Nuclear War as a Global Catastrophic Risk

James Scouras, Title

The George Washington University Regulatory Studies Center

It might be thought that we know enough about the risk of nuclear war to appropriately manage that risk. The consequences of unconstrained nuclear attacks, and the counterattacks that would occur until the major nuclear powers exhaust their arsenals, would far exceed any cataclysm humanity has suffered in all of recorded history. The likelihood of such a war must, therefore, be reduced to the point that it becomes as low as we can feasibly achieve. But this rather simplistic logic raises many questions and does not withstand close scrutiny.

Regarding consequences, does unconstrained nuclear war pose an existential risk to humanity? The consequences of existential risks are truly incalculable, including the lives not only of all human beings currently living but also of all those yet to come; involving not only our Homo...
Sapiens but all species that may descend from it. At the opposite end of the spectrum of consequences lies the domain of “limited” nuclear wars. Are these also properly considered global catastrophes? After all, while the only nuclear war that has ever occurred devastated Hiroshima and Nagasaki, it was also instrumental in bringing about the end of the Pacific War, thereby saving lives that would otherwise have been lost in the planned invasion of Japan. Indeed, some scholars similarly argue that many lives have been saved over the nearly three-fourths of a century since the advent of nuclear weapons because those weapons have prevented the large conventional wars that otherwise would likely have occurred between the major powers. This, too, is a consequence of the fear induced by the attacks that devastated the two Japanese cities.

Regarding likelihood, how do we know what the likelihood of nuclear war is and the degree to which our national policies affect that likelihood, for better or worse? How much confidence should we place in any assessment of likelihood? What level of likelihood poses an unacceptable level of risk? Even a very low (nondecreasing) annual likelihood of the risk of nuclear war would result in near certainty of catastrophe over the course of many years.

Most fundamentally and counterintuitively, are we really sure we want to reduce the risk of nuclear war? The successful operation of deterrence, which has been credited—which perhaps too generously—with preventing nuclear war during the Cold War and its aftermath, depends on the risk that any nuclear use might escalate to a nuclear holocaust. Many proposals for reducing risk focus on reducing nuclear weapon arsenals and, therefore, the possible consequences of the most extreme nuclear war. Yet, if we reduce the consequences of nuclear war might we also inadvertently increase its likelihood? It’s not at all clear that would be a desirable trade-off.

This is all to argue that the simplistic logic described above is inadequate, even dangerous. A more nuanced understanding of the risk of nuclear war is imperative. This paper thus attempts to establish a basis for more rigorously addressing the question, What is the risk of nuclear war? Its more specific goals include increasing awareness of the complexities involved in addressing this question and evaluating alternative measures proposed for managing nuclear risk.

To establish the necessary context for considering the risk of nuclear war, I begin with discussions of four foundational topics: (1) nuclear war as a global catastrophic risk; (2) risk terminology; (3) the strategy of deterrence; and (4) national security policy formulation. Turning to the issue of risk assessment, I present a variety of assessments by academics and statesmen of the likelihood component of the risk of nuclear war, followed by an assessment of what we do and do not know

---

4 My own view is that the long “nuclear peace” has occurred as a result of the combined influences of three principal factors: the successful implementation of the strategy of deterrence, the emergence of the nuclear taboo, and sheer luck. To better appreciate the role of luck, see Scott D. Sagan, The Limits of Safety: Organizations, Accidents, and Nuclear Weapons (Princeton, NJ: Princeton University Press, 1993). It might be also argued that the Soviet Union’s development of nuclear weapons contributed to the nuclear peace, because one sole state possessing nuclear weapons and not threatened by nuclear retaliation might be less inhibited in using them.
about the consequences of nuclear war, emphasizing uncertainty in both factors. Then, I discuss the difficulties of determining the effects of risk mitigation policies, focusing on nuclear arms reduction. Finally, I address the question of whether nuclear weapons have indeed saved lives. I conclude with recommendations for national security policy and multidisciplinary research approaches.

Context

To more fully appreciate the reasons and establish a firm basis for a more rigorous analysis of the risk of nuclear war, the following subsections clarify the reasoning behind categorizing nuclear war as a global catastrophic risk, but not an existential risk; risk terminology and practices as applied to nuclear war; the central role of risk in the evolution of Cold War and post-Cold War deterrence strategy; and the effects that intuitive perceptions of the risk of nuclear war have had on presidential national security policy initiatives.

Why Is Nuclear War a Global Catastrophic Risk?

One need only view pictures of Hiroshima and Nagasaki, as shown in Figure 1, and imagine such devastation visited on thousands of cities across warring nations in both hemispheres to recognize that nuclear war is truly a global catastrophic risk. Moreover, many of today’s nuclear weapons are an order of magnitude more destructive than Little Boy and Fat Man, and there are many other significant consequences—prompt radiation, fallout, etc.—not visible in such photographs. Yet, it is also true that not all nuclear wars would be so catastrophic; some, perhaps involving electromagnetic pulse (EMP) attacks using only a few high-altitude detonations or demonstration strikes of various kinds, could result in few casualties. Others, such as a war between Israel and one of its future nuclear neighbors might be regionally devastating but have limited global impact, at least if we limit our consideration to direct and immediate physical consequences. Nevertheless, smaller nuclear wars need to be included in any analysis of nuclear war as a global catastrophic

---

5 Public domain images via Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Hiroshima_aftermath.jpg and https://commons.wikimedia.org/wiki/File:Nagasaki-person_burned.jpg. Note that the image of Hiroshima was signed by Col. Paul Tibbets, pilot of the Enola Gay, the aircraft used to bomb Hiroshima.

6 Many mistakenly believe that the congressionally established Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack concluded that an EMP attack would, indeed, be catastrophic to electronic systems and consequently to people and societies that vitally depend on those systems. However, the conclusion of the commission, on whose staff I served, was only that such a catastrophe could, not would, result from an EMP attack. Its executive report states, for example, that “the damage level could be sufficient to be catastrophic to the Nation.” See www.empcommission.org for publicly available reports from the EMP Commission. See also Michael Frankel, James Scouras, and Antonio DeSimone, Assessing the Risk of Catastrophic Cyber Attack: Lessons from the Electromagnetic Pulse Commission (Laurel, MD: Johns Hopkins University Applied Physics Laboratory, 2015).
risk because they increase the likelihood of larger nuclear wars. This is precisely why the nuclear taboo is so precious and crossing the nuclear threshold into uncharted territory is so dangerous.7

Figure 1. Images of devastation caused by nuclear war. Left, Hiroshima after the atomic bomb attack of August 6, 1945. Right, An atomic bomb burn victim in Nagasaki, attacked August 9, 1945.

While it is clear that nuclear war is a global catastrophic risk, it is also clear that it is not an existential risk. Yet over the course of the nuclear age, a series of mechanisms have been proposed that, it has been erroneously argued, could lead to human extinction. The first concern8 arose among physicists on the Manhattan Project during a 1942 meeting in New Mexico some three years before the first test of an atomic weapon. The meeting was chaired by Robert Oppenheimer and included Edward Teller, Hans Bethe, Robert Serber, the young theoretician Emil Konopinski, and others.9 The concept of a “super” bomb envisioned using the burst of an atomic fission device to initiate fusion of light element fuels. Since the atmosphere consists mostly of nitrogen, which is also considered a light element, one of the physicists questioned the possibility of ignition of a self-sustaining nitrogen fusion reaction that might propagate through earth’s atmosphere, thereby extinguishing all air-breathing life on earth. Konopinski, Cloyd Margin, and Teller eventually published the calculations that led to the conclusion that the nitrogen-nitrogen reaction was virtually impossible from atomic bomb explosions—calculations that were used to justify going forward with Trinity, the first atomic bomb test.10

In 1975, in an article in the Bulletin of Atomic Scientists, H. C. Dudley quoted an interview of Arthur Compton in which Compton claimed that calculations had shown that the probability of

---

8 I am indebted to Edward Toton for his substantial contributions to this discussion based on his current research on physics-based global catastrophic risks.
igniting the earth’s atmosphere with the Trinity test was slightly less than three in one million.\textsuperscript{11} In 1976, H. Bethe responded to this article, declaring in the \textit{Bulletin of Atomic Scientists} that “there was never any possibility of causing a thermonuclear chain reaction in the atmosphere. There was never ‘a probability of slightly less than three parts in a million,’ as Dudley claimed.”\textsuperscript{12,13} Of course, the Trinity test was subsequently conducted, and we are fortunately still here.

After the bomb was used, extinction fear became based on invisible and deadly fallout, an unanticipated consequence of the bombings of Japan, that would spread by global air currents to poison the entire planet. Public dread was reinforced by the depressing, but influential, 1957 novel \textit{On the Beach} by Nevil Shute and the subsequent 1959 movie version. The story describes survivors in Melbourne, Australia, one of a few remaining human outposts in the far Southern Hemisphere, as fallout clouds approached to bring the final blow to humanity.\textsuperscript{14}

In the 1970s, after fallout was better understood, depletion of the ozone layer, which would cause increased ultraviolet radiation to fry all humans who dared to venture outside, became the extinction mechanism of concern. Again, one popular book, \textit{The Fate of the Earth} by Jonathan Schell, which described the nuclear destruction of the ozone layer leaving the earth “a republic of insects and grass,” promoted this fear. Schell did at times try to cover all bases, however: “To say that human extinction is a certainty would, of course, be a misrepresentation—just as it would be a misrepresentation to say that extinction can be ruled out.”\textsuperscript{15}

Finally, the current mechanism of concern for extinction is nuclear winter, the phenomenon by which dust and soot created primarily by the burning of cities would rise to the stratosphere and attenuate sunlight such that surface temperatures would decline dramatically, agriculture would fail, and humans and other animals would perish from famine. The public first learned of nuclear winter in a \textit{Parade} article by Carl Sagan,\textsuperscript{16} published a month or so before its scientific counterpart.\textsuperscript{17} While some policy advocates promote the idea that nuclear winter is an extinction threat, and the general public is probably confused to the extent it is not disinterested, few scientists seem to consider it an extinction threat. At least one scientist does not completely dismiss the possibility of human extinction. Luke Oman, a nuclear winter scientist, speculated that “the probability I would estimate for the global human population of zero resulting from the 150 Tg

\textsuperscript{15} Jonathan Schell, \textit{The Fate of the Earth}, 1982, Alfred A. Knopf Incorporated.
[teragrams] of black carbon scenario in our 2007 paper would be in the range of 1 in 10,000 to 1 in 100,000.”\(^{18}\) However, as far as I can tell, Oman’s estimate has no basis in analysis.

It is understandable that some of these extinction fears were created by ignorance or uncertainty and treated seriously by worst-case thinking, as seems appropriate for threats of extinction. But nuclear doom mongering also seems to be at play for some of these episodes. For some reason, portions of the public active in nuclear issues, as well as some scientists, appear to think that their arguments for nuclear arms reductions or elimination will be more persuasive if nuclear war is believed to threaten extinction, rather than merely the horrific cataclysm that it would be in reality.\(^{19}\) Based on current public and governmental general indifference to nuclear winter, this logic may be faulty. It also risks undermining the credibility of both the nuclear winter science and policy advocacy communities as the exaggeration is exposed.

To summarize, large nuclear war is a global catastrophic risk. Such wars may cause billions of deaths and unfathomable suffering, as well set civilization back centuries. Smaller nuclear war poses a regional catastrophic risk and also a national risk in that the continued functioning of, for example, the United States as a constitutional republic is highly dubious after even a relatively limited nuclear attack. But what nuclear war is not is an existential risk to the human race. There is simply no credible scenario in which humans do not survive to repopulate the earth.\(^{20}\)

**Risk Terminology and Analysis**

While risk terminology is fairly mature, some special considerations apply to the case of nuclear war. *Risk* is exposure to danger due to the likelihood and consequences of an adverse event. In our case the adverse event is nuclear weapon use, which we define as the detonation of one or more nuclear weapons, whether intentionally or accidentally, except for nuclear weapons tests, anywhere in the world. As touched on earlier in this paper, the reason for such an expansive scope

---


\(^{19}\) Brian Martin, “Critique of Nuclear Extinction,” *Journal of Peace Research* 19, no. 4 (1982): 287–300. As summarized by Martin, “The idea that global nuclear war could kill most or all of the world's population is critically examined and found to have little or no scientific basis.” Martin also critiques possible reasons for beliefs or professed beliefs about nuclear extinction, including exaggeration to stimulate action.

\(^{20}\) Nuclear war could pose an existential risk if it were followed by a second global catastrophe that destroyed all human life because the nuclear war made it impossible to effectively respond to the secondary threat. For example, if a nuclear war destroyed spacefaring states’ abilities to deflect a very large asteroid, and such an asteroid happened to threaten earth in the aftermath of the nuclear war, the human race might not survive. But this rather special case invokes a second global catastrophic risk, and I will not consider it further in this paper.
is that any nuclear use could have consequences that would directly or indirectly cascade to involve
the major nuclear states.

*Likelihood* can be described in qualitative terms (e.g., unlikely, highly likely, a remote possibility)
or quantitatively, such as in probabilistic terms. To be meaningful, a time frame must be specified
(e.g., “There is a moderate likelihood of nuclear use within the next ten years.”). In some risk
assessments, frequency is used to portray likelihood (“We can expect two attacks over the course
of the next decade.”). However, this is not appropriate for nuclear attacks, where the original
nuclear use and the reaction to it can be expected to significantly affect the likelihood of a
subsequent use.

*Consequences* include fatalities, injuries, physical and economic damage, social and psychological
impacts, and all other forms of harm. They can be immediate or can unfold over decades.
Important, but often overlooked, consequences include those that would result from the reaction
to nuclear weapon use. Because its consequences would be extreme, even the remote likelihood
of nuclear weapon use may well motivate policy changes because remote possibilities can
accumulate to worrisome levels when aggregated over the long term. For both likelihood and
consequences, it is important that an uncertainty be associated with any estimation. Research in
psychology suggests that humans are not very good at estimating “confidence levels” for their
estimations. For example, people are generally poor at tasks like the following: “Set the upper
and lower bounds on the probability that a nuclear weapon will be used in the next ten years, in
such a way as to be 90 percent confident that the actual probability will fall between your lower
and upper bounds.” Yet if we fail to press experts to associate a confidence level or uncertainty
with their estimates, we can easily fall into the trap of assuming that the uncertainty is negligible.

Finally, the common practice of multiplying likelihood and consequences, which would result in
an expected risk, is inappropriate for low-probability, high-consequence risks, such as nuclear war.
There are policy-relevant differences between the combination of lower likelihood and higher
consequences (perhaps interstate nuclear war between established nuclear states) and the
combination of higher likelihood and lower consequences (perhaps terrorist use of nuclear
weapons, or nuclear war between an established and a nascent nuclear state). This critical
distinction is lost when the product is used.

**The Role of Risk in the Evolving Strategy of Deterrence**

During the near half-century between the end of World War II and the fall of the Berlin Wall, the
United States and its allies were focused on the threat posed by the Soviet Union. Broadly

---


speaking, the overarching US national security policy was containment of Soviet expansionism, and the cornerstone of US strategy for preventing such expansion by military means was deterrence. Deterrence threatened the Soviet Union with “unacceptable consequences,” code for nuclear devastation, should it attack the United States or its allies.

The capability to inflict unacceptable consequences was embodied in a nuclear weapons triad of intercontinental ballistic missiles, submarine-launched ballistic missiles, and long-range bombers and was evaluated in the context of what was viewed as the most stressing, but not implausible, scenario: a massive surprise attack on nuclear forces and associated command and control. The redundancy of both the US and Soviet nuclear triads, and the inability of either side to strike preemptively and simultaneously against all three legs of the other side’s nuclear triad with confidence of success, even in the context of this so-called bolt from the blue scenario, was thought to provide robust deterrence for both sides and to nearly eliminate the incentives to be the first to use a nuclear weapon. Neither side would have the temptation to strike first because massive retaliation was virtually certain; nor would either side have to fear a disabling first strike by the other. The residual risk of nuclear weapons use, in this view, was best reduced through arms control agreements that further limited the incentives for a nuclear first strike, and perhaps eventually through missile defenses should such defenses become technologically and economically feasible.

In contrast, the unforeseen and abrupt end of the Cold War initiated a period of continuing uncertainty about the most likely paths to the use of a nuclear weapon and the best means of addressing them. For a period of time after the collapse of the Soviet Union, one source of this confusion was the unresolved question of whether Russia still did, or might once again, pose a mortal threat to the United States. Today, there is increased antagonism between the United States and Russia. And Russia remains the one country other than the United States with a nuclear triad that under the latest arms control agreement will still have more than 1500 nuclear weapons of global range. But it must also be acknowledged that the mutual hostility and mistrust that characterized much of the US–Soviet relationship are today far reduced, and the robustness of mutual deterrence that held during the Cold War still applies.

In any event, the risk of nuclear war with Russia has clearly receded relative to the Cold War in terms of both its likelihood and potential consequences. As a result, there is a tendency to discount the residual Russian threat relative to other nuclear threats that appear to be more immediate, growing, or perceived to be more likely to result in nuclear use, even if their consequences might be orders of magnitude less severe than those of an unconstrained nuclear war with Russia. The most significant examples of such threats include North Korea’s nuclear program, under which multiple nuclear weapons tests have already been conducted, and Iran’s apparent desire to eventually develop, or at least have the capability to develop, a nuclear weapon and ballistic missiles that would threaten Europe and the United States. Cascading regional proliferation, especially if Iran becomes a nuclear state, is not implausible. Meanwhile, China continues to
increase its nuclear capabilities, extend the range of its missiles, and diversify its means of delivering nuclear weapons. India tested a nuclear weapon in 1998, after having foregone any additional tests since its first in 1974, and Pakistan followed suit with its first nuclear test a few weeks thereafter; both states are considered to have scores of nuclear weapons or more. Israel is widely believed to also possess scores, if not hundreds, of nuclear weapons, and many more states have the technological ability to produce nuclear weapons should they decide to do so. The present number of nuclear weapons states is not as large as President Kennedy and others predicted in the early 1960s, but it has grown, and it is widely believed that each additional nuclear power, including long-term US allies Britain and France, presents an added set of risks that nuclear weapons will be used someday against someone. Perhaps of greatest concern is the possibility that terrorist organizations willing to carry out mass-casualty attacks will eventually get their hands on a nuclear weapon by buying, stealing, or building one. The present and future number of such organizations and the likelihood of their obtaining a nuclear weapon are even harder to assess than the future number of nuclear weapons states.

In retrospect, the apparent simplicity and robustness of nuclear deterrence during the Cold War were neither as simple nor as robust as they seemed at the time. The gradual release of historical evidence has made clear that the actual risks of nuclear weapons use during the Cold War, and the most likely paths through which nuclear use could have been realized, were quite different from the scenario of large-scale and intentional use of nuclear weapons that preoccupied American and Soviet leaders. The considerable number of close calls, accidents, incidents, misunderstandings, and false alarms that we now know arose during the Cold War were arguably more likely to have resulted in the use of nuclear weapons than the intentional calculation that the use of such weapons could advance some strategic purpose (and presumably there were additional close calls that are not publicly known). Indeed, perhaps the most serious incident was revealed only in 2002: during the Cuban missile crisis, Captain Valentin Savitsky, commander of a Soviet submarine, reportedly ordered his crew to prepare to launch a nuclear-armed torpedo against the American ships that were dropping depth charges to force his submarine to the surface. Fortunately, Soviet procedures required the consent of three top officers on the submarine for a nuclear weapon to be used, and Savitsky’s second in command, Vasili Arkhipov, succeeded in convincing Savitsky to surface for orders from Moscow instead of launching a nuclear-armed torpedo without higher authorization.23

The divergence between contemporary impressions of nuclear risks and the accumulating historical evidence on actual close calls regarding nuclear weapons warrants caution in the assessment of current risks and humility in estimating future ones. Yet while precise and confident

estimates of nuclear risks are not possible, the task of assessing and addressing the most pressing risks of nuclear weapons use is too important to forgo.

The Policy Impact of Nuclear Risk Perceptions

Detailed consideration of the likelihood and consequences of nuclear war is not usually explicit in formulating national security strategy. Yet implicit assumptions about these questions have a strong influence on nuclear policy. The entire nuclear arms control enterprise—from the “hotline” memorandum of understanding through the Anti-Ballistic Missile Treaty and Strategic Arms Limitation Treaty (SALT), the Intermediate Nuclear Forces (INF) Treaty, the Strategic Arms Reduction Treaty (START), the Strategic Offensive Reductions Treaty (SORT), and the current New START Treaty—was motivated principally by fear of nuclear war. In the 1950s the dominant theoretical concern involved a disarming surprise attack, but fear of nuclear war was made all too tangible by the Cuban missile crisis of 1962 and has been reinforced throughout the Cold War by the nuclear arms race and nuclear posturing.

Similarly, arguments for national missile defenses depend in no small part on the judgment that deterrence is unreliable. As expressed by President Reagan in his Strategic Defense Initiative speech of 1983:24

> Tonight . . . I am directing a comprehensive and intensive effort to define a long-term research and development program to begin to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles. This could pave the way for arms control measures to eliminate the weapons themselves. We seek neither military superiority nor political advantage. Our only purpose—one all people share—is to search for ways to reduce the danger of nuclear war. [Emphasis added.]

President George W. Bush invoked the inadequacy of deterrence and the consequences of nuclear use by “rogue” states and terrorists to justify preemptive attack as a critical element of national security strategy:25

> It has taken almost a decade for us to comprehend the true nature of this new threat. Given the goals of rogue states and terrorists, the United States can no longer solely rely on a reactive posture as we have in the past. [Emphasis added.] The inability to deter a potential attacker, the immediacy of today’s threats, and the magnitude

---


of potential harm that could be caused by our adversaries’ choice of weapons, do not permit that option. We cannot let our enemies strike first.

More recently, the prospect of nuclear use has motivated President Obama’s call for a nuclear-free world:\(^\text{26}\)

Today, the Cold War has disappeared but thousands of those weapons have not. In a strange turn of history, the threat of global nuclear war has gone down, but the risk of a nuclear attack has gone up . . . So today, I state clearly and with conviction America’s commitment to seek the peace and security of a world without nuclear weapons.

It is apparent from this historical review that presidential-level declarations of national policies have been motivated by the fear that deterrence might fail. It is also apparent that different presidents have invoked quite different policies to address this fear. However, the assertions that deterrence cannot be relied on, whether right or wrong, have been based on intuition and limited perspectives rather than syntheses of the broadest expertise and most appropriate analytic methods that can be brought to bear.

**Risk Assessment**

With this foundation, I now turn to assessments of the risk of nuclear war, first addressing likelihood and then consequences.

**Likelihood**

Consider the current state of analysis for assessing the likelihood of nuclear war. In 2005 the office of Senator Richard Lugar published *The Lugar Survey on Proliferation Threats and Responses* (hereinafter, the Lugar survey), which addresses the risk of nuclear use.\(^\text{27}\) Among the questions asked in the survey was, “What is the probability (expressed as a percentage) of an attack involving a nuclear explosion occurring somewhere in the world in the next ten years?” The distribution of replies from seventy-nine respondents is shown in Figure 2.

What is most striking about Figure 2 is the divergence of opinion. Responses span the full spectrum from 0 to 100 percent, with the mode occurring at 1 to 9 percent, but with only eighteen respondents. From a classical statistics perspective, the true probability lies in only one unknown

---


The fact that most experts’ answers missed that value, whichever bin it lies in, means that most experts must necessarily be wrong. There are a number of possible explanations for this. One reason for the wide variation could be the lack of control of biases in the elicitation of the answers. Without bias control, experts can interpret and think differently about how to answer the question, resulting in wide variability. Even if biases are controlled, wide dispersion can still occur because of high uncertainty in the current state of knowledge. In any event, the most significant conclusion to be drawn from Figure 2 is that there is no consensus on the answer to the question. In contrast, the Lugar survey highlights the mean (29 percent) of these data as the most relevant finding. If it had also reported the standard deviation (approximately 26 percent) with this mean, the high variability in Figure 2 would have been more apparent.

![Bar chart](chart.png)

**Figure 2. The Lugar survey, question 5**

In other respects as well, the Lugar survey did not follow best practices in elicitation and analysis.  
While each survey respondent was presumably an expert in some aspect of nuclear policy, arguably no single person is truly an expert on all the factors that must be considered when answering broadly phrased questions such as that depicted in Figure 2. Additionally, the survey provides no information about the experts’ assumptions, reasoning, and uncertainties. Such

---


29 According to the Lugar survey, “Many of these men and women have dedicated their professional careers to the study and practice of preventing weapons of mass destruction and materials from falling into unauthorized hands. Others have been national security leaders within their countries. As a group, they possess enormous experience in the fields of non-proliferation, counter-proliferation, diplomacy, military affairs, arms inspection, intelligence gathering, and other national security fields relevant to the questions asked.” The fault of the survey is to confuse the expertise of the group as a whole, if it could be brought to consensus, with the sum of individual expertise within the group.
information could, for example, be useful in understanding the apparently anomalous peak at 50–59 percent and the extremes of 0 percent and 100 percent. The cumulative impact of these and other deficiencies is that the survey falls short of what could be achieved by using best practices in expert elicitation. Yet references to the Lugar survey are almost uniformly uncritical, and policy advocates have used its results to argue for important policy decisions. Clearly, a more scientific survey could be conducted that would improve on the reliability of the Lugar survey. Nevertheless, the fact that the survey was undertaken demonstrates that the question of the likelihood of deterrence failure is relevant to policy makers, analysts, and the public.

Another exercise in characterizing the likelihood of nuclear war has been ongoing since 1947, when the Doomsday Clock first appeared on the cover of the *Bulletin of Atomic Scientists*. The setting of the clock is intended to represent how close the world is to nuclear war, metaphorically midnight. The clock was originally set at seven minutes to midnight and has been reset periodically every several (one to seven) years. As shown in Figure 3, the time of greatest danger—two minutes to midnight—was set in 1953 after US and Soviet hydrogen bomb tests, while the time of least danger, seventeen minutes to midnight, was set in 1991 after the START Treaty was signed and unilateral initiatives on both sides removed many nuclear weapons from “hair-trigger” alert.

There are multiple problems with taking the clock seriously as an assessment of the likelihood of nuclear war. In setting the clock there could be motives beyond accurately characterizing the nuclear threat, such as to promote certain policies, especially with respect to arms control treaties, or simply to draw attention to the *Bulletin of the Atomic Scientists*. The process by which the clock is set is obscure, although brief summaries of the reasons for changing the clock’s setting have been provided. No attempt has been made to define the clock’s scale, which is almost certainly nonlinear. Does ten minutes to midnight indicate half the probability of five minutes to midnight? And finally, the clock is unable to reflect the risks associated with short-duration, high-risk episodes, such as the Cuban missile crisis of 1962 and the coup attempt against Gorbachev in August 1991. Ironically, the former occurred during a period of reducing risk, according to Figure 3, and the latter occurred during the period of least risk.

Notwithstanding these points, the Doomsday Clock does seem to have captured the broad trends in the nuclear threat as it derives from the international political climate. Gaining a better understanding of the processes by which the clock has been set could prove useful in developing more scientific approaches. Unfortunately, the clock’s future utility as an indicator of the risk of

---

31 Public domain image via *Wikimedia Commons*, [https://commons.wikimedia.org/wiki/File:Doomsday_Clock_graph.svg](https://commons.wikimedia.org/wiki/File:Doomsday_Clock_graph.svg).
33 “Timeline,” *Bulletin of the Atomic Scientists*.
nuclear war has been diminished since 2007 by the inclusion of climate change and harmful developments in the life sciences as additional harbingers of doomsday.

Several individuals have also estimated the likelihood of interstate nuclear war or nuclear terrorism. These estimates are summarized in Table 1. Most are subjective judgments (Kennedy, 35

Figure 3. The Doomsday Clock, 1947-2004. The clock indicates then-current perspectives of the Bulletin of the Atomic Scientists on the dangers of nuclear war. Since 2007, dangers associated with climate change and developments in the life sciences have been added.

Several individuals have also estimated the likelihood of interstate nuclear war or nuclear terrorism. These estimates are summarized in Table 1. Most are subjective judgments (Kennedy, 35

---

35 Theodore C. Sorensen, Kennedy (New York: Harper & Row, 1965), 705. The exact date of Kennedy’s estimate is not specified in this source, but the estimate appears to apply to Kennedy’s belief in the midst of the crisis. According to Sorenson (special counsel to the Kennedy), “the odds that the Soviets would go all the way to war, he [Kennedy] later said, seemed to him then ‘somewhere between one out of three and even.’” Note that Kennedy’s estimate refers to the likelihood of war but does not explicitly specify nuclear war. Nevertheless, it seems clear that if the Soviets initiated a conventional war (in Berlin, perhaps), the likelihood of escalation to nuclear conflict was high.
Bundy, Allison, Perry, Albright, and Garwin) without a formal underlying analysis, while others are based on a quantitative analysis (Hellman, Bunn, and Mueller).

Table 1. Individual estimates of the probability of nuclear war

<table>
<thead>
<tr>
<th>Probability that the Cuban missile crisis could have escalated to (nuclear) war</th>
<th>Probability</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between 1 in 3 and even</td>
<td>John F. Kennedy</td>
<td>1962</td>
</tr>
<tr>
<td>1 in 100</td>
<td>McGeorge Bundy</td>
<td>1988</td>
</tr>
<tr>
<td>Probability of a future Cuban missile-type crisis that results in nuclear use</td>
<td>Probability</td>
<td>Year</td>
</tr>
<tr>
<td>2 in 1,000 to 1 in 100 per year</td>
<td>Martin Hellman</td>
<td>2008</td>
</tr>
<tr>
<td>Probability that terrorists will detonate a nuclear bomb</td>
<td>Probability</td>
<td>Year</td>
</tr>
<tr>
<td>50% probability within the next decade</td>
<td>Graham Allison</td>
<td>2004</td>
</tr>
<tr>
<td>50-50 odds within the next decade</td>
<td>William Perry</td>
<td>2004</td>
</tr>
<tr>
<td>1% probability over 10 years</td>
<td>David Albright</td>
<td>2005</td>
</tr>
<tr>
<td>29% probability within the next decade</td>
<td>Matthew Bunn</td>
<td>2007</td>
</tr>
<tr>
<td>Less than 1 in 1,000,000 per attempt</td>
<td>John Mueller</td>
<td>2008</td>
</tr>
<tr>
<td>20% per year against a US or European city</td>
<td>Richard Garwin</td>
<td>2007</td>
</tr>
</tbody>
</table>

Arguably, the most compelling assessments are those of crisis managers who experienced a nuclear close call firsthand: President Kennedy and his national security advisor, McGeorge Bundy. Not long after the Cuban missile crisis, Kennedy told Ted Sorenson, special counsel to the president, that during the crisis he believed that the chances that the Soviets would go to war were between one in three and even, while Bundy, reflecting twenty-six years after the crisis, came to the dramatically lower estimate of up to one in one hundred. Of course, the crisis occurred almost a half-century ago, and even with the additional information now available, it is hard to estimate its risks retrospectively. For example, depending on one’s interpretation of the probabilities associated with the Soviet submarine incident discussed above, and the risks one should attach to

---

other “close-call” incidents during the Cuban crisis, one could argue for either Kennedy’s estimate or Bundy’s. Moreover, neither Kennedy nor Bundy knew at the time they made their estimates that a Soviet submarine had come close to launching a nuclear torpedo, but they could have imagined this and other scenarios as part of their risk estimates, so it is unclear whether either of them would have raised or lowered their estimates if they had known at the time of their estimates everything we know now. Of course, beyond the question of what the actual risk was at the time of the Cuban crisis is the problem of the relevance of that information to the assessment of future risks. Recently, Martin Hellman assessed the risk of a future “Cuban missile-type” crisis that results in nuclear use as between two in one thousand and one in one thousand per year. Note that this is only one of two estimates in Table 1 that provides a range of values, a useful approach to addressing uncertainty. Hellman also points to a dearth of analyses of the risk of deterrence failure and proposes that “several prestigious scientific and engineering bodies undertake serious studies to estimate its failure rate.”

Not surprisingly, a number of recent estimates have focused on the probability of nuclear use by terrorist organizations. Of the subjective estimations (i.e., those not based on a specific analysis), Richard Garwin’s estimate of 20 percent per year against a US or European city is the highest. Assuming that this probability remains constant over the period, it equates to a probability of approximately 90 percent within a decade. In the middle of the range of subjective estimates are Graham Allison and William Perry, who independently judge this probability to be 50 percent within a decade. At the low end is David Albright, who estimates less than 1 percent over ten years. These subjective assessments span almost the complete range of possibility from near 0 to 90 percent.

Two nuclear terrorism estimates in Table 1 are based on quantitative analysis. Matthew Bunn estimates 29 percent within the next decade, and John Mueller estimates less than one in one million per attempt. This large difference in estimates is not an encouraging indicator that quantitative analysis will facilitate convergence on a consensus estimate, but at least it provides valuable insights into the basis for each estimate.

In summary, the principal insights I take from the estimates in Table 1 are the same as for the Lugar survey: (1) they differ widely, and (2) they are all of questionable validity because they do differ widely and because they are fundamentally either intuitive or based on simple, perhaps simplistic, analysis. Also, subjective judgments appear to gravitate to either 1 percent or 50 percent as an estimate, which suggests that the resolution of human intuition is relatively coarse on this question.

44 Sagan, *The Limits of Safety*. 
Consequences

Nuclear risk assessment must consider the entire spectrum of potential consequences of all levels of nuclear war, ranging from a single detonation in a remote area to a large-scale nuclear exchange. These consequences must include all types of harm, including fatalities and injuries to humans, damages to infrastructures and the environment, and harm to militaries, economies, and other social structures. Assessments must consider not only the short-term harms but also harms that extend through time to future generations, likely centuries into the future.

We should also acknowledge, if only for the sake of completeness, that something positive might come out of some nuclear usages. In particular, limited nuclear use might reinforce the nuclear taboo, which is seen as increasingly fragile.\(^{45}\) Of course, the greatest challenge to the norm will occur when nuclear weapons are used. There is a presumption that once violated, the norm against use of nuclear weapons cannot endure. But, this presumption is not based on a body of research; it is possible that the response to first use could act to reaffirm the relevance of the norm, so that a single violation would not necessarily irreversibly undermine its existence. In fact, norm theory suggests that the response to the norm violation is pivotal in determining the ultimate impact of the initial violation.\(^{46}\) An extension of this thinking holds that norms, in general, cannot endure indefinitely without periodic violations that provide tangible reminders of their value. In any event, this area is highly speculative, and no one seriously advocates limited nuclear use as a mechanism to reinforce the nuclear taboo.

Our knowledge base on nuclear effects is extensive in some areas but meager in others. It is not an exaggeration to say that, as a whole, it is woefully inadequate to support a comprehensive consequences assessment. There are several reasons for this state of affairs. First, while the United States has conducted over one thousand nuclear tests and spent billions of dollars on nuclear effects research, the great majority of this effort focused on fulfilling Cold War military requirements. In support of nuclear mission planning, the United States sought high-confidence estimates of the effects of nuclear weapons of various designs with different outputs on targets of varying characteristics in the Soviet Union. Military planning for damage assessment and the possible need for subsequent attacks also demanded confidence in determining postattack target damage. These imperatives led to a focus on the nuclear damage mechanisms of air blast, cratering, ground shock, and similar phenomena. Our knowledge base is relatively good on these nuclear effects.

Second, somewhat less attention was paid to those phenomena that were inherently hard to predict or whose effects were delayed. In the former category is fire initiated by the thermal radiation of


\(^{46}\) James Scouras and Erin Hahn, “Responding to North Korean Nuclear First Use: Minimizing Damage to the Nuclear Taboo,” technical proposal (Laurel, MD: Johns Hopkins University Applied Physics Laboratory, 2018). This study, funded by the Defense Threat Reduction Agency, is anticipated to result in a paper late in 2019.
nuclear explosions. The US Defense Nuclear Agency, now the Defense Threat Reduction Agency, tried hard to model this phenomenon, but only very recently has this effort showed signs of potential payoff. In the latter category are radiation effects of many kinds, including fallout. While fallout modeling was a research area, and we now have good models of fallout production and propagation, the vagaries of weather, the uncertainties related to population evacuation and shielding, and other variables are impediments to confident prediction of the effects of fallout.

Third, some phenomena were discovered late, and by surprise, in the nuclear test program. For example, an unexpectedly large EMP was observed in the Starfish Prime atmospheric nuclear test in 1962. Further high-altitude testing was prohibited by the 1963 Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space, and Under Water, which relegated future research to the domain of modeling. Starfish Prime also resulted in the unanticipated destruction of all commercial satellites in low-earth orbit due to pumping the Van Allen radiation belts with electrons.

Fourth, the physical consequences to the infrastructures that sustain societies—power, water, finance, transportation, etc.—has never been a focus of nuclear weapons effects research. However, the Department of Homeland Security has funded the National Infrastructure Simulation and Analysis Center (https://www.sandia.gov/nisac-ssl/), a large effort by Sandia National Laboratories, Los Alamos National Laboratory, and Pacific Northwest National Laboratory to model the interdependencies among these infrastructures, with limited success. Nonphysical societal effects (e.g., social, psychological, political, and economic effects), are even more difficult to assess and have never been adequately investigated.

Arguably, the two phenomena most in need of further research are nuclear winter and EMP. Nuclear winter has the potential to pose even greater harm to the life on earth than all the more immediate damages due to blast and radiation. A small research community continues to model nuclear winter in various nuclear war scenarios with ever-more sophisticated models. But controversy over the many uncertainties associated with the inputs to these models and the underlying physics, as well as possible biases of some of the researchers, have impeded acceptance of nuclear winter predictions. As a result, the Department of Defense simply does not consider nuclear winter in its policy formulation or military planning. In fact, it argues that by making nuclear war even more horrific, nuclear winter is a positive contribution to deterrence. Similarly, the consequences of EMP may be catastrophic, but we simply do not know whether a nuclear attack will bring down the electric grid or otherwise cause great damage to the electronic systems that power our economy, military, and society.47

47 Michael Frankel, James Scouras, and George Ullrich, The Uncertain Consequences of Nuclear Weapons Use (Laurel, MD: Johns Hopkins University Applied Physics Laboratory, 2015).
As a result of this limited state of knowledge of the consequences of nuclear war, a comprehensive consequences assessment is simply not possible. The best we can do is estimate lower bounds on consequences and recognize that the true consequences of nuclear war may be significantly higher.

Risk Management

There is no shortage of ideas about what to do about the nuclear risk. The three pillars of US policy are (1) nonproliferation to reduce the threat from ever-increasing numbers of nuclear states, (2) counterterrorism to prevent nonstate organizations from acquiring nuclear materials and weapons, and (3) deterrence to prevent attack from hostile nuclear states. I will briefly address the first two of these, then discuss in greater depth the role of the nuclear balance and arsenal size in underwriting deterrence strategy. I do not address a multitude of other ideas, such as reducing dependency on launch on warning, increasing missile defenses, moving toward a nuclear-free world, and the relationships among strategic nuclear weapons, tactical nuclear weapons, and conventional, cyber, and space capabilities.

Nonproliferation

It might seem obvious that the fewer the number of nuclear states, the safer we are, and indeed that appears to be the consensus view in the national security community. The main argument is that with fewer nuclear states, there are fewer paths to nuclear war. This may be true, but it’s not the whole story. The United States benefits from both the British and French nuclear arsenals in deterring Russia from waging nuclear and large conventional attacks in Europe. This is not primarily because of our allies’ arsenals themselves, but because they provide independent decision authorities that Russia must consider when contemplating an attack.

It is not entirely clear why the development and possession of nuclear weapons by Japan or South Korea, for example, would not similarly contribute to international security, especially because further proliferation in northeast Asia is unlikely to be provoked. More generally, Kenneth Waltz has argued that the more states that have nuclear weapons, the safer the world will be from nuclear war.48 His argument is based on the historical experience that demonstrates that nuclear weapon states have shown great forbearance in engaging in any direct combat with each other.

In addition, new nuclear states pose special risks that established nuclear states do not. One risk arises from the fact that they have little or no experience with nuclear diplomacy and crisis management, which could lead to reckless posturing or behavior. We may have witnessed this dynamic in the 2018 war of words between US President Donald Trump and North Korean Supreme Leader Kim Jong Un.

Counterterrorism

After the attacks of September 11, 2001, fear that a terrorist organization would succeed in stealing, building, or buying a nuclear weapon or weapons dominated nuclear concerns. The thought was that such organizations were immune from the logic of deterrence, because they did not present targets of value in the way that states do. Hence, counterterrorism strategy focused on preventing substate actors from acquiring both weapons and nuclear materials. These efforts have been largely successful—so far—although more can and should be done. Terrorist organizations are unlikely to have given up their nuclear ambitions.

As discussed earlier, President George W. Bush emphasized the need for preemptive attack options in our deterrence strategy to counter the threat of nuclear terrorism. More recently, we have begun to understand that deterrence still has a role to play against terrorism. But the focus of deterrent threats must be the countries that harbor terrorist organizations, either willfully or through neglect or incompetence.

Deterrence

Deterrence of a nuclear first strike depends on the fear of a retaliatory strike, which, in turn, depends on the nuclear capabilities of the victim of the first strike. Here I summarize two analyses that illustrate the complexity of assessing the relationship between nuclear capabilities and deterrence: (1) the importance, or irrelevance, of nuclear parity and (2) how many weapons are enough to underwrite deterrence.

Nuclear Parity

The imperative to achieve nuclear superiority—or, at a minimum, nuclear parity—drove the Cold War arms race to dizzying heights, as illustrated in Figure 4.49 Yet, the United States has also tolerated a significant imbalance in nuclear weapons during the last decade of the Cold War and the first post-Cold War decade, and China has embraced a minimum deterrence posture. As we look ahead, we must consider the potential for both further negotiated arms reductions and the opposite—abandonment of strategic arms control—as well as continuing growth in the Chinese arsenal and vertical and horizontal nuclear proliferation in other states. Facing this highly entropic future, how should nearly three-quarters of a century of nuclear experience inform US policy with respect to the nuclear balance with Russia and other adversarial nuclear states?

Because all involved states would suffer enormously in a nuclear war regardless of the nuclear balance, nuclear crisis management is the default mechanism through which nuclear balance affects states’ behaviors, and nuclear crisis outcome is the primary measure of the value of nuclear superiority. Scholars and strategists debate the importance of relative nuclear capabilities as well as myriad other factors, especially political stakes, resolve, risk tolerance, the conventional military balance, and domestic politics. Multiple factors are often at play in any particular crisis, and there are important relationships among them. The key policy-relevant question for the United States is, Are nuclear-superior states more likely to prevail in nuclear crises?

Perspectives on this question underlie national security policies regarding, inter alia, arms control, triad recapitalization, nonstrategic weapon deployments, nuclear proliferation, nuclear crisis management, and cross-domain and extended deterrence. Over the next decade, these perspectives will be reflected in decisions on implementing the 2018 Nuclear Posture Review, strategic arms control after the New START Treaty, the future (if any) of the INF Treaty, and the fate of the Comprehensive Test Ban Treaty. They will also impact US crisis management strategy vis-à-vis North Korea and nonproliferation policy vis-à-vis Iran.

Recent research has incorporated quantitative analysis into traditionally qualitative investigation. However, there are concerns about the appropriateness of these studies’ statistical methods. One important result of a recent analysis is displayed in Figure 5.\textsuperscript{50} Based on historical data on nuclear

\textsuperscript{50} Kelly Rooker and James Scouras, \textit{Uncertainty in the Binomial Distribution Parameter} (Laurel, MD: Johns Hopkins University Applied Physics Laboratory, forthcoming).

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figures/arsenals.png}
\caption{US and Soviet Union/Russian nuclear arsenals over time}
\end{figure}
catastrophes compiled by Matthew Kroenig,\textsuperscript{51} the probabilities of winning a nuclear crisis are plotted for both the side with the superior and the side with the inferior nuclear arsenal. Both probabilities are highly uncertain, reflections of the small data set and the importance of variables other than the nuclear balance. Notwithstanding these uncertainties, the probability of winning is significantly lower with an inferior arsenal. These results suggest that (1) even the side with the superior arsenal should not confidently expect to win a nuclear crisis, and (2) if a nuclear state anticipates nuclear crises in its future and wishes to win, it should strive to avoid nuclear inferiority.

To summarize, the importance of the nuclear balance vis-à-vis our principal adversary has been the subject of intense but unresolved debate since the Soviet Union acquired nuclear weapons some seven decades ago. This issue remains at the heart of nuclear force structure, nonproliferation, and arms control policies, as well as deterrence and crisis management strategies. Though nuclear superiority has not always swayed crisis resolution, it has mattered in some crises. We cannot dismiss the possibility that it will matter in some future crises—perhaps even the next crisis. Given profound uncertainties about the implications of asymmetries in nuclear arsenals, the most prudent approach is to hedge against the possibility of dire consequences of nuclear inferiority.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Relative Nuclear & Crisis Outcome & \multicolumn{2}{|c|}{Total} \\
Arsenal Size & & Win & Lose \\
\hline
Superior & 14 (54\%) & 12 (46\%) & 26 \\
Inferior & 4 (15\%) & 22 (85\%) & 26 \\
\hline
\end{tabular}
\caption{Data Source: Matthew Kroenig (2013)}
\end{table}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5}
\caption{Uncertainty in the probability of winning a nuclear crisis}
\end{figure}

How Much Is Enough?

Even after we answer the parity question, we still have questions about how many nuclear weapons we need. Figure 6 shows US nuclear warheads under the New START Treaty.\textsuperscript{52} Five states of these forces are arrayed along the $x$ axis. Total number of warheads is equivalent to arsenal size. It includes both deployed and nondeployed warheads. Available warheads, which exclude nondeployed warheads, are those that realistically could be used in a nuclear war. But not all available warheads are on alert, ready to be launched within minutes of a presidential order, or are based in a survivable posture to be launched at any time. On day-to-day alert, fewer than half of these available warheads could be launched rapidly or are survivable. Then, we must consider whether the United States launches intercontinental ballistic missiles on tactical warning (LOW) or rides out an attack (ROA). Riding out the attack will further decrease the warhead count. Finally, we must factor in the system reliabilities and probabilities of penetrating Russian defenses. At the end, we are left with the number of warheads that we—and Russia—can reasonably anticipate would detonate in a US retaliatory strike on Russian targets. It is this quantity, not arsenal size or any of the other intermediate quantities, that underwrites deterrence.

In Figure 6, we see four scenarios with different numbers of arriving weapons. The lowest level is defined as assured retaliation. I argue that our focus should be on this number as the single best measure of our nuclear forces’ contribution to deterrence. This is because it is the most stressing case. Although it might not be the most likely of the four scenarios, it is still probable enough, relative to the others, that we must plan for it. Furthermore, while we may be able to control whether or not we ride out an attack or launch on warning, there is great uncertainty in what we will actually do. Thus, we should not count on launching on warning. And finally, whether we are on generated alert as opposed to day-to-day alert is actually a decision that our attacker will make, because the timing of any attack would be up to them.

\textsuperscript{52} For a more detailed discussion, see chap. 2 in Steven Cimbala and James Scouras, \textit{A New Nuclear Century: Strategic Stability and Arms Control} (Westport, CT: Praeger Publishers, 2002).
So, what level of assured retaliation do we need? In fact, this has been subject to debate throughout the nuclear age. During most of the Cold War, we focused on being able to achieve high damage levels to military, economic, and leadership targets in the Soviet Union. And as our arsenals grew, so did our target lists. The prevailing view was that deterrence required us to be able to utterly destroy the Soviet Union as a functioning entity in a retaliatory strike under the worst plausible circumstance.

Today, other views are gaining traction. As weapon arsenals have shrunk in the post-Cold War era, so too have target damage requirements. At this point, there appear to be two intellectual camps among deterrence analysts, one advocating at least some additional nuclear arms reductions and the other questioning whether we can safely go to lower levels. There are important distinctions within the group that advocates for further reductions. Some call for a minimum deterrence posture. Proponents of minimum deterrence argue that far fewer weapons (hundreds) are sufficient to deter Russia. They point to China, and to a lesser extent the United Kingdom and France, all of which have adopted minimum deterrent postures. Some minimum deterrence advocates believe that we can safely adopt such a posture, even if Russia does not, while others believe that we should proceed in lockstep with Russia through a succession of arms control agreements to greatly reduce both arsenals.

**Residual Risk and Risk Acceptance**

It is clear that we cannot reduce nuclear risk to zero unless we eliminate all nuclear weapons from the earth, and perhaps not even then. And while President Obama was a strong advocate for “global zero” as a long-term objective, no other nuclear state seems to have seriously embraced this vision.
But there is also a possible serious downside to reducing nuclear risk to zero. One important argument for nuclear weapons is that they save lives by reducing the frequency and intensity of conventional wars between great powers and that, by implication, they will continue to do so indefinitely.

The United States developed nuclear weapons during World War II because of fear that Nazi Germany would do so first. While the weapons were not operational in time to be used in Europe, the atomic bombings of Hiroshima and Nagasaki helped end the Pacific War with Japan. In the immediate aftermath of World War II, their primary role abruptly shifted to deterring Soviet conventional aggression against Western Europe. Subsequently, after the Soviet Union acquired nuclear weapons in 1949 and eventually built an arsenal comparable to—and ultimately exceeding—that of the United States, the primary role of nuclear weapons gradually evolved to deterring a Soviet nuclear attack. At the same time, the role of deterring conventional war by threatening escalation to nuclear war remained a key element of US strategy throughout the Cold War and the post-Cold War decades.

Citing the absence of great power wars since 1945, some scholars and national military leaders have emphasized the importance of nuclear weapons in saving lives. Moreover, they implicitly suggest that nuclear weapons will continue to save lives, while underemphasizing the risk that deterrence of nuclear war could fail with cataclysmic consequences. To support their viewpoint, these proponents of nuclear weapons often point to a particular analysis of wartime fatalities from the year 1600 to the present. While the original graph of the results of this analysis was circulated in the defense community in the mid-1990s, it has evolved over the decades, with the most recent variant (shown in Figure 7) appearing in the 2018 Nuclear Posture Review report. It indicates that wartime fatalities have been lower in the nuclear era than during any previous time since 1600, implicitly crediting the advent of nuclear weapons for these saved lives.
A recent Johns Hopkins University Applied Physics Laboratory study has analyzed this graph and finds that it is fatally flawed. In particular, it is irreproducible from information provided by the Department of Defense Historical Office, the cited source of data; it uses dubious analytical methods (among them, concatenation of incompatible databases and erroneous normalization by world population); and it presents results in a profoundly misleading manner, primarily due to varying histogram bin widths.

A more rigorous analysis results in the graph in Figure 8. All the cited flaws of the preceding histogram have been rectified. In particular, wartime fatalities are shown on an annual basis, which enables more insight into the aperiodic nature of wartime fatalities and entails less bias. This graph indicates that the incidence of annual wartime fatalities after World War II (as a percentage of world population) is comparable to that of many earlier times. Also, periods of diminished fatalities typically follow major wars; for this reason alone, we cannot conclude with certainty that nuclear weapons are the source of the current relatively quiescent period. Finally, we observe a clear trend in the intensity of major wars. Projecting this trend to the future reminds us what we already know—that nuclear war will be unprecedented in its human toll, potentially exceeding the fatalities of all previous wars combined. There is simply no basis in this analysis to conclude that nuclear weapons will continue to deter either nuclear or large-scale conventional wars.

---

Finally, it is important to understand that statistical analysis—done correctly—can at most show a correlation between the advent of nuclear weapons and a change in wartime fatalities. Proving a causal relationship would require a complex multidisciplinary analysis. Understanding the potential for nuclear weapons in preventing great powers from waging conventional war is a worthy pursuit that deserves a thorough and rigorous analysis. Basing vital national security decisions on irreproducible, misleading, and logically flawed reasoning is a dangerous practice.

Nuclear war is a global catastrophic risk that will be with us for the foreseeable future. Unlike most other global catastrophic risks, there is an interplay between consequences and likelihood that forces us to question just how low we should try to reduce the risk.

Our understanding of the risk of nuclear war is highly uncertain, both for likelihood and consequences. But steps can be taken to improve this situation. Regarding likelihood assessments, the first important step is to develop a more refined sense of humility about whatever intuition is informing our judgments. We can and should also undertake more disciplined analytic studies. These should be multidisciplinary because no single analytic approach has proven to be satisfactory. We can learn something from historical case studies, expert elicitation, probabilistic risk assessment, complex systems theory, and other disciplines. Regarding consequence assessments, the Defense Threat Reduction Agency needs explicit direction to focus on less understood nuclear effects, particularly EMP and nuclear winter. There are no fundamental barriers to obtaining a better understanding of these important phenomena.

It is also apparent that the optimal strategy for reducing nuclear risk is also uncertain. This suggests a cautionary and balanced approach. Extremes, such as global zero, or replacing nuclear deterrence with widely deployed missile defenses, are untested gambles and either politically or
technologically prohibitive. Some combination of measured and slowly implemented reductions, while maintaining parity with our largest adversary, seems prudent.

Because the stakes are so high, nuclear deterrence (like liberty) requires eternal vigilance. The good news is that we can afford whatever we decide we need to underwrite nuclear deterrence. The challenge is to wisely decide what we need.