

New models of nuclear war risk assessment

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After the end of the Cold War, the risk of nuclear war had largely fallen out of view. But while most nuclear weapons have been disarmed, a staggering 15,350 weapons still remain, of which 14,300 are held by the US and Russia. Right now, 4,000 of these weapons are in active deployment, meaning that they are available for use at any time. A nuclear war could be just moments away.

The risk of nuclear war is central to a number of major policy questions. How high on the agenda should nuclear war risk be? Which policies are most effective at reducing the risk? How should nuclear states manage their nuclear weapons? Under what conditions should the weapons be disarmed? These are important questions for policy makers of every country and concerned citizens around the world.

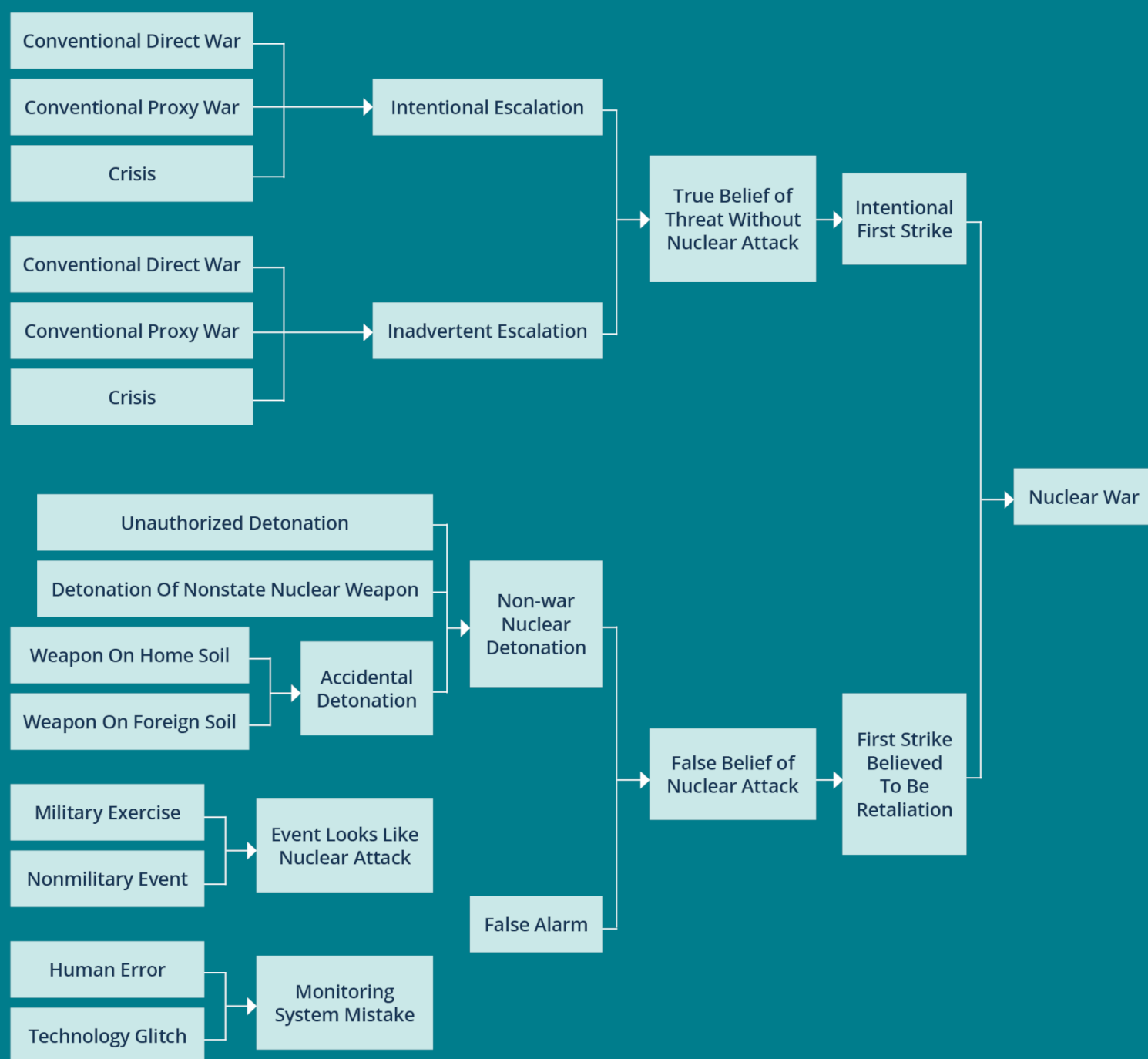
To address them, it is essential to understand the risk of nuclear war. But despite the topic's importance, there has been little risk analysis of nuclear war. Prior studies have focused on specific scenarios, such as crises escalating to nuclear war (as in the Cuban missile crisis) and false alarms being misinterpreted as real attacks (as in the Norwegian rocket incident). This is important work, but stops short of answering the question of overall nuclear war risk, which is crucial for a range of major policy issues. In order to help characterize the overall risk, researchers at the Global Catastrophic Risk Institute (GCRI) have completed the first-ever risk models that consider the total probability and impact of nuclear war.

Traditional risk analysis is based on the historical frequency and severity of harmful events. For example, the World Health Organization reports that 1.25 million people die each year worldwide due to road traffic crashes. This means that, for the average person, the risk of dying in a road traffic crash is about one-in-5,700 per year. But the history of nuclear war does not allow for the risk to be calculated accurately on this basis. Nuclear weapons have only been used once in a military context – during World War II – and under circumstances very different from today. Particularly, at the time, only one country possessed nuclear weapons, and nuclear deterrence did not play a role. It would likely be inaccurate to calculate the ongoing risk of nuclear war using nothing but the one occurrence of nuclear weapon use in WWII.



Our probability model, instead, explores the various pathways through which nuclear war could occur. These pathways were developed through consideration of historical data and possible future conflict scenarios, considering potential chains of successive events, in the form of a fault tree. This model makes it possible to incorporate the probability of each successive event across the range of scenarios, and obtain the overall probability.

Mapping pathways to nuclear war





The model contains two main sets of pathways. One set considers a nuclear-armed state intentionally making a first strike attack. This could involve conventional wars going nuclear (as in WWII) or crises leading directly to nuclear war (as in the Cuban missile crisis). The other set of pathways results in a nuclear-armed state unintentionally making an attack under the mistaken belief that they are under nuclear attack. This can occur if a nuclear weapon detonates for some other reason (such as a nuclear terrorist attack) and is mistaken for a first-strike attack by another state. It can also occur if a false alarm (such as a military exercise) is mistaken as an actual nuclear attack. These various pathways are detailed in the figure above.

Except for conventional war going nuclear, none of these pathways have ever led to nuclear war. However, there have been many near-misses: incidents that went partway to nuclear war. Our research created a new data set of 40 such historical near-miss incidents. They range from the Korean War in 1950-1951, when the U.S. considered using nuclear weapons against Chinese forces, to recent moments in the Ukrainian Civil War, in which Russia has made several nuclear threats. This is not a complete set of nuclear war near-miss incidents, but provides important insight to assess ongoing probabilities.

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This historical record shows that nuclear deterrence can fail and that the world has been lucky to avoid a second nuclear war. Repeatedly throughout history, aggressive actions have been taken against nuclear-armed states, despite the threat of nuclear retaliation. In some cases, nuclear attacks were seriously considered by state leadership or by military officers with the capability of launching nuclear weapons without explicit permission of state leadership. There have also been many false alarms that went partway to prompting nuclear weapons launches. It may only be a matter of time until one such incident goes all the way to nuclear war.

The impact model is based on the various ways that nuclear war can affect human society. Five effects of detonating nuclear weapons are modeled. Four of those are physical: thermal radiation (mainly visible light, essentially a bright flash of light), blast (air moving at high pressure), ionizing radiation (high energy radiation capable of dislodging electrons from atoms and molecules), and electromagnetic pulse (an electromagnetic field that can couple with and destroy electronics). Each of these can cause extensive harm to human bodies and/or built infrastructure. The fifth effect is human perception of nuclear weapons detonations, which can also lead to major consequences, such as shifts in norms about future weapons use, making it more or less likely that nuclear weapons would be used in future disputes.

In order to properly assess impact, many elements must be accounted for. Nuclear war can destroy buildings, cause fires, disrupt telecommunications, shut down supply chains, induce dehydration and starvation, cool the entire planet, and directly harm people exposed to the blast by causing hemorrhaging, embolisms, and other injuries. Various factors in the scenarios will affect the overall impact. How many nuclear weapons were detonated? What types of nuclear weapons were they? Where and when did the



detonations occur? On this basis, the risk of nuclear war is not a single number but a complex array of phenomena, all of which are important to understand in order to successfully characterize and manage the risk.

The impact model also considers other global catastrophic risks that might result from the use of nuclear weapons. Nuclear war can lead to infectious disease outbreaks, such as by destroying health care infrastructure. It can affect global warming by changing greenhouse gas emissions, such as by disrupting energy supply chains. It can affect the development and use of risky new technologies, including stratospheric geo-engineering. Each of these consequences could be as large or larger than the more direct impacts of nuclear war. Modeling the full impacts of nuclear war thus requires models for each of these other global catastrophic risks. Future work is needed to connect the nuclear war impacts model to these other models.

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This research on nuclear impact and probability modeling is the first to take such a comprehensive and systematic view of the issue. Our research takes a major step by offering the first full models of the probability and impacts of nuclear war. These models lay the foundation for quantifying probability and impacts. However, they stop short of quantification. At this stage of the research, quantification would require a lot of guesswork as to the probability or impact of each event, and would likely be very inaccurate. Successful risk analysis and risk management requires that people not cut corners or place too much belief in unfounded numbers.

The GCRI research does offer a full account of how nuclear war can happen and what its impacts could be. The models show the many facets of nuclear war risk and how they fit together. This is valuable in its own right for helping people understand the risk of nuclear war. Indeed, understanding the risk can be just as important as quantifying it. Each part of the risk points to unique opportunities for risk management. For example, an understanding of false alarm scenarios can highlight opportunities to make nuclear weapon monitoring systems less prone to false alarm. An understanding of how nuclear war can disrupt food supplies can highlight opportunities to improve postwar food security. The GCRI risk models make it easy to identify these sorts of opportunities. The models also show how risk management opportunities affect different aspects of the risk, which can point to synergies across different opportunities. There is a wide range of nuclear war risk management opportunities available for a wide range of people, both government officials and private citizens.

Rigorous quantification of probability and impacts is an important task for future research. For probability, this would entail research activities such as creating a more comprehensive set of historical incidents, analyzing each incident in terms of how close it got to nuclear war, and developing and applying theory to extrapolate from near-misses to actual nuclear wars. It could also involve eliciting expert judgment on sections of the model for which historical data is scarce, and developing forecasts on how components of the model might change in future years. In addition, it will be important



to model distinctions between different nuclear-armed states, so as to identify which states are most likely to engage in nuclear war and under what circumstances.

For impacts, quantification would entail quantifying each type of impact and how it affects the other types of impacts. Some types of impacts are already well characterized, with models available in existing literature. Future research could comb this literature for models applicable to the nuclear war impacts model. Other impacts require original modeling. Those in most need of characterization are impacts involving systemic effects to critical infrastructure systems and to other catastrophic risks, especially where there is potential for cascading effects across systems and geographic regions, as well as long-term effects on human civilization.

The work needed to further understand probability and impacts makes for a sizable research agenda, which speaks to the complexity of nuclear war risk. However, given how high the risk could be, and its importance to policy decisions, this is an important activity for society to pursue.