nuclear deterrents would be superior to those predicated on current arsenals.

Yet, the idea of recessed nuclear deterrence strains political imaginations.[85] Rather than go "that far," as various analysts and governments have put it, they have proffered that nuclear deterrence could be achieved with much smaller arsenals than the enormous stockpiles that the United States and Russia maintain.[86] After all, no other nuclear-armed state deploys more than 300 nuclear weapons. Further, there is plenty of evidence that, in the words of U.S. Air Force authors, "Small numbers of nuclear weapons produce dramatic effects. In times of crisis, they compel statesmen to act with restraint."[87]

Five lines of argument (or assertion) have been made against the idea of achieving nuclear deterrence with "low" numbers. Each is more flawed than commonly understood in the handful of states that are now pursuing escalation dominance. In considering them, recall that nuclear policy debates historically have not assessed what number, yield, and targeting plans of nuclear arsenals would make a significant difference in the probability of adhering to IHL and averting environmental catastrophe in the event that deterrence fails.[88]

First, critics argue that the definition of low numbers or minimal deterrent forces is arbitrary rather than a product of rigorous analysis of how many targets of which type must be held at risk to deter a given adversary. Often, such critics add that determining how much is enough is fraught with uncertainty. As Keith Payne put it, "No one knows with precision the minimal US nuclear capability necessary to deter attack, now or in the future."[89] (Payne leaves ambiguous what type and scale of attack is to be deterred—nuclear, conventional, hybrid, terrorist, or all of the above.)

It is indeed difficult to predict the robustness of the deterrence provided by low numbers or recessed nuclear weapon capabilities.[90] But similar uncertainties also obtain in sizing exceptionally large arsenals of land-based, sea-based, and air-based systems of varying ranges. Since the late 1970s, U.S. and Russian decisions have been shaped largely by the need to balance each other's forces within parameters set by arms control treaties. It is not a priori evident why such mutual balancing could not be done at much lower levels of forces. Whether the United States and Russia could negotiate agreements to mutually reduce their nuclear forces is a separate issue. The initial step should be to assess whether and how they would, with similarly much smaller nuclear arsenals, be able to deter each other from major aggression and the use of nuclear weapons *and* reduce the risks of catastrophic escalation.

Second, U.S. (and presumably Russian) escalation dominators assert that if their country reduced its arsenal toward a minimal deterrent level, China and perhaps India and Pakistan would expand their arsenals to seek parity.[91] This is a legitimate concern, though Chinese thought and action regarding nuclear weapons strongly suggest that China would not make parity a major goal.[92] Still, the prudent course would be to explore whether Chinese leaders would make binding verifiable commitments to limit or even somewhat reduce China's nuclear arsenal in order to encourage a U.S. (and Russian) shift to an "accountable" or minimal nuclear deterrent.[93] Chinese leaders have hinted as much when answering whether and when they would enter into multilateral nuclear arms control.[94] However, the United States and Russia have not seriously explored this possibility. As an added bonus, if China were to limit its potential nuclear forces, a necessary condition would be created for motivating India and, therefore, Pakistan to undertake nuclear arms control. (India reacts to China's capabilities, and to China's assistance to Pakistan. Pakistan reacts to capabilities India possesses or wishes to possess, which the United States and others are increasingly willing to supply. Thus, if the United States and Russia reversed the trajectory of China's nuclear requirements, this could enable parallel reversal of Indian and Pakistani requirements.)

Third, critics argue that deterrent forces based on low numbers would be highly vulnerable to attack by adversaries' non-nuclear and/or precision conventional strike weapons, and/or could be negated by effective ballistic missile defenses. [95] Such concerns are already complicating nuclear arms control between the United States and Russia. Similar concerns no doubt would arise in negotiations with China, and then with India and Pakistan. The vulnerabilities that contesting states seek to exploit with combinations of new nuclear and non-nuclear systems increase instability in crises. This includes missile defenses and possible nonkinetic capabilities. In actual conflicts, fear of force vulnerability could intensify pressures to "use them or lose them." That prospect could make the adversary with the less vulnerable nuclear forces conclude that pressing the advantage would risk

motivating the more vulnerable state to unleash its nuclear weapons early. This risk could self-deter the more capable state. Or, the advantaged state could bet that the more vulnerable state, fearing consequences of triggering a nuclear exchange, would seek to de-escalate the conflict. This in turn could embolden the more capable state to press harder. Overall, the emergence of new military technologies and potential operations that can entangle nuclear forces is undermining claims that escalation can be avoided or managed.[96]

Indeed, it does seem probable that if military competitions among the United States, Russia, and China, and between India and Pakistan, remain as adversarial and unregulated as they are today, at least some of these antagonists would be tempted to negate the other's minimum deterrent. As the Chinese nuclear expert Li Bin has written, improved intelligence capabilities, precision-strike conventional weapons, and ballistic missile defenses could enable adversaries to more effectively target relatively small nuclear deterrents.[97]

In Li's view, states would agree to manage these various capabilities in stabilizing ways only if the goal was complete nuclear disarmament.[98] In that case, "strong intelligence capabilities would be a positive force because they could detect violations against the disarmament regime. Missile defense could deter violations because it would make a small number of hidden weapons less effective." In sum, Li concludes, "a minimum deterrence regime might prove a useful interim step toward disarmament. But the ultimate goal must remain complete abolition of nuclear weapons."[99]

Yet, the vulnerability/instability problem could be addressed in another way, too. If considerations of climatic and agricultural risks, and of international humanitarian law, made influential states conclude that some types of arsenals and operational plans are more acceptable than others, states with "unacceptable" arsenals and plans could seek at least temporary validation by adjusting them downward. In today's international politics it would be best if the move toward minimal deterrents was posited as a step toward nuclear disarmament. But, in any case, the environmental and humanitarian gains of transitioning to minimal deterrents could strengthen incentives for competing states also to constrain deployments of numbers and types of nuclear *and* non-nuclear weapons that could threaten these deterrents. Actors who would undermine the pursuit of stable relationships between safer, more accountable deterrents would be subject to greater and more widespread international resistance than is the case today. Indeed, an interest in averting renewed nuclear arms racing and the threat of globally catastrophic nuclear war could motivate states to reject escalation dominance in favor of more stable strategic relationships.

Furthermore, if vulnerability is such a decisive problem, proponents of much larger nuclear forces should explain why the seven states with arsenals under 300 nuclear weapons have not suffered major aggression. (More broadly, why have states that have foregone nuclear deterrence since 1945 so rarely

suffered aggression of the sort that nuclear weapons could plausibly be used to defeat?) One likely answer is that such states have not faced adversaries with the combinations of hostile intentions and robust military capabilities that produce major aggression. This could mean that such states do not need nuclear weapons in the first place. Or, on the contrary, as a senior French official retorted recently, "nuclear deterrence is why no nuclear-armed state today faces an adversary that could pose a genocidal threat."[100] However, he quickly added, "this does not require anything like the numbers that the United States and Russia deploy."

A fourth critique of low numbers (related to the third) is that higher numbers are necessary for the United States to be able to reassure its allies that it can and will deter aggression against them.[101] However, the extended deterrence argument also is problematic. First, it applies only to the United States and its allies. No other states provide nuclear deterrence for allies or friends. Second, the scale of additional nuclear capabilities that extended deterrence requires is rarely, if ever, specified.

Meeting the extended deterrence requirement depends on the balance of the United States' and NATO's overall coercive capabilities compared with Russia's, and those of the United States and its Asian allies compared with China. Assuming that the United States will not be compelled to fight major wars simultaneously against Russia and China, and that overall U.S. and allied coercive power roughly balances that of Russia and China, the issue should be how many additional nuclear weapons are required to make Russian and Chinese leaders conclude that the risk of major aggression is too great? If China has 300 nuclear weapons, does providing extended deterrence against it require the United States to retain 3,500 more nuclear weapons? And, if Russia calibrates its nuclear force requirements to balance those of the United States and NATO, then how can NATO maintain over time the additional number of weapons required for extended deterrence without driving Russia to match this to negate the U.S./NATO advantage? Indeed, Russia today deploys more strategic and substrategic weapons (combined) than the United States and NATO. Yet, NATO states are not demanding deployment of additional nuclear weapons. This suggests that some range of nuclear disparity is tolerable as long as overall military power is balanced. Ultimately, everyone would be better off if the destructive potential of escalation—in all directions—were reduced.

The fifth critique is that even if low numbers would deter, this deterrence would be immoral.[102] Such arguments usually assume that minimal deterrent forces would be primarily targeted against "civilians and other societal targets" *and* that such targeting is different from that done with current nuclear forces.[103]

However, U.S. and Russian counterforce postures now direct at least hundreds of nuclear weapons at military targets that happen to be in or near cities.[104] Furthermore, arsenals targeting adversary nuclear forces operationally "require" extremely high probabilities of destroying these targets. This often results in more than one weapon being directed at a given target.

A fairer, more accurate comparative analysis would take the aimpoints in current U.S. and Russian nuclear operation plans and subtract the targets that would disappear through negotiated reductions of nuclear weapons from today's levels to, say, 300. Then strategists in each country would be asked to choose from the remaining targets (under current plans) the 300 they deem most important to threaten. These targets and their moral quality would not change, only the overall number would. Inasmuch as escalation dominators argue that counterforce doctrines and arsenals are morally and legally superior to countervalue ones, it is difficult to see how operations with many fewer weapons (including with lower yields) and targets would be less moral than under current nuclear plans with much larger arsenals. No different targets would be added. Indeed, assuming that each competing state had reduced its forces to a similar number, an ethic of consequences would seem to favor the deterrents whose overall destructiveness would be materially less likely to produce humanitarian and environmental disaster.[105]

Of course, advocates of prohibition will argue that no use of nuclear weapons would be legal and moral—the weapons must be prohibited and eliminated. While they undoubtedly would welcome major reductions, these advocates and others will also argue that low-yield weapons reduce inhibitions against the use of these or other nuclear weapons.

Advocates of escalation dominance will argue that relatively large arsenals of varying types of weapons are necessary to deter the moral calamity of major aggression and escalatory nuclear war. They will also say that if low-yield weapons increase the credibility of use, this would strengthen deterrence.

Both sides of this debate could be correct, at least in part. Escalation dominators inadequately address the consequences escalatory nuclear war would inflict on each other *and* nonbelligerent nations. They also fail to demonstrate that such overkill is necessary. Prohibitionists inadequately address how, in the absence of nuclear weapons, weaker nations can deter or defeat potentially genocidal aggression. Many other experts and states will reasonably favor positions in between these two extremes. If some such in-between positions better reconcile the competing imperatives of deterring nation-threatening aggression and physically reducing the risks of humanitarian and environmental disaster, then political power could be mobilized behind a renewed agenda of reductions that would strengthen the global nuclear order.[106] To the extent that reducing the numbers and yields of weapons also advances the world toward the goal of nuclear disarmament, the vast majority of states should be expected to support it. This, in turn, could strengthen the overall nuclear order that has helped restrain proliferation and prevent nuclear war for fifty years.

About the Author

Georg Perkovich is the Ken Olivier and Angela Nomellini Chair and vice president for studies at the Carnegie Endowment for International Peace. Perkovich works primarily on nuclear strategy and nonproliferation issues; cyberconflict; and new approaches to international public-private management of strategic technologies.

Notes

1 Damien Sharkov, "Putin: Russia Would Retaliate If Hit by a Nuclear Attack, Even If It Led to 'Global Catastrophe'," *Newsweek*, March 7, 2018**,** https://www.newsweek.com/putin-russia-nuclear-war-834553; https://www.youtube.com/watch?v=OV-Hf6II_p4. I thank Zia Mian for bringing this movie to my attention.

2 See for example, Keir Lieber and Daryl Press, "How Much is Enough? Testing Theories of Nuclear Deterrence," November 2015, https://politics.virginia.edu/wp-content/uploads/2015/11/Lieber-Press-VISC.pdf; Keith B. Payne, "Future of Deterrence: The Art of Defining How Much Is Enough," *Comparative Strategy*, 29 (2010): 217–222, https://www.nipp.org/wp-content/uploads/2014/11/Future-of-Deterrence.pdf; William Burr, ed., "'How Much is Enough?': The U.S. Navy and 'Finite Deterrence,' National Security Archive Electronic Briefing Book No. 275, May 1, 2009, https://nsarchive2.gwu.edu/nukevault/ebb275/index.htm.

3 Alain C. Enthoven, K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program, 1961-1969* (Harper and Row, 1971). In 2013, the U.S. president and Department of Defense concluded that strategic deterrent requirements could be met with one-third fewer weapons than allowed under New START, and that such a reduction of approximately 500 weapons could be pursued unilaterally without endangering national security. See https://obamawhitehouse.archives.gov/the-press-office/2013/06/19/fact-sheet-nuclear-weapons-employment-strategy-united-states. Political calculations precluded such reductions unless they were done bilaterally with Russia.

4 122 countries voted in favor of the Treaty on the Prohibition of Nuclear Weapons in July 2017.

5 "2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons Final Document," section on "Disarmament, Conclusions and Recommendations for Follow-On Actions," Actions 4 and 5, https://undocs.org/NPT/CONF.2010/50%20(VOL.I). Also, as this paper was in production I read (belatedly) Malcolm Chalmers, *Less Is Better: Nuclear Restraint at Low Numbers* (London: RUSI, 2012). Chalmers makes a number of points similar to those presented in this paper.

6 Office of Secretary of Defense, "Nuclear Posture Review," February 2018, p. 23, https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF.

7 Nuclear-armed states with relatively small arsenals have not suffered aggression that has warranted use of nuclear weapons. What could any rational actor hope to gain from major aggression against a nuclear-armed state or alliance that would be worth the risk of inviting nuclear retaliation as destructive as the arsenals of the UK, France, and China could inflict?

8 For two recent discussions of potential Chinese interests in engaging in nuclear arms control, see Alexei Arbatov, "A New Era of Arms Control: Myths, Realities and Options," October 24, 2019, https://carnegie.ru/commentary/80172; and Tong Zhao, "Arms Control Engagement with China," *Arms Control Today*, forthcoming.

9 For an outstanding analysis of the failure of canonical studies of nuclear doctrine and policy to address international legal issues, and of international legal scholarship to address strategic security issues, see Scott D. Sagan and Allen S. Weiner, "Rethinking U.S. Nuclear Doctrine: The Rule of Law and the Role of Strategy," manuscript, November 8, 2019.

10 Vladimir Putin interview transcript, *Financial Times*, published June 27, 2019, https://www.ft.com/content/670039ec-98f3-11e9-9573-ee5cbb98ed36.

11 Office of Secretary of Defense, "Nuclear Posture Review," February 2018, p. 17, https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF.

12 On the question of the efficacy of nuclear deterrence, I find it hard to argue with the conclusion offered in 2010 by United States Air Force scholars James Wood Forsyth Jr., B. Chance Saltzman, and Gary Schaub Jr.: "Nuclear weapons socialize statesmen to the dangers of adventurism, which in turn conditions them to set up formal and informal sets of rules that constrain their behavior. No statesmen want to be part of a system that constrains them, but that is the kind of system that restrains nuclear powers. Each state is conditioned by the capabilities of the other, and the relationship that emerges is tempered by caution despite the rhetoric of its leaders." It is also quite possible that since 1945, for many reasons beyond nuclear deterrence, statesmen have concluded that major cross-border aggression is imprudent. "Remembrance of Things Past: The Enduring Value of Nuclear Weapons," *Strategic Studies Quarterly* (Spring 2010): 80. For a range of contending arguments about the value of nuclear deterrence, see Robert Jervis, *The Meaning of the Nuclear Revolution: Statecraft and the Prospect of Armageddon* (Cornell, 1989); Todd S. Sechser and Matthew Fuhrmann, *Nuclear Weapons and Coercive Diplomacy* Paperback (Cambridge University Press, 2017); John Mueller, *Atomic Obsession: Nuclear Alarmism from Hiroshima to Al-Qaeda* (Oxford University Press, 2012); National Institute for Public Policy, "A New Nuclear Review for a New Age," Advance Draft, 2017, pp. 44–46.

13 Nuclear deterrents have not prevented possessor states from being attacked: China in 1969; Israel in 1973, 2006, not to mention nonstate terrorism; Great Britain in the Falklands in 1984; India in 1999, not to mention alleged Pakistan-backed terrorism in 2001, 2008, 2016, and others. Nor have nuclear weapons enabled major powers to avoid defeat in conflict, as happened to the United States in Vietnam and the Soviet Union in Afghanistan. But, nuclear weapons were never seriously meant to deter these sorts of aggressions and wars or win them. Briefly, this is because use of nuclear weapons would be so disproportionate to the severity and scale of the threat, which open the authorizers of nuclear weapons use to unacceptable near- and long-term political and security consequences.

14 Vladimir Putin expressed one variant of this concern when he said, "The capacities of many kinds of high-precision [non-nuclear] weapons are already close to those of weapons of mass destruction, and in the event that nuclear weapons are given up completely or significantly reduced, countries that are the leaders in creating and manufacturing high-precision systems will have a clear military advantage." Vladimir Putin, "Meeting of the Valdai International Discussion Club," October 22, 2015, http://en.kremlin.ru/events/president/news/50548. For its part, the Pakistani security establishment and political parties aligned with it have long felt that diplomacy alone will not motivate India to improve the treatment of Muslims in Indian-controlled Kashmir and to negotiate an acceptable resolution of the two countries' deepest differences. Nor would Pakistan succeed if it pursued conventional war to compel India to change its position. India's superior economic resources can be translated into conventional military

capabilities that Pakistan cannot match. Instead, it is Pakistan's nuclear capability that deters India from applying its full potential coercive power to impose hegemony on Pakistan.

15 Linton Brooks, interview, July 5, 2018, Washington DC.

16 Sir Michael Quinlan, "Thinking Deterrence Through," in James R. Woolsey ed., *Nuclear Arms: Ethics, Strategy, Politics* (San Francisco: ICS Press, 1984), 59.

17 Escalation probably has different features when one or more antagonist has a "minimal deterrent." Such deterrents based on relatively low numbers entail fewer rungs to climb. This could likely mean that the reach for the first step—initiating nuclear use—is higher than for states with many rungs. It also could likely mean that decisions to escalate by using a large fraction of surviving weapons would come sooner than in contests between adversaries that have many more options, as for example the United States and Russia do. All of this is uncertain and debatable of course, as indicated by U.S. nuclear war games described below.

18 Lieber and Press, "The New Era of Nuclear Weapons, Deterrence, and Conflict," *Strategic Studies Quarterly*, USSTRATCOM 2016, p. 33. Soviet leader Yuri Andropov, in 1981, perceived the U.S. intention this way: "They strive for military superiority in order to 'check' us and then declare 'checkmate' against us without starting a war." Quoted in Brendan R. Green and Austin Long, "The MAD Who Wasn't There: Soviet Reactions to the Late Cold War Nuclear Balance," *Security Studies* 26, no. 4 (2017): 619.

19 Dave Johnson, "Russia's Conventional Precision Strike Capabilities, Regional Crises, and Nuclear Thresholds," Livermore Papers on Global Security No. 3, February 2018, p. 79. The 2018 U.S. Nuclear Posture Review declares, "If deterrence fails, the initiation and conduct of nuclear operations would adhere to the law of armed conflict and the Uniform Code of Military Justice. The United States will strive to end any conflict and restore deterrence at the lowest level of damage possible for the United States, allies, and partners, and minimize civilian damage to the extent possible consistent with achieving objectives." Op. cit., p. 23. It is difficult to see the difference between using nuclear weapons to restore deterrence and using them to de-escalate a conflict.

20 One famous formulation of Russian military thinking on this challenge appeared in 2003: Russia planned for the "de-escalation of aggression . . . [by] the threat to deliver or by the actual delivery of strikes of various intensity using conventional and (or) nuclear weapons." "Current Goal in the Development of the Armed Forces of the Russian Federation," *Red Star*, October 11, 2003, http://old.redstar.ru/2003/10/11_10/3_html; Austin Long, "Russian Nuclear Forces and Prospects for Arms Control," testimony presented before the U.S. House of Representatives Committee on Foreign Affairs, Subcommittee on Terrorism, Nonproliferation, and Trade, June 21, 2018, p. 6.

21 Yevgeny Akmerov, Marat Valeev, and Dmitry Akhmerov, "The Balloon is a Friend of 'Sarmat'," Militaray-Industrial Courier, October 12, 2016, https//vpk.name/news/165525_aerostat_drug-sarmata.htm., translated by Alexei Arbatov, in "Nuclear Deterrence: A Guarantee or Threat to Strategic Stability," Carnegie Moscow Center, March 22, 2019, https://carnegie.ru/2019/03/22/nuclear-deterrence-guarantee-or-threat-to-strategic-stability-pub-78663.

22 Johnson, "Russia's Conventional Precision Strike Capabilities," 79. For an exceptionally nuanced discussion of these issues, see Arbatov, "Nuclear Deterrence."

23 General John Hyten, U.S. Strategic Command, July 17, 2018, at the Mitchell Institute Triad Conference,
http://www.stratcom.mil/Media/Speeches/Article/1577239/the-mitchell-institute-triad-conference/.

24 General Robert Kehler said he did essentially the same thing Hyten is now doing when he was commander from 2011 to 2013. C. Robert Kehler, "Nuclear Weapons and Nuclear Use," *Daedalus* 145, no. 4 (Fall 2016): 50–61. Preceding civilian and military leaders of the U.S. nuclear establishment also claimed success in reducing escalation risks, from Robert McNamara in 1962, to James Schlesinger in 1974, to Franklin Miller and Lee Butler in the 1980s. See, Daniel Ellsberg, *The Doomsday Machine:*

Confessions of a Nuclear War Planner (Bloomsbury, 2017); Franklin Miller in General George Lee Butler, *Uncommon Cause - Volume II: A Life at Odds with Convention - The Transformative Years* (Outskirts Press, 2016).

25 Reid Pauly, "Would U.S. Leaders Push the Button?," *International Security* 43, no. 2 (Fall 2018).

26 Soviet military and civilian leaders in the 1980s feared such escalatory capabilities and intentions and sought (perhaps unsuccessfully) to compete against them, as Brendan Green and Austin Long have detailed. "The MAD Who Wasn't There," 606–641.

27 Arbatov, "Nuclear Deterrence." "Deterrence in a crisis may collapse simply under the weight of plans and capabilities intended to deter the enemy. . . . Only an understanding of strategic stability that is agreed upon by both sides and embodied in arms limitation and reduction agreements can put strict limits on destabilizing concepts, plans, and arms of nuclear deterrence."

28 James Wood Forsyth Jr., Col. B. Chance Saltzman, Gary Schaub Jr., "Minimum Deterrence and Its Critics," *Strategic Studies Quarterly* (Winter 2010): 5.

29 Israeli officials have long said or intimated, in effect, that Israel will not be the first to "introduce" nuclear weapons into the Middle East. See, for example, Alan Dowty, "Nuclear Proliferation: The Israeli Case," *International Studies Quarterly* 22, no. 1 (March 1978): 83. The word "introduce" is obviously ambiguous. Given that in recent decades Israel has not faced a neighbor or other adversary that poses nuclear threats to it, the meaning seems to be that Israel will not politically or physically introduce nuclear weapons into its relations with others unless and until others threaten Israel with nuclear weapons. If and when such threats did manifest, it is ambiguous whether Israel would actually unleash nuclear weapons before the adversary would.

30 India's views on this may be changing, but this remains unclear.

31 Three authors from the United States Air Force, in 2010, argued that the United States could meet its nuclear deterrent needs with a force of 311 nuclear weapons. Forsyth Jr., Saltzman, Gary Schaub Jr., "Remembrance of Things Past," 74–89. As discussed further below, the 300 figure is used by the authors of the U.S. National Academy of Sciences study, *The Future of U.S. Nuclear Weapons Policy* (Washington, DC: The National Academies Press, 1997), 80, https://doi.org/10.17226/5796.

32 See Chalmers, *Less Is Better*, for an exception.

33 Memoranda, Eisenhower-Bulganin and Eisenhower-Zhukov conversations, July 18 and 20, 1955, *Foreign Relations of the United States*: *1955-7*, v. 376, pp. 413, quoted in John Lewis Gaddis, *We Now Know: Rethinking Cold War History* (Oxford University Press, 1997), 229.

34 Ibid., 230.

35 For the canonical description of fire effects of nuclear war, and their omission from damage calculations that determined "how much was enough" during much of the Cold War, see Lynn Eden, *Whole World on Fire*: *Organizations, Knowledge, and Nuclear Weapons Devastation* (Cornell University Press, 2004).

36 P. J. Crutzen, J. W. Birks, "The Atmosphere After Nuclear War: Twilight at Noon," *Ambio* 11 (1982): 114; R. P. Turco et al., *Science* 222 (1983): 1283; V. V. Aleksandrov, G. L. Stenchikov, *On the Modeling of the Climatic Consequences of the Nuclear War: Proceedings on Applied Mathematics*, Computing Center, USSR Academy of Sciences, Moscow (1983).

37 Matthias Dorries, "The Politics of Atmospheric Sciences: 'Nuclear Winter' and Global Climate Change, *Osiris* 26, no. 1 (2011): 198–223.

38 Alan Robock, et al., "Climatic Consequences of Regional Nuclear Conflicts," *Atmospheric Chemistry and Physics* 7 (2007): 2003–2012, www.atmos-chem-phys.net/7/2003/2007/; Owen B. Toon, et al., "Atmospheric Effects and Societal Consequences of Regional Scale Nuclear Conflicts and Acts of Individual Nuclear Terrorism," *Atmospheric Chemistry and Physics* 7 (2007): 1973–2002, https://www.atmos-chem-phys.net/7/1973/2007/.

39 Lili Xia and Alan Robock, "Impacts of a Nuclear War in South Asia on Rice Production in Mainland China, *Climatic Change*, May 2012, http://rd.springer.com/article/10.1007/s10584-012-0475-8.

40 In 2019, a ten-researcher team led by Toon updated the prior assessment of effects of an Indo-Pak nuclear war in which cities were primarily targeted, "Rapidly expanding nuclear arsenals in Pakistan and India portend regional and global catastrophe," Owen B. Toon, et al., *Science Advances* 5, no. 10 (October 2, 2019), https://advances.sciencemag.org/content/5/10/eaay5478. I find their test scenario implausible, but that only affirms the value of conducting and debating such studies with officials and experts from the involved states.

41 In 2018 a team of scientists from the United States' Los Alamos National Laboratory technically challenged the Robock studies on climatic effects of Indo-Pak nuclear conflict. Their research, published in 2018 in the *Journal of Geophysical Research: Atmospheres*, concludes that carbon at lower altitudes is more quickly removed from the atmosphere than posited by the 2007 studies by Robock et al and Toon et al, resulting in "significantly lower global climatic effects" than the earlier studies predict. Jon Reisner, et al., "Climate Impact of a Regional Nuclear Weapons Exchange: An Improved Assessment Based On Detailed Source Calculations." The Los Alamos group reported that "None of the simulations produced a nuclear winter effect." The UC Berkeley earth and planetary scientist, Raymond Jeanloz, in correspondence with the author, concludes that the Los Alamos critique is not dispositive: the key mechanism of self-lofting of soot "is real and can be of the magnitude that has been proposed by Crutzen and others" who developed the concept of nuclear winter. Jeanloz email to author, September 27, 2018. Since that correspondence, Toon, Robock, and twelve colleagues published an article in *Science* detailing how smoke from wildfires in Western Canada in 2017 self-lofted into the stratosphere, affirming models of nuclear winter. Pengfei Yu, et al, *Science* 365, 6453 (August 9, 2019): 587–590.

42 For example, an otherwise thoughtful U.S. Air Force study of "lower numbers" does not mention the possibility of environmental consequences such as nuclear winter: Jeffrey A. Larsen, et al., "Qualitative Considerations of Nuclear Forces at Lower Numbers and Implications for Future Arms Control Negotiations," INSS Occasional Paper no. 68, July 2012, U.S. Air Force Institute for National Security Studies, USAF Academy, Colorado. See also, Steven Starr, "Turning a Blind Eye Towards Armageddon—U.S. Leaders Reject Nuclear Winter Studies," Federation of American Scientists, January 9, 2017, https://fas.org/2017/01/turning-a-blind-ey-towards-armageddon-u-s-leaders-reject-nuclear-winter. Brad Roberts, interview, September 27, 2018, Washington, DC; Elaine Bunn, former deputy assistant secretary of defense for nuclear and missile defense policy, interview, July 13, 2018, Washington, DC.

43 Linton Brooks, interview, July 5, 2018, Washington, DC.

44 Dave Johnson, "Russia's Conventional Precision Strike Capabilities," 71.

45 Jin Feng, Na Sang Yeop, "Nuclear Winter: Insights form Chinese Writings," Carnegie-Tsinghua Center, Beijing, unpublished memorandum, August 23, 2018.

46 Manoj Joshi, interview, November 27, 2018, Washington, DC. A longtime Indian diplomat specializing in nuclear weapons policy concurred in a December 19, 2018, interview in Bengaluru, asking "did this guy Robock come to India? If he had, it might have gotten attention."

47 Conversations with former current and former senior officials from two nuclear-armed states (not the United States, Russia, or China).

48 Franklin Miller, interview, December 3, 2018, Washington, DC.

49 Joshua Coupe, Charles G. Bardeen, Alan Robock, Owen B. Toon, "Nuclear Winter Responses to Nuclear War Between the United States and Russia in the Whole Atmosphere Community Climate Model Version 4 and the Goddard Institute for Space Studies ModelE," *Journal of Geophysical Research: Atmospheres*, 124, August 8, 2019, pp. 8522–8543, https://doi.org/10.1029/2019JD030509, p. 8524m.

50 Raymond Jeanloz, "Environmental Effects of Nuclear War," in *Andrei Sakharov, The Conscience of Humanity* (S. D. Drell and G. P. Shultz, eds.), (Hoover Press, 2015), pp. 53-68.

51 Alan Robock and Owen Brian Toon, "Self-Assured Destruction: The Climate Impacts of Nuclear War," *Bulletin of Atomic Scientists* 68, no. 5 (2012): 72.

52 This harm would be magnified if nuclear reactors were damaged or destroyed in such conflict.

53 To explicitly reduce the risk of nuclear winter, Daniel Ellsberg proposes that the United States, Russia, and India and Pakistan adjust their force postures and doctrines accordingly. Ellsberg, *The Doomsday Machine* (Bloomsbury, 2017), 342–346. Two recent articles have taken up the nuclear winter challenge in ways that invite further work: Seth D. Baum, "Winter-Safe Deterrence: The Risk of Nuclear Winter and Its Challenge to Deterrence," *Contemporary Security Policy* 36, no. 1 (2015): 123–148; Joshua M. Pearce and David C. Denkenberger, "A National Pragmatic Safety Limit for Nuclear Weapon Quantities," *Safety* 4, no. 2 (2018): 4, 25; doi:10.3390/safety-4020025, www.mdpi.com/journal/safety. The need for such new thinking can be seen in Brendan Green and Austin Long's "back of the envelope" analysis of a theoretically successful U.S. counterforce damage-limitation campaign against Soviet nuclear forces in a late Cold War scenario. Green and Long conclude it could "require 4,134 warheads to wipe out the entire Soviet land-based arsenal." They do not consider the possible consequences that could entail for U.S. and allied populations even if the Soviet Union did not retaliate. Green and Long, "The MAD Who Wasn't There," 611.

54 The Austrian Foreign Ministry's published list of conference attendees does not include any Chinese. However, a media source reported that a Chinese official attended posing as an academic. A Bora, Kukil (9 December 2014). Kukil Bora, "China Sends Official Posing As 'Academic' To Attend Vienna Nuclear Conference," *International Business Times*, September 12, 2014, https://www.ibtimes.com/china-sends-official-posing-academic-attend-vienna-nuclear-conference-report-1744914.

55 U.S. Department of Defense, "Report on Nuclear Employment Strategy of the United States Specified in Section 491 of 10 U.S.C.," June 12, 2013, pp. 4–5; U.S. Department of Defense, "Nuclear Posture Review," February 2018, p. 23. https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF.

56 Comments of the Government of the United Kingdom of Great Britain and Northern Ireland, "Human Rights Committee Draft General Comment No. 35 on Article 6 of the International Covenant on Civil and Political Rights, on the Right to Life," September 25, 2017, https://www.ohchr.org/Documents/HRBodies/CCPR/GCArticle6/UnitedKingdom.pdf. I am grateful to Zia Mian for sending this reference to me.

57 In the 2003 documentary *The Fog of War*, former U.S. secretary of defense Robert McNamara recalled that following the atomic bombings of Hiroshima and Nagasaki, General Curtis LeMay "said, 'if we'd lost the war, we'd all have been prosecuted as war criminals.' And I think he's right. He, and I'd say I, were behaving as war criminals." See "'Fog Of War' Director Remembers McNamara," *All Things Considered*, NPR, July 6, 2009, https://www.npr.org/templates/story/story.php?storyId=106318407.

58 Reid Pauly notes that records of wargames suggest that foreign and defense policy professionals "conform" to what they thought that senior political leaders, especially the president, expected of them, based on presidential statements: "a president's public or private signals about nuclear restraint have a reinforcing effect within the bureaucracy." Pauly, "Would U.S. Leaders Push the Button?," 189–190. Peter Hayes made a similar point in email correspondence with the author, July 3, 2018.

59 In President Donald Trump's January 2020 discourse about targeting Iranian cultural sites, it was obvious that he did not know that the law of armed conflict prohibited such targeting. Nor did he seem aware that the legal right of pre-emptive self-defense depends on the imminence of the adversary's attack that is to be pre-empted. See Mark Nevitt, "Trump's Threat to Target Iranian Cultural Sites: Illegal Under International, Domestic and Military Law," Just Security, January 8, 2020, https://www.justsecurity.

org/67961/trumps-threat-to-target-iranian-cultural-sites-illegal-under-international-domestic-and-military-law/.

60 Sir Michael Quinlan, "Thinking Deterrence Through," in James R. Woolsey ed., *Nuclear Arms: Ethics, Strategy, Politics* (San Francisco: ICS Press, 1984), 59.

61 John K. Warden, "Limited Nuclear War: The 21st Century Challenge for the United States," *Livermore Papers on Global Security* No. 4, Lawrence Livermore National Laboratory Center for Global Security Research, July 2018, p. 42; Andrew J. Coe and Victor A. Utgoff, "Restraining Nuclear War," Institute for Defense Analyses, June 2011, p. 5.

62 "Legality of the Threat or Use of Nuclear Weapons," ICJ Advisory Opinion, July 8, 1996, paragraph 94, https://www.icj-cij.org/files/case-related/95/095-19960708-ADV-01-00-EN.pdf.

63 Criteria such as these could correct a weakness in projects like ICNND and the Elders that call for reducing U.S. and Russian stockpiles to 500 each, but do not provide material rationales for setting this number rather than others.

64 Jeffrey Lewis and Scott Sagan, "The Nuclear Necessity Principle: Making U.S. Targeting Policy Conform with Ethics & the Laws of War," *Daedalus* (Fall 2016), https://www.amacad.org/publication/nuclear-necessity-principle-making-us-targeting-policy-conform-ethics-laws-war.

65 Alex Wellerstein has created an interactive site where the user can explore the damage and casualties caused by weapons of various yields over targets of one's choosing, see NUKEMAP, https://nuclearsecrecy.com/nukemap/.

66 If governments commit themselves to the principle of lowest-yield-that-is-necessary and declare generally or specifically which categories or numbers of their nuclear weapons are relatively low-yield (compared to older systems or alternatives), cheating on such commitments and declarations would carry complications and risks. It would complicate targeting and operational planning. The number of military officers and others who would know of the cheating could be substantial, which could heighten risks of whistleblowing and/or the burden of maintaining secrecy.

67 "Eliminating Nuclear Threats," report of the International Commission on Nuclear Non-proliferation and Disarmament, Gareth Evans and Yoriko Kawaguchi, chairs, 2009.

68 Lewis A. Dunn, "The Strategic Elimination of Nuclear Weapons: An Alternative Global Agenda for Nuclear Disarmament," *Nonproliferation Review* 24, nos. 5–6 (2017): 401–507, https://doi.org/10.1080/10736700.2018.1440733.

69 Ibid., 418.

70 Ibid.

71 Arbatov, "A New Era of Arms Control."

72 Zhao Tong, "Arms Control Engagement With China," *Arms Control Today*, forthcoming.

73 "If China were to change its traditional stance [resisting providing information about its nuclear capabilities and plans], it could earn substantial political and possible strategic dividends," see Arbatov, "A New Era of Arms Control."

74 Christopher Clary and Vipin Narang, "India's Counterforce Temptations: Strategic Dilemmas, Doctrine, and Capabilities," *International Security* 43, no. 3 (Winter 2018/19): 7–52, https://doi.org/10.1162/ISEC_a_00340.

75 As noted above, this number coincides with the heuristic proposed by three authors from the United States Air Force, in 2010, who argued that the United States could meet its nuclear deterrent needs with a force of 311 nuclear weapons. Forsyth Jr., Saltzman, Schaub Jr., "Remembrance of Things Past," 74–89. The 300 figure is used by the authors of the U.S. National Academy of Sciences study, *The Future of U.S. Nuclear Weapons Policy* (Washington, DC: The National Academies Press, 1997), 80, https://doi.org/10.17226/5796. Robock et al. suggest similarly sized US and Russian arsenals, if used, would not produce nuclear winter.

76 Stephen J. Cimbala, "Minimum Deterrence and Missile Defenses: U.S. and Russia Going Forward," *Comparative Strategy* 30, no. 4 (2011): 348, https://doi.org/10.1080/01495933.2011.605024.

77 Chalmers, *Less Is Better*, explores these challenges as well as domestic obstacles to shifting the United States and Russia onto a path toward what he calls "finite deterrence."

78 Jonathan Schell, *The Gift of Time* (Metropolitan Books, 1998), 216. The U.S. National Academy of Sciences study says 300, page 80.

79 Zia Mian, interview, July 12, 2018, Washington, DC.

80 Thomas C. Schelling, "A World Without Nuclear Weapons?," *Daedalus* 138, no. 4 (Fall 2009): 124–129. Interview, Natalie Howley Quillian, September 26, 2018, Washington, DC.

81 Conversation with Jill Hruby, December 6, 2018, Washington, DC. Hruby acknowledged that the sophistication and safety of reconstituted weapons would be a less pressing issue if it is assumed that such weapons would only be necessary and deployed during an extreme emergency and were not the basis for an enduring deployed arsenal.

82 Harald Muller, "Icons Off the Mark," *The Nonproliferation Review* 20, no. 3 (2013): 554–555.

83 Ibid., 556.

84 General (ret.) George Lee Butler, speech, University of Pittsburgh, May 13, 1999, https://www.waging-peace.org/general-george-lee-butler-university-of-pittsburgh-speech.

85 For a penetrating and exhaustive critique of [recessed deterrents], see Christopher A. Ford, "Nuclear Weapons Reconstitution and its Discontents: Challenges to 'Weaponless Deterrence," in George P. Shultz, Sidney D. Drell, and James E. Goodby Ed's, *Deterrence: It's Past and Future* (Hoover Institution Press, 2011), 131–215; in the same volume, see also Sidney D. Drell and Raymond Jeanloz, "Nuclear Deterrence in a World Without Nuclear Weapons," 99–112.

86 Report of the International Commission on Nuclear Non-proliferation and Disarmament, 2009; Dunn, "The Strategic Elimination of Nuclear Weapons"; Camille Grand writes: "France would probably be more ready to engage in talks involving deeper cuts aimed at reinforcing minimum deterrence than in any project formally targeted at zero nuclear weapons." See Grand, "France and Nuclear Stability at Low Numbers," in *Small Nuclear Forces: Five Perspectives*, eds. Malcolm Chalmers, Andrew Somerville, and Andrea Berger (RUSI, 2011), 35.

87 Forsyth Jr., Saltzman, Schaub Jr., "Remembrance of Things Past," 80.

88 See Sagan and Weiner, "Rethinking U.S. Nuclear Doctrine."

89 Keith B. Payne, "Why Do US Nuclear Force Numbers Matter for Deterrence," National Institute for Public Policy, Information Series No. 404, March 9, 2016, p. 2, http://www.nipp.org/2016/04/05/payne-keith-b-why-do-us-nuclear-force-numbers-matter-for-deterrence.

90 Joseph F. Pilat, "Nuclear Latency, Nonproliferation, and Disarmament," in Zachary Davis, Ronald Lehman, and Michael Nacht eds., *Strategic Latency and World Power: How Technology is Changing our Concepts of Security* (Center for Global Security Research, Lawrence Livermore National Laboratory, February 2014), 39–41.

91 General (retired) Peter Pace, USMC, Hearing of the House Armed Services Committee, September 8, 2011.

92 Michael O. Wheeler, "Nuclear Parity With China?," Institute for Defense Analyses, IDA Paper P-4801 January 2012, pp. 23–24.

93 For a thoughtful exploration of the kind of qualitative analysis that should be undertaken, see Paul K. Davis, "Structuring Analysis to Support Future Decisions About Nuclear Forces and Postures," RAND Working Paper, September 2011. NAS; Princeton.

94 For example, see Wu Riqiang, "Trilateral Arms Control Initiative: A Chinese Perspective," *Bulletin of the Atomic Scientists*, September 4, 2019

https://thebulletin.org/2019/09/trilateral-arms-control-initiative-a-chinese-perspective/

95 Payne, "Why Do US Nuclear Force Numbers Matter for Deterrence."

96 James M. Acton, "Escalation through Entanglement: How the Vulnerability of Command-and-Control Systems Raises the Risks of an Inadvertent Nuclear War," *International Security* 43, no. 1 (Summer 2018): 56–99, doi:10.1162/ISEC_a_00320.

97 Li Bin, "Major Problems With Minimum Deterrence," *Bulletin of Atomic Scientists*, August 21, 2014, https://thebulletin.org/roundtable_entry/major-problems-with-minimum-deterrence/.

98 Here it is important to distinguish the dynamics involving the United States, Russia, and China, and those involving the United States and much less capable adversaries such as North Korea. The United States will seek defenses that could negate North Korea's nuclear capabilities, while it to date recognizes that Russia and China will be able to overcome whatever defenses the United States could deploy against their nuclear deterrents.

99 Li Bin, "Major Problems With Minimum Deterrence."

100 Conversation with director of strategic affairs, security and disarmament, French Ministry of Foreign Affairs, November 29, 2018, Washington, DC.

101 Keith Payne, "Why Do US Nuclear Force Numbers Matter for Deterrence," 5.

102 Counterforce deterrers frequently make this argument in meetings with disarmers and/or advocates of minimal deterrence. See Keith Payne, "Why Do US Nuclear Force Numbers Matter for Deterrence?," 3; Major Joshua D. Wiitala, USAF, "Challenging Minimum Deterrence," *Air & Space Power Journal* (Spring 2017): 22. See for example, "A New Nuclear Review for a New Age," National Institute for Public Policy, April 2017, p. 6.

103 Ibid.

104 Bruce Blair, interview, September 7, 2018, Washington, DC.

105 Moreover, as a former high-level Pentagon official told Steve Kull, "being able to do something which isn't so obviously self-destructive . . . that makes [the threat] more credible." Kull, *Minds at War* (Basic Books, 1988), 178.

106 Paul Doty heuristically postulated that total megatonnage of an arsenal could be as important or more important a metric for designing minimal deterrents, especially if environmental effects and "collateral damage" are to be minimized. The megatonnage metric, though, would need to account for weapons with variable yields. Paul Doty, "The Minimum Deterrent & Beyond," *Daedalus* (Fall 2009): 130–139.

1779 Massachusetts Avenue NW | Washington, DC 20036 | P: + 1 202 483 7600

CarnegieEndowment.org