Consequences of Regional-Scale Nuclear Conflicts: Understanding and Avoiding Nuclear Catastrophe

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Abstract

The three-fold decline since 1986 in global nuclear weapons and the relaxation of world tensions since the end of the cold war suggest that nuclear war is no longer a serious global concern. In fact, the probability of nuclear conflict soon may expand greatly due to nuclear proliferation. Large numbers of new nuclear states with widely differing political views will present new challenges to world order. Conflicting demands
and defense agreements can lead to chaos. New analyses show that nuclear powers with arsenals of 50 Hiroshima-sized weapons, such as those likely possessed already by India and Pakistan, are capable of inflicting casualties rivaling those of World War Two or even a counterforce war between Russia and the United States. New studies also show that significant climate changes may follow a regional war, directly threatening people everywhere, not just in the region of conflict.

In the twentieth century, nuclear weapons were invented, mass-produced, and actively deployed as political and military tools. About 125,000 warheads were manufactured, and about 2,000 were tested (1,2). However, only two weapons—the first operational nuclear fission bombs ever built—were used against Japan toward the end of World War II (WWII). The experience in Japan, and the realization of the powerfully destructive nature of these weapons, effectively prevented any pragmatic use, except as a deterrent against aggression in the form of the policy of Mutually Assured Destruction (MAD). In the 1980’s, potentially severe global environmental effects and other indirect effects on the structure of society resulting from nuclear war were identified and found to threaten as many fatalities as the direct effects of the war, and to put non-combatant nations at risk. Starting in the mid-1980s, a series of unilateral decisions and international treaties led to significant reductions in the main nuclear arsenals (Fig. 1). Moreover, by the 1990’s, the Soviet Bloc had disintegrated, and the Cold War had ended. The justification for massive nuclear arsenals held by the world’s “superpower” nations dissipated along with the Cold War, and in step with the emergence of Eastern democracies.
While the world in the twenty-first century may no longer face a serious threat of global nuclear warfare and its indirect consequences, regional conflicts continue unabated, in some cases exacerbated by advancing technologies. Within this milieu of hostility, acquisition of nuclear weapons has been perceived as a potent political, military and social tool. National ownership of small numbers of nuclear weapons offers international status and insurance against aggression at a modest financial cost. We are approaching a dangerous crossroads, where nuclear proliferation may significantly expand the number of nuclear weapons states. The complexity of relationships in a world with tens of such states, each with competing goals, suggests a future of political confrontation, with the danger of nuclear war or state-sponsored terrorism. Meanwhile, the developing world, which provides fertile ground for proliferation, has experienced rapid population growth, and an accelerated congregation of people and socioeconomic activities in “megacities”, and they now are potential targets for nuclear weapons. This combination of nuclear proliferation, political instability, and urban demographics may constitute one of the greatest dangers to the stability of society since the dawn of humans.

With this modern threat in mind, we evaluated the potential for casualties in a regional-scale nuclear conflict, or a terrorist attack, and the associated environmental impacts (3,4). Surprisingly, we find that in a regional war, total fatalities could rival those worldwide during WWII, and that global scale climate changes induced by smoke emissions could jeopardize the survival of non-combatants far removed from the hostilities.

Eight nations are known to have nuclear weapons. In addition, North Korea may have acquired a small but growing arsenal. Iran appears to be seeking nuclear weapons
capability, but is likely to require several years to obtain sufficient fissionable material to construct weapons. Of great concern, 32 other nations—including Brazil, Argentina, Japan, South Korea, and Taiwan—already possess sufficient fissionable materials to produce weapons if they wished. A de facto nuclear arms race has emerged in Asia between China, India and Pakistan, which could expand quickly to include North Korea, South Korea, Taiwan and Japan. A nuclear confrontation in the Middle East between Israel and Iran would be of great concern, and Egypt may also seek to form a sort of nuclear ménage à trois. Nuclear arms programs in South America, notably in Brazil and Argentina, were ended by several treaties in the 1990s. Hopefully these agreements will continue to restrain these countries and serve as a model for other regions, despite Brazil having new, large uranium enrichment facilities.

Nuclear arsenals containing 50 or more weapons of low yield (15 kt, equivalent to the Hiroshima bomb) are relatively easy to construct. India and Pakistan, the smallest current nuclear powers, have or will soon achieve such arsenals. Modern weapons are compact and lightweight, and are readily carried by a small vehicle (car, truck, missile, plane, or boat). Terrorists are actively seeking nuclear explosives, and proliferation may increase the likelihood they will succeed. Indeed, all of the basic concepts of weapons design are readily obtained by casual browsing of the Internet. The only serious obstacle to a terrorist bomb is the limited availability of purified fissionable fuels.

A single low yield weapon detonated in a modern megacity could cause more than 1 million casualties (3). Even one such explosion might lead to 100 times as many fatalities as Egypt and Israel, Pakistan and India, or Argentina and Brazil have experienced in historical conflicts. Only a handful of detonations in the U.S., U.K., or
France could lead to more fatalities than were suffered in past major conflicts, including WWII. Hence, the use of nuclear weapons greatly raises the potential level of destruction that might occur when regional hostilities escalate, as happens regularly in this world.

There are many circumstances that could trigger a regional-scale nuclear conflict, and many scenarios for the conduct of the ensuing war. In our analysis, it is assumed that the densest population centers in each country are attacked. Scenarios that purposefully target population centers with nuclear weapons, at least in the case of escalating military hostilities between nations, might be challenged on several grounds. However, rapid-fire, intense urban targeting would inflict the greatest damage to an adversary nation or alliance of states. That, combined with military bombardment, would constitute an all-out engagement aimed at permanently crippling an opponent. In that sense, the “small” war scenarios we have adopted are similar in principal, if not in scale, to the strategies of all-out nuclear warfare and warfighting embraced by the superpowers in the mid-20th century in the context of MAD. We (3) consider a nuclear exchange involving 100 low yield weapons (amounting to 0.3% of the total number of existing weapons, or about 0.03% of the total explosive yield). Using a standard population database, casualties were estimated for a number of countries that might be targeted in a regional conflict (Fig. 2). The results vary, of course, depending on the country attacked. For instance, such an exchange between India and Pakistan, which is consistent with the arsenals they are believed to possess currently, could produce about 21 million fatalities—about half as many as occurred globally during WWII. An attack on the U.S. consisting of 50 low-yield weapons could lead to 3-4 million fatalities, similar to what was once predicted for a full “counterforce attack” by the Soviet Union using thousands of high yield weapons.
While the direct effects of nuclear blast, prompt radiation and thermal radiation would cause most of the casualties, longer-lived radioactive fallout could also pose unprecedented problems. Notably, if one or more groundbursts were detonated in a megacity, extensive damage to infrastructure, contamination by long-lived radionuclides, and psychological trauma among the population, would likely result in the indefinite abandonment of a large tract, leading to severe economic and social sequelae, perhaps having global dimensions.

Fires inevitably ignited by nuclear bursts in cities, paralleling the firestorm in Hiroshima, would release copious amounts of light-absorbing smoke into the upper atmosphere. 100 small nuclear weapons detonated within cities may be capable of generating 1-5 million tons of carbonaceous smoke particles (3) with the potential to create greater optical and radiative perturbations in Earth's atmosphere than major volcanic eruptions like Mt. Pinatubo (1991) or Tambora (1815) (4). The latter event has been associated with the “Year Without a Summer” in 1816.

Robock et al. (4) provide a new, detailed assessment of the potential climate responses to such smoke emissions. Simulations were carried out using the latest version of the NASA Goddard Institute for Space Studies climate system model, or ModelE (5), which treats the entire atmosphere from Earth’s surface up to 80 km, along with coupled dynamic oceans. In these calculations, carbonaceous smoke particles are transported interactively throughout the atmosphere in response to solar heating and induced circulations. The model predicts that such radiative-dynamical interactions stabilize the smoke aerosol, allowing it to persist in the atmosphere far longer than previously assumed.
The present simulations also lead to the conclusion that, for smoke emissions generated by 100 low-yield urban explosions, significant global-scale climate anomalies are possible in the aftermath of a regional nuclear conflict. Indeed, the resulting indirect effects on surface land temperatures, precipitation rates, and growing season lengths would be likely to degrade agricultural productivity substantially (Fig. 3). Moreover, climatic anomalies are found to persist for up to a decade or more owing to the stabilization of smoke in the middle and upper atmosphere. Many noncombatants far removed from the original detonations could therefore be threatened with starvation. The number of casualties might then rival historical catastrophes, including natural disasters, famines and wars.

The severity and seriousness of these issues suggest that governments and citizens worldwide, and especially in countries considering nuclear weapons, need to evaluate more critically the consequences of nuclear proliferation. There is precedent for successful international responses to the threats described here. Recognition of the danger of globally distributed radioactivity from atmospheric nuclear tests led to the 1963 Limited Test Ban Treaty. China, a non-signatory, conducted the last atmospheric test in 1980. The majority of nations in Africa, Latin America and the Caribbean, South East Asia, and the South Pacific have agreed to regional treaties banning nuclear weapons, creating nuclear free zones. The Antarctic Treaty of 1961 made it a nuclear-free zone.

There are also successful environmental agreements. For example, the 1987 Montreal Protocol—the world’s first global environmental treaty—moved world society to find replacements for ozone-depleting substances. Consequently, the concentration of these compounds has begun to decrease in both the troposphere and stratosphere, and ozone
has started a gradual recovery to pre-1980 levels (6). It follows that the international community is capable of considering and addressing threats to the global community, and the environment that supports society.

Unfortunately, the Nuclear Non-Proliferation Treaty has failed to prevent the expansion of nuclear states. There are numerous steps that could be taken to inhibit or prevent the spread of nuclear weapons, such as: greater clarity in accounting for nuclear weapons and materials that countries already possess (7,8); increasing the role of the United Nations in safeguarding nuclear materials worldwide (currently less that 1% of highly enriched uranium and about 35% of plutonium is safeguarded); devising new treaties that further reduce current arsenals while maintaining a stable deterrent; and developing meaningful incentives for states to forsake nuclear weapons capability and avoid regional nuclear arms races. It is clear that these actions should be taken simultaneously and in a coordinated manner, not independently and piecemeal, if a truly universal resolution is to be achieved. Solutions must obviously involve concessions on both sides of the fence. The ongoing reductions in the U.S. and Russian nuclear arsenals (Fig. 1) should continue, providing momentum for a wider long-range solution. The major nuclear weapons states must be willing to provide developing states with economic and technological assistance, while emerging nuclear states must be willing to forego autonomous nuclear weapons programs and accept strict monitoring regimes. Further, countries with access to nuclear materials and processing facilities must be willing to implement policies to safeguard facilities, and track nuclear materials unambiguously through procedures established, say, through the UN. Conflict resolution could also take on increasing importance, with the UN similarly playing a key role.
We should not be naïve in offering quick answers to what may be the most complex, vexing and critical issues confronting global human society. However, neither should we avoid facts and implications. The many problems society faces today are interconnected. Accordingly, policy responses to the threat of nuclear proliferation should be consistent with solutions posed for other environmental and social problems.

The analysis summarized here shows that the world has suddenly and unexpectedly reached a crossroads. Having survived the threat of global nuclear war between the superpowers the world is increasingly threatened by the prospects of regional nuclear war, the consequences of which are unexpectedly large, as we have shown. The decline in world tensions and nuclear arms of the past two decades had suggested that the world was on a path toward a prosperous and peaceful 21st century. However, if we take the wrong path at this crossroads and do not control nuclear proliferation we may be headed toward a dangerous world containing many nuclear powers with conflicting interests who may engage in regional conflicts with the potential to become global catastrophes.

References


**Figure 1.** Number of nuclear weapons worldwide, which is dominated by the United States and Russia (formerly the Soviet Union). Although not even visible in this diagram, the smaller numbers possessed by France, Britain, China, Israel, India, and Pakistan, if used, could produce millions of deaths and global climate change. While many Russian and American weapons are deployed, large numbers are in reserve, storage or various stages of disassembly. Although the number of nuclear warheads worldwide decreased by nearly a factor of three since its peak in 1986, roughly 26,000 thousand warheads still exist in 2006 and more than 11,000 are effectively deployed. Current treaties call for both the U.S. and Russia to reduce their arsenals to 1700-2200 deployed warheads by 2012. Data from refs. 2,8 and related works by those authors.

**Figure 2.** Fatalities predicted due to prompt radiation, blast and fire damage from an attack using 50 nuclear weapons with 15 kt yield on various countries. Airbursts were assumed, estimates for ground bursts, including early radioactive fallout, are about 25% less (3).
**Figure 3.** Change in growing season (period with freeze-free days) in the first year following smoke injection from 100 15-kt nuclear explosions, about 0.03% of the yield of the current global arsenal (Figure 4 from ref. 4). Combined with colder temperatures during the growing season and reductions in sunlight and precipitation, these effects would threaten global food supplies for a decade.
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