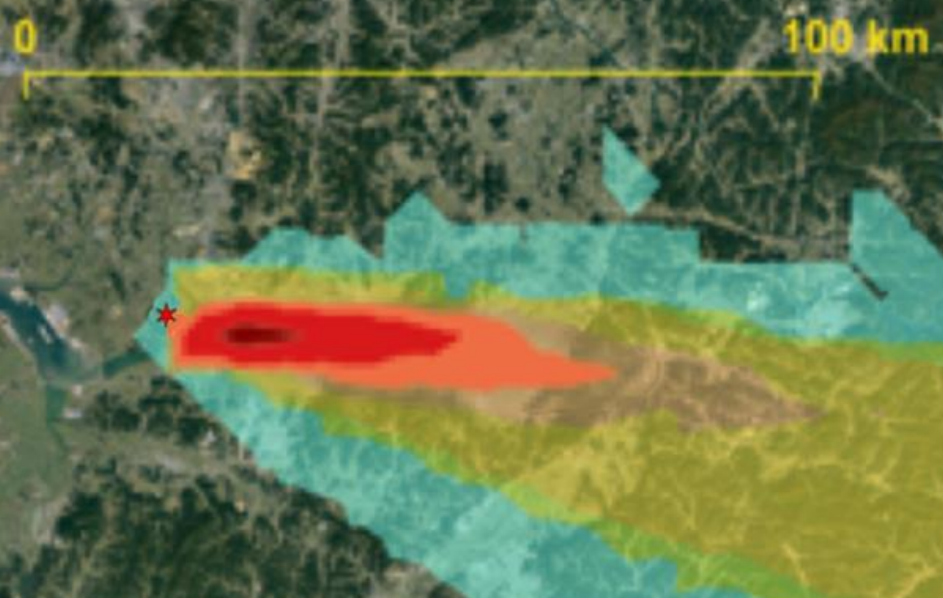

Humanitarian Impacts of Nuclear Weapons Use in Northeast Asia: Implications for Reducing Nuclear Risk

Project on Reducing the Risk of Nuclear Weapons Use in Northeast Asia

March 2023

Reducing the Risk of Nuclear Weapons Use in Northeast Asia (NU-NEA) Project

Humanitarian Impacts of Nuclear Weapons Use in Northeast Asia: Implications for Reducing Nuclear Risk

Co-sponsored by

The Research Center for Nuclear Weapons Abolition, Nagasaki University (RECNA)

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On the Cover:

Top right: Photo of Nagasaki after atomic bombing on August 9, 1945, with statuary from a destroyed Buddhist temple in the foreground. Photo by Cpl. Lynn P. Walker, Jr., U.S. Marine Corps, via Wikimedia Commons.

Bottom left: Photo of Hiroshima after atomic bombing on August 6, 1945, with Genbaku (Atomic Bomb) Dome in the background. From Records of the U.S. Strategic Bombing Survey, via National Archives (United States).

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RECNA 長崎大学核兵器廃絶研究センター Nagasaki University Research Center for Nuclear Weapons Abolition

APLN ASIA-PACIFIC LEADERSHIP NETWORK FOR NUCLEAR NON-PROLIFERATION AND DISARMAMENT

NAUTILUS INSTITUTE FOR SECURITY AND SUSTAINABILITY

Humanitarian Impacts of Nuclear Weapons Use in Northeast Asia: Implications for Reducing Nuclear Risk

Executive Summary

The risk of nuclear war—that is, the risk of attacks carried out by detonating nuclear weapons, hereafter "nuclear weapons use"— as of early 2023 is judged by many observers to be at its highest since the end of the Cold War. This risk is increasing due to nuclear threat-making during the Ukraine conflict, the India-Pakistan conflict, the Korean conflict, and the Middle Eastern conflict. Northeast Asia represents one of four potential flash points where nuclear weapons might be used for the first time since the last time they were used, on Nagasaki on August 9, 1945—hereafter called "first use" in this report.[1]

Northeast Asia includes two nuclear weapons states (China and Russia), a third nuclear weapons state with a key presence as a guarantor of security (the United States), a fourth and more recent self-declared, if not universally accepted, nuclear-armed state (the Democratic People's Republic of Korea, or DPRK), and two non-nuclear weapons nations under the US "nuclear umbrella" with the technology to produce nuclear weapons and at least some voices arguing for access to or ownership of nuclear weapons (the Republic of Korea, or ROK, and Japan). Add to this group of actors the long-simmering and occasionally boiling issue of nuclear weapons on the Korean Peninsula, tensions over Taiwan, and other regional disputes, and a number of potential nuclear weapons "use cases" become plausible.

The second year of the Project on Reducing the Risk of Nuclear Weapons Use in Northeast Asia (NU-NEA), set out to better understand the risks of nuclear weapons use in the region. To this end, we produced quantitative estimates of the likely direct deaths and delayed cancer deaths resulting from nuclear weapons use. Five different nuclear "use cases" were simulated and analyzed. The hypothesized use cases were designed to be plausible, span a range of outcomes from a single detonation to limited global nuclear war, and include a range of nuclear actors and targets initiated in Northeast Asia, involving the Korean Peninsula, and in some cases spreading to other regions or continents. The estimated deaths and radiation-induced cancers resulting from the following six impacts were evaluated:

- Thermal fluence (heat) from nuclear blasts.
- Firestorms: multiple fires lit by thermal fluence that coalesce into large-area conflagrations encircled by hurricane-force winds as the heat rising from the fires pulls

[1] There is no legal or institutional definition of Northeast or East Asia. The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) uses "East and North East Asia (ENEA) to refer to "China; Democratic People's Republic of Korea; Hong Kong, China; Japan; Macao, China; Mongolia; Republic of Korea". See UNESCAP (undated), "4 List of countries in the Asia-Pacific region and subregions", available as https://data.unescap.org/dataviz/methodology/list-of-countries-in-the-asia-pacific-region-and-subregions.html

An examination of the contested usage related to "Asia" and its sub-regions is found in P. Hayes and C.I. Moon, ed (2018), *The Future of East Asia*, Palgrave MacMillan, available at: https://link.springer.com/book/10.1007/978-981-10-4977-4 cooler air in behind it. Physical damage caused by blast overpressure provides fuel for firestorms, which could burn for weeks.

- Blast overpressure, causing building damage and collapse.
- Prompt radiation from the nuclear detonation itself.
- Fallout radiation, as radioactive material from the blast and contaminated debris are spread by wind and rain.
- Radiation-induced cancer deaths suffered by those exposed to prompt and fallout radiation but not killed by the nuclear blast immediately or in the short term (within several months to a year).

Out of the 30 plausible use cases developed in Year 1 of the NU-NEA project, five use cases were simulated and evaluated quantitatively:

1. "We're Still Here" Variant 1, involving nuclear weapons use by the DPRK followed by the United States, with 3 total detonations of 10 kT (kiloton) and 8 kT weapons.
2. "US Leadership Hubris," involving first nuclear weapons use by the United States, followed by use by the DPRK, and China, with 18 total detonations ranging in yield from 8 to 300 kT.
3. "Use by Terrorists" Variant 1, with one 10 kT weapon detonated by a terrorist group.
4. "Conflict from Ukraine Spreads East," involving first nuclear weapons use by Russia and followed by the United States, totaling eight detonations of 8, 150, and 200 kT weapons.
5. "Not Going Well in Taiwan," involving first nuclear weapons use by China followed by responses from the United States, with a total of 24 detonations ranging in yield from 8 to 300 kT.

The table below summarizes the estimated prompt and short-term deaths and radiation-induced cancer deaths resulting from the impacts above for each of the five use cases evaluated. Even in the most limited of nuclear conflicts, deaths were in the tens or hundreds of thousands, with the more extensive conflicts resulting in millions of deaths and hundreds of thousands of cancer deaths. It should be noted that even the most extensive conflicts evaluated here were halted short of an all-out exchange of intercontinental nuclear missile attacks, but certainly could have ended that way. In the table below, "prompt" deaths are those caused by physical damage or fires in the immediate aftermath of detonations, including victims not killed immediately but dying within days or weeks, and "short-term" deaths include victims who succumbed to their injuries within the year following the nuclear attack.

Estimated Likely Direct and Cancer Deaths in Each of Five Modeled Use Cases[2]

Estimated Likely Deaths	Prompt (days to weeks)	Short-Term (weeks to months)	Additional Impact: Firestorms	Total Fatalities within 0.5 psi Zone (Total Population, % Lethality)	High Radiation Dose (Fallout) (short-term deaths)	Radiation-induced Cancer (long-term deaths)
Use Case 1 **Airburst: 1, Surface-burst: 2**	5,500	5,600	Firestorm Unlikely	**11,000** (41,000, 27%)	Low Fallout	**16,000 - 36,000**
Use Case 2 **Airburst: 11, Surface-burst: 7**	1,100,000	810,000	170,000	**2,100,000** (6,200,000, 33%)	11,000 - 1,200,000	**480,000 - 920,000**
Use Case 3 **Surface-burst: 1**	82,000	140,000	Small Centralized Firestorm	**220,000** (890,000, 25%)	0 - 1,600,000	**410,000 - 560,000**
Use Case 4 **Airburst: 8**	170,000	100,000	15,000	**290,000** (800,000, 36%)	Low Fallout	**14,000 - 85,000**
Use Case 5 **Airburst: 16, Surface-burst: 8**	1,500,000	930,000	190,000	**2,600,000** (7,600,000, 35%)	400 - 19,000	**96,000 - 830,000**

These results show that use cases that include many high-yield (50-300 kT) airbursts result in a higher relative impact, roughly 35% lethality, than use cases with a limited number of detonations or with mostly surface-bursts, which average roughly 25% lethality. As a conflict escalates, especially when progressively larger nuclear detonations target more populated areas, the humanitarian impacts of a nuclear conflict not only increase, but often grow by orders of magnitude. One contributing impact is the occurrence of deadly firestorms resulting from high-yield weapons detonated as airbursts that cause far-ranging thermal fluence, demonstrating that firestorms can be a significant contributor to the lethality of nuclear weapons. Furthermore, even use cases with a limited number of surface-bursts or using weapons of relatively low yield can cause a disproportionately high number of fatalities when acute health effects from high radiation doses and long-term cancer deaths are considered.

In Use Case 3, for example, a single surface-burst in an urban area results in estimated cancer fatalities on the same order of magnitude as the limited global nuclear war cases shown in Use Cases 2 and 5. The death toll in the short-term from exposure to high fallout radiation could also be the same or higher in Use Case 3, even though only one nuclear weapon has been detonated in an urban area. This result emphasizes how unpredictable the long-term and health impacts of nuclear use cases can be because it is nearly impossible to foresee whether a conflict will end after one detonation, 18 detonations, 24 detonations, or more, and whether urban areas will be targeted. Even when the conflict does not escalate to global nuclear war, it is possible that impacts consistent with those expected in a global-scale nuclear war can be felt after only one nuclear detonation.

In addition to devastating losses of human life, a range of economic and societal impacts, such as billions of dollars in infrastructure damage and health care costs, and a further set of global, regional, and local ecological impacts such as climate effects or effects on oceans, would also result from these use cases. The evaluation of these and other impacts will be addressed in the third project year.

The use cases evaluated in the NU-NEA project are intended to be plausible, but they capture only a small fraction of the possible pathways to nuclear war and its consequences identified in this project, which in turn do not even begin to encapsulate the universe of possible ways that a

[2] Note that Individual impacts in this table may not add up to the exact total shown in column five due to rounding.

nuclear conflict could start and play out. Several conclusions, however, can be drawn from the limited number of use cases evaluated in this project:

- A nuclear conflict based on regional issues can escalate to a global nuclear conflict within hours or days after the first use of nuclear weapons.
- Any nuclear detonations, even in relatively unpopulated areas, are likely to result in at least thousands of deaths, with possible fallout crossing international borders, causing additional health risks and increasing political tensions even when fallout levels are low.
- Even when focused on military targets, nuclear detonations may kill many hundreds of thousands of people within days or months, as well as cause hundreds of thousands of additional cancer deaths and great economic damage.
- The impact of mass fires or firestorms that sometimes result from nuclear explosions can surpass the lethality of other direct impacts of nuclear use. Historically, military planning for nuclear use has lacked sufficient consideration of firestorm impacts.
- Many of the plausible nuclear use cases developed for this project have their genesis in misinterpretation of intentions and lack of communication between adversaries, underscoring the need for communication between nations to avert nuclear weapons use, especially during times of conflict and crisis.
- There are many plausible pathways to nuclear war that would have cataclysmic effects. Most of these pathways involve "slippery slopes" of descent into nuclear war, where an action by one party is misinterpreted by another, leading to conflict escalation that proceeds further and more rapidly than adversaries intend or foresee. As such, these potential pathways to nuclear war are often invisible to policymakers.
- It is urgent to reduce the risk of choosing or stumbling onto one of these pathways by developing and applying regional and global policy measures such as increasing transparency of nuclear stockpiles, deployments, and operational and declaratory doctrine—especially relating to integration of nuclear firestorms into nuclear targeting—such as increasing communications with nuclear hotlines.
- In addition, it is important to explore policy measures to reduce the role of nuclear weapons in security policy and to revive arms control and disarmament diplomacy. Such measures include introducing a nuclear no-first threat norm; resolving regional conflicts; and, ultimately, establishing a regional security framework including denuclearization of the Korean Peninsula and a nuclear weapon free zone in the region towards elimination of nuclear weapons altogether.

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1 Summary of Results and Provisional Policy Lessons

The goal of the project, "Reducing the Risk of Nuclear Weapons Use in Northeast Asia," (NU-NEA) is to prevent the escalation of conflicts in Northeast Asia that could result in the detonation of a nuclear weapon. To achieve this goal, the project aims to develop a better understanding of events that could lead to a first use of nuclear weapons and the potential outcomes of such nuclear weapons use. An improved understanding of the possible paths to and impacts of nuclear weapons use will inform the development and implementation of policies that reduce the risk of nuclear weapons detonation. Ultimately, our goal is to prevent armed aggression and war, with a focus on preventing any use of nuclear weapons.

In the second year of the NU-NEA project, our focus was on adapting, developing, and applying methods to quantitatively estimate the impacts of nuclear weapons use. Five nuclear weapons "use cases" defined during and subsequent to the first year of the project were simulated in detail. These use cases each begin with a first use detonation of one or more nuclear weapons in an attack or counterattack against an opponent and continue with response detonations by one or more adversaries as the conflict escalates. In some cases, multiple exchanges between several nations escalate to global nuclear war.

1.1 Summary of use case evaluations

During Year 1 and 2 of the NU-NEA project, a total of 30 plausible nuclear weapons use cases were developed. The focus of the second year of the project was to quantitatively evaluate five of these use cases. The fatalities and health effects due to six physical impacts of nuclear detonations were estimated:

- **Thermal fluence**, or thermal radiation from the nuclear fireball, depending on the distance from the fireball and other factors, which causes skin burns to exposed flesh, and causes combustible materials, such as fuel, building materials, and clothing, to ignite.
- **Firestorms** started by the thermal fluence from the nuclear detonation under certain conditions, with the occurrence and extent of firestorms dictated by weapon yield, height of burst for the detonation, weather, geographical conditions, the presence or absence of fuel for the fire, and other factors.
- **Blast overpressure**, the blast wave and hurricane-force-or-greater winds caused by the explosion, which destroys buildings and other structures, sends debris flying, and shatters glass windows even at distances far from "ground zero" (the point on the ground where or over which a weapon detonates).
- **Prompt (or immediate) radiation exposure** from the nuclear explosion, reaching affected people within hundreds of meters to kilometers of ground zero.
- **Radiation exposure from fallout**, which occurs as radioactive materials from the weapon itself and contaminated soil and debris are thrust into the air, dispersed, and deposited downwind.
- Cancer deaths caused by **biological radiation doses** acquired from **exposure to prompt radiation, cloudshine** (fallout suspended in the air)**,** and **groundshine** (fallout deposited on the ground).

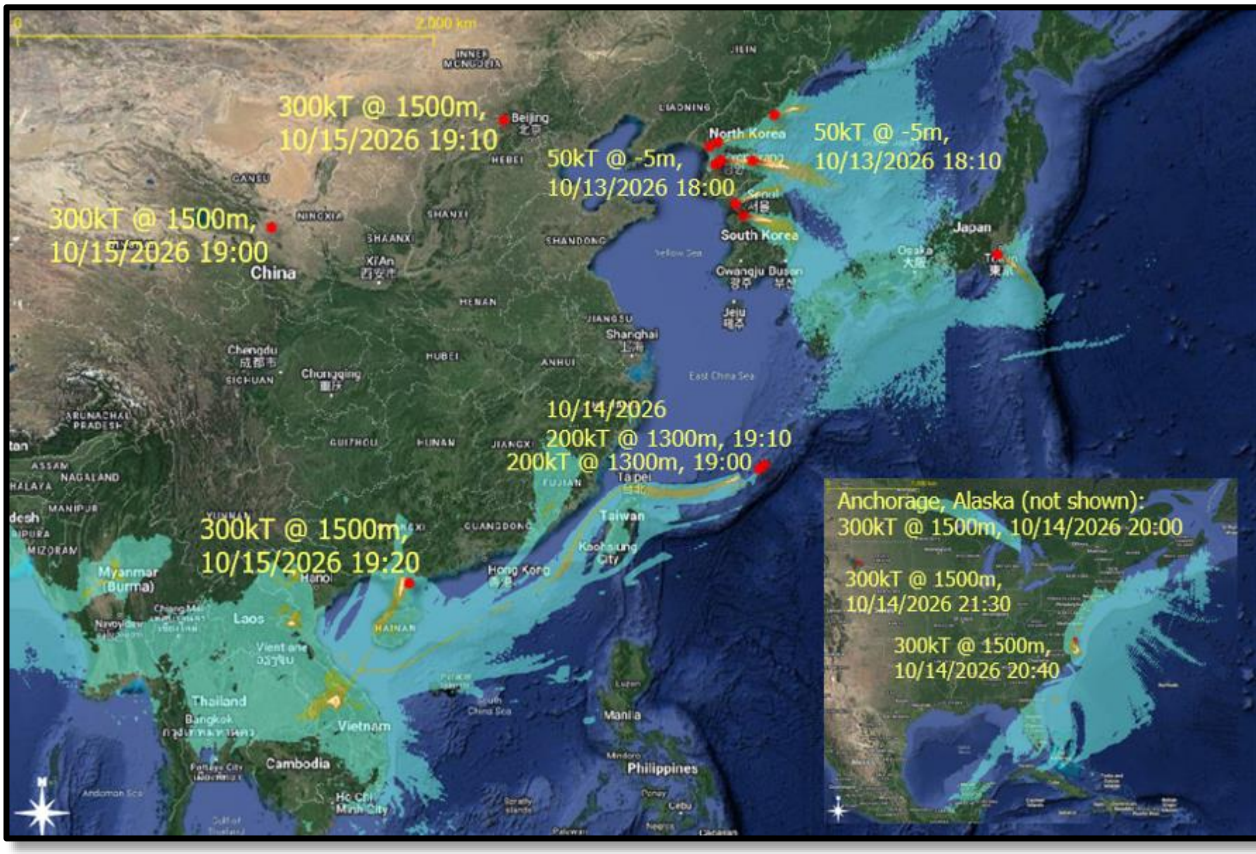
Thermal fluence, firestorm, overpressure, and prompt radiation exposure impacts were estimated by calculating the distance from the point of detonation (ground zero) to "contours" (circles of damage) associated with different levels of impact, then estimating the population within each contour. To estimate nuclear fallout, HYSPLIT software was used to simulate the dispersion and deposition of radioactive particles from the nuclear cloud, taking into account the location and time of each detonation, and using historical wind and precipitation weather data. Cancer deaths were estimated by counting the population within contours who were not victims of other detonation impacts but received below-lethal levels of radiation exposure, then applying a standard dose-response relationship to estimate excess cancers in the lifetime of the exposed population.

The following summarized example demonstrates how these methods were applied to the use case entitled "US Leadership Hubris" (Evaluated Use Case #2), in which the United States detonates the first nuclear weapon.

First, the general use case narrative was elaborated into a set of specific detonations to illustrate the potential outcome of a plausible series of events that might result from a first use of nuclear weapons by the United States. In this use case, an overconfident US president and his or her advisors, due to various internal and external pressures, mount a partially successful attack on nuclear and missile systems in the Democratic People's Republic of Korea (DPRK). The DPRK responds with a nuclear missile attack on a US base in the Republic of Korea (ROK) and attacks on industrial targets in the ROK and in Yokohama, Japan using weapons conveyed by DPRK military units. Further response by the United States, in the form of attacks on the DPRK, inadvertently drags China into the conflict, which leads to nuclear attacks on both Chinese and American homeland soil.

For each of three detonation phases—first use, response use, and additional use—summing to a total of eighteen locations attacked with nuclear weapons, contours for the lethal and sub-lethal levels of each of the above impacts were modeled and overlayed on maps in QGIS software. Figure 1-1 shows the likely extent of the firestorm resulting from one of the detonations, and Figure 1-2 shows the map of fallout results from all of the detonations in this use case. Depending on the weather patterns at the time of detonation, the resulting fallout in Use Case 2 could cover the entirety of the Korean Peninsula, and even reach regions uninvolved in the conflict, such as Southeast Asia and the Caribbean Sea.

Figure 1-1: Image Depicting the Area Likely Affected by a Firestorm (Orange Shaded Area) from Evaluated Use Case 2, Response Detonation 2 (Yokohama, Japan).



Exceeds the USNRC Annual Limit (Public)	0.1 – 5.0
Exceeds the USNRC Annual Limit (Radiation Worker)	5.0 – 10.0
Mid to Long-term Health Effects	10.0 – 50.0
High Dose, Acute Radiation Symptoms May Appear	50.0 – 100.0
High Survivability, Weakened Immune System	100.0 – 200.0
Survival Chance Highly Dependent on Medical Care	200.0 – 600.0
Almost Always Fatal Despite Medical Care	> 600.0

Figure 1-2: Map of Fallout in Asia and North America from Detonations in Evaluated Use Case 2 (Radiation Dose Units in rem, Time in UTC).

A summary of the five use cases evaluated during the second year of the NU-NEA project is provided in Table 1-1. The yields of the weapons used are shown in kilotons (kT). The five use cases range from cases with a single detonation or just a few detonations, resulting in a limited nuclear conflict, to cases with a first-use, response, and additional detonations totaling up to 24 total nuclear attacks in what becomes a global nuclear conflict.

Table 1-1: Summary of Assumptions for Evaluated Use Cases

Evaluated Use Case	First User	Responding User(s)	Weapon Sizes	Total Detonations
#1: "We're Still Here" Variant 1	DPRK	United States	10 kT (fission), 8 kT (2-stage H-bombs)	**3**
#2: "US Leadership Hubris"	United States	DPRK, China	20 and 10 kT (fission), 8, 50, 200, and 300 kT (2-stage H-bombs)	**18**
#3: "Terrorist" Variant 1	Terrorist	[None]	10 kT (fission)	**1**
#4: "Conflict from Ukraine Spreads East"	Russia	United States	2-stage H-bombs, 150, 200 kT, and 8 kT	**8**
#5: "Not Going Well in Taiwan"	China	United States, China	8, 50, 250, and 300 kT (2-stage H-bombs)	**24**

Table 1-2 summarizes the estimated likely deaths and excess cancers resulting from all detonations in each use case, with the impacts of potential firestorms and high radiation dose from fallout indicated separately. These results show that firestorm and fallout impacts can significantly increase the death toll of a nuclear war. Depending on the weapon yield, height of burst, weather patterns, time of day, and burnable material in the blast area to fuel firestorms, death tolls may vary significantly, but tragic levels of deaths are a certainty. Although the total number of detonations in each use case spans from one to 24 detonations, the results vary widely regardless of the number of detonations. Depending on the decisions leaders make in times of crisis, such as what types of targets to attack and when, the resulting death toll could vary widely and cannot be reliably predicted.

Table 1-2: Summary of Estimated Deaths and Excess Cancers Resulting from Each of the Five Modeled Use Cases[1]

Estimated Likely Deaths	**Prompt (days to weeks)**	**Short-Term (weeks to months)**	**Additional Impact: Firestorms**	**Total Fatalities within 0.5 psi Zone (Total Population, % Lethality)**	**High Radiation Dose (Fallout) (short-term deaths)**	**Radiation-induced Cancer (long-term deaths)**
Use Case 1 Airburst: 1, Surface-burst: 2	5,500	5,600	Firestorm Unlikely	**11,000** **(41,000, 27%)**	Low Fallout	**16,000 - 36,000**
Use Case 2 Airburst: 11, Surface-burst: 7	1,100,000	810,000	170,000	**2,100,000** **(6,200,000, 33%)**	11,000 - 1,200,000	**480,000 - 920,000**
Use Case 3 Surface-burst: 1	82,000	140,000	Small Centralized Firestorm	**220,000** **(890,000, 25%)**	0 - 1,600,000	**410,000 - 560,000**
Use Case 4 Airburst: 8	170,000	100,000	15,000	**290,000** **(800,000, 36%)**	Low Fallout	**14,000 - 85,000**
Use Case 5 Airburst: 16, Surface-burst: 8	1,500,000	930,000	190,000	**2,600,000** **(7,600,000, 35%)**	400 - 19,000	**96,000 - 830,000**

[1] Note that Individual impacts in this table may not add up to the exact total shown in column five due to rounding.

In addition to the impacts evaluated in Table 1-1, the economic and social impacts of nuclear weapons use are also crucial to consider when discussing solutions to avoid nuclear weapons use. Economic and social impacts not yet evaluated include, but are not limited to:

- The **health impacts** of nuclear detonation and radiation exposure.
- The **infrastructure rebuilding** following nuclear detonation.
- The **environmental contamination** with radioactivity.
- The ecological damages at global, regional, and local levels such as nuclear winter, acidification of oceans, and other impacts.[2]
- The **social and political consequences** of nuclear use.

Some of these topics will be taken up by the NU-NEA project in its upcoming third year.

1.2 Initial policy lessons

Although Year 2 of the NU-NEA project was largely devoted to the quantitative assessment of the potential impacts of nuclear weapons use in the region, some initial policy conclusions from the evaluations of use cases described above include:

- The range of use cases evaluated shows the potential for a nuclear conflict based on regional issues—such as DPRK nuclear weapons issues or Taiwan policies—to escalate to a nuclear global conflict within hours or days.
- Any nuclear detonations, even in relatively unpopulated areas, are likely to result in at least thousands of deaths, thus even at the more restrained end of the spectrum of possibilities, potential nuclear weapons use represents a humanitarian, political, and social tragedy.
- Radioactive fallout from nuclear detonations can cross borders, and sometimes fall on populations hundreds or thousands of kilometers from the original target of a detonation. These populations may well be in nations or even regions not involved in the conflict that spawned nuclear weapons use, and thus justifiably incensed at being put at risk. As such, and even though the doses of radioactivity received in those locations may be low, even limited nuclear exchanges have the potential to cause social, political, and health impacts far beyond the borders of the combatants. It thus behooves potential users of nuclear weapons to take into account potential impacts of weapons use on populations and nations distant from the immediate attack zones, as those far-flung impacts may well have unintended social and political consequences for nuclear weapons users. Conversely, the potential spread of radiation to distant places—again, even if in low concentrations—means that nations seemingly not associated with potential conflicts

[2] As just one example of such impacts, a recent article explores the effect of nuclear war on wild-caught fish stocks, both in the context of how changes in climate from nuclear conflict might affect fisheries and how fisheries might be affected by increased use of wild-caught fish to replace food supplies where agriculture is affected by the impacts of nuclear war. Kim J. N. Scherrer, Cheryl S. Harrison, Ryan F. Heneghan, Eric Galbraith, Charles G. Bardeen, Joshua Coupe, Jonas Jägermeyr, Nicole S. Lovenduski, August Luna, Alan Robock, Jessica Stevens, Samantha Stevenson, Owen B. Toon, and Lili Xia (2020), Marine wild-capture fisheries after nuclear war", *PNAS*, November 24, 2020, vol. 117, no. 47, available as www.pnas.org/cgi/doi/10.1073/pnas.2008256117

have a vested interest in cooperating to defuse those conflicts before they "go nuclear." As such, non-nuclear nations, including those that have established their own nuclear weapons-free zones, could reasonably claim the right and responsibility to work to reduce the risk of nuclear weapons use, just as do nuclear weapons states. Non-nuclear nations, based on the threat of fallout from distant detonations, may also demand more transparency in nuclear weapons deployment, and more accountability from nuclear weapons states for potential impacts of weapons use.

- Many nuclear detonations, even when focused on military targets, have the potential to kill hundreds of thousands of people within the following days, weeks, and months, cause hundreds of thousands of additional long-term (years or decades) cancer deaths, and cause economic damage that would likely be in the tens of billions of dollars or more, adding economic misery as an additional cost of these humanitarian disasters.

Policy lessons related to potential firestorms ignited by attacks with nuclear weapons include:

- The potential impacts of mass fires/firestorms can, for some targets and detonations, outstrip the lethality of other direct impacts of nuclear use, but historically they have had little consideration in military planning for nuclear use.
- It is clear that the radius of firestorm lethality will exceed the radius of lethal/near-lethal damage from other effects (overpressure, radiation, thermal fluence) in many possible nuclear attacks.
- Many, possibly all nuclear "targeteers"—those individuals and organizations responsible for identifying, setting, and justifying potential targets for nuclear weapons—have not historically considered the impacts of firestorms properly and thus underestimate the impacts of nuclear weapons use.
- If firestorm effects are properly considered, the impact of all nuclear weapons above the minimum size at which firestorms are created could be much larger than originally expected.
- Nuclear war planners and targeteers may argue the legality of using nuclear weapons with yields (and/or targets) below the "firestorm threshold." They must, however, now confront the fact that nuclear targeting today using weapon-and-target combinations that spawn firestorms cause greater damages than the direct physical and radiological impacts of the weapons themselves. These greater damages make such nuclear weapons use irrefutably contravene international humanitarian law (proportionality, military necessity, civilian principles) due to the firestorm effects for which most targeteers neglect to account.

Most of the nuclear use cases evaluated in this report, as well as most of the use cases developed in Year 1 of this project but not evaluated quantitatively, have their genesis in misinterpretation of adversaries' intentions and lack of communication between adversaries. Nuclear weapons use is thus instigated at least in part by adversaries misunderstanding each other's intentions, actions, or statements as posing a military threat, including interpreting words or deeds as being threats of nuclear use. This commonality underscores that:

- Nations must communicate their intentions, particularly their military intentions (for example, regarding military exercises and missile tests) to adversaries to avoid situations where actions are unintentionally misinterpreted as attacks or impending attacks.

- Communications between nuclear states, and between those groups responsible for nuclear weapons deployment in nuclear states, must be built or rebuilt if adequate channels do not now exist, and must be maintained no matter what issues arise to erode political relations.
- There are many plausible pathways to nuclear war that would have cataclysmic effects. Most of these pathways involve "slippery slopes" of descent into nuclear war, where an action by one party is misinterpreted by another, leading to conflict escalation that proceeds further and more rapidly than adversaries intend or foresee.
- It is urgent to reduce the risk of choosing or stumbling onto one of these pathways by developing, agreeing on and implementing policy measures such as:
    - Increasing transparency of nuclear stockpiles, deployments, and operational and declaratory doctrine—especially relating to integration of nuclear firestorms into nuclear targeting; and
    - Increasing communications via the development/recommitment to the use of nuclear hotlines and revived arms control and disarmament diplomacy.
- In addition, it is important to explore policy measures to reduce the role of nuclear weapons in security policy and revived arms control and disarmament diplomacy, such as:
    - Introducing a nuclear no-first threat norm[3]; resolving regional conflicts; and
    - Establishing a regional security framework including denuclearization of the Korean Peninsula and establishment of a nuclear weapon free zone in the region as steps towards elimination of nuclear weapons altogether.

1.3 Project next steps

Some of the expected next steps in the NU-NEA project, to be addressed in the third project year, include:

- Developing and applying methods for analysis of selected additional impacts of nuclear detonations, such as
    - Cost of infrastructure rebuilding
    - Cost of environmental contamination with radioactivity
    - Costs of ecological damage
    - Social and political consequences

[3] No First Use is a well-established norm (often called the "nuclear taboo") although only some nuclear weapons states have adopted it as declaratory policy (China 1964, India 1998). "No First Threat" is a concept for a possible parallel norm that aims to establish a set of threats to use nuclear weapons that are so clearly illegal in terms of specificity as well as likely illegal due to disproportionality, military non-necessity, and transgression of the civilian targeting principle that would result from the threatened nuclear weapons use that all nuclear weapons and non-nuclear weapons states should be able to agree that such threats should not be made, ever, and if made, would be prosecutable under international law. In general, international law prohibits the threat and use of force. How such injunctions apply to nuclear weapons threats and use is contested. This project has commissioned an expert study of nuclear weapons threats and related norms to ascertain the validity and soundness of the concept of No First Threat, to be completed in 2023.

- Identify additional policy lessons learned from conducting the NU-NEA project.
- Develop policy options that minimize the risk of nuclear weapons use and the role of nuclear weapons in security policies.

1.4 Contents of subsequent sections of this Report

The remainder of this Report is organized as follows:

- **Section 2** briefly reviews the background of the project, including the nuclear weapons situation in Northeast Asia and a summary of project goals and approaches.
- **Section 3** provides a summary description of what is meant, in the context of this project, by "nuclear use cases," how they are used, and project goals and criteria for use case development, and lists the subset of use cases developed under the project, carried out by a range of state and non-state actors, that has been selected for quantitative analysis in Year 2 of the NU-NEA project.
- **Section 4** describes the nuclear detonation impacts evaluated quantitatively during the second year of the project, including thermal fluence (heat), "firestorms" that can result from some nuclear attacks, blast overpressure, exposure to prompt radiation from nuclear detonations and from fallout, and excess cancer deaths implied by radiation exposures.
- **Section 5** summarizes the methods used for use case analysis and quantitative estimation of fatalities resulting from selected direct impacts.
- **Section 6** details the estimated fatalities and cancers in the affected population resulting from nuclear detonation impacts in each of the five evaluated use cases.

Following the main sections of this report, a **Glossary** that includes the definitions of terms and acronyms is provided, along with Annexes that include summaries of the NU-NEA project use cases, more detailed descriptions of the use cases chosen for analysis, and additional quantitative results and maps related to the use cases evaluated.

2 Background: Regional Setting and Project Goals

2.1 The risks of nuclear conflict as an increasing concern for our times

In our Year 1 Report, published in January 2022,[4] we noted that the risk of nuclear war—that is, the risk of attacks carried out by detonating nuclear weapons, hereafter "nuclear weapons use"—was at its highest since the end of the Cold War.[5] Although it was difficult, at the time, to determine how the world could move close to the brink of nuclear use without actually going over the edge, by December of 2022 world events had, in fact, taken the globe and the Northeast Asia region to an even higher level of nuclear anxiety. Since early 2022, Russia's invasion of neighboring Ukraine, described by Russia as a "special military operation," has led to concerns—fed by comments by Russian President Vladimir Putin and the West's interpretation of same—that Russia might choose to use tactical nuclear weapons in Ukraine.

Western nations (the European Union, the United States, and others) have responded to Russia actions in Ukraine with economic sanctions against Russia and specific Russian political and business leaders. In addition, they have provided tens of billions of dollars in military and economic aid to Ukraine to support its defense of its territory. How the conflict in Ukraine has unfolded has not escaped the attention of actors in Northeast Asia,[6] and although the ways in

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[4] RECNA-Nagasaki University, Asia Pacific Leadership Network, Nautilus Institute (2022), *Possible Nuclear Use Cases in Northeast Asia: Implications for Reducing Nuclear Risk*, NAPSNet Special Reports, January 27, 2022, available as https://nautilus.org/napsnet/napsnet-special-reports/possible-nuclear-use-cases-in-northeast-asia-implications-for-reducing-nuclear-risk/. Also available from the APLN and RECNA websites, respectively as https://apln.network/projects/nuclear-weapon-use-risk-reduction/final-report-year-1 and https://www.recna.nagasaki-u.ac.jp/recna/bd/files/Year_1_NU-NEA_Report_E_220128-1.pdf?utm_source=CPB&utm_medium=cms&utm_campaign=JRD27735

[5] The "Doomsday Clock" of the *Bulletin of the Atomic Scientists*, which is set closer to "midnight" by the Bulletin's Science and Security Board when the Board deems the risks of nuclear war are greater, was just, as of this writing, set at 90 seconds before midnight, the closest it has ever been to that symbol of pending nuclear threat. See Bill Chappell (2023), "The Doomsday Clock moves to 90 seconds to midnight, signaling more peril than ever", dated January 24, 2023, and available at https://www.npr.org/2023/01/24/1150982819/doomsday-clock-90-seconds-to-midnight. Even before the events of 2022 caused the *Bulletin* to further advance the Doomsday Clock toward midnight, the *Bulletin*'s Science and Security Board condemned the Russian invasion of Ukraine, saying, in part, "[f]or many years, we and others have warned that the most likely way nuclear weapons might be used is through an unwanted or unintended escalation from a conventional conflict. Russia's invasion of Ukraine has brought this nightmare scenario to life, with Russian President Vladimir Putin threatening to elevate nuclear alert levels and even first use of nuclear weapons if NATO steps in to help Ukraine. This is what 100 seconds to midnight looks like" (Bulletin Science and Security Board, 2022, "Bulletin Science and Security Board condemns Russian invasion of Ukraine; Doomsday Clock stays at 100 seconds to midnight", *Bulletin of the Atomic Scientists,* dated March 7, 2022, and available as https://thebulletin.org/2022/03/bulletin-science-and-security-board-condemns-russian-invasion-of-ukraine-doomsday-clock-stays-at-100-seconds-to-midnight/?utm_source=ClockPage&utm_medium=Web&utm_campaign=DoomsdayClockMarchStatement.

[6] The potential implications of the Ukraine conflict on nuclear weapons policies and postures among the nations of Northeast Asia and beyond are provided from the point of view of each nation in a series of Nautilus Institute Policy Forum papers and have also been published on RECNA and APLN websites. These papers include CHEON Myeongguk (2022), "Implications of the Ukraine War for ROK Security", *NAPSNet Policy Forum*, December 05, 2022, available as https://nautilus.org/napsnet/napsnet-policy-forum/implications-of-the-ukraine-war-for-rok-security/; Anastasia Barannikova (2022), "Potential Implications of the Situation in Ukraine for Russia's Nuclear

which political and military leaders will ultimately reflect the lessons of Ukraine into nuclear policy have yet to be fully determined, events and leader statements thus far in 2022 make it clear that potential conflicts still have great potential to trigger either planned or accidental use of nuclear weapons in the region. The DPRK's "new nuclear doctrine" and some of China's most recent statements about Taiwan have certainly increased concerns over potential nuclear weapons use in the region. As we noted in our Year 1 NU-NEA Report, even the first use of only one nuclear weapon would likely bring horrific and unacceptable outcomes, and the events following from a first use of nuclear weapons could easily spin out of control, leading to an "open-ended" outcome with so much uncertainty that global catastrophic war would be a distinct possibility. The memory of the horrific loss of life and catastrophic damage from the nuclear bombings of Hiroshima and Nagasaki in 1945 underscore the near-universal conviction that nuclear weapons must never again be used. At the same time, nuclear arsenals continue to grow, and nuclear "deterrence" remains a key part of military plans and geopolitics generally. Abolition of nuclear weapons remains a distant hope. In the interim, the risk of the use of nuclear weapons must be reduced. "Let Nagasaki be the Last!" must therefore be the goal of all policymakers in maintaining international peace and security.[7]

2.2 Updated summary of nuclear weapons situation on the Korean Peninsula

Northeast Asia is home to two declared nuclear weapons states and United Nations Security Council members in the People's Republic of China (the PRC, or China) and the Russian Federation (Russia); one de-facto nuclear weapons state—the DPRK—and two non-nuclear weapons states with large nuclear power programs and advanced technological prowess in the ROK and Japan; and Mongolia, which has neither nuclear power nor nuclear weapons and, although it does have uranium resources, has declared itself a "nuclear weapons free zone."[8] The definition of Northeast Asia for the purposes of this Report includes Taiwan (Chinese Taipei), as it is regularly in the news, particularly following the conflict in Ukraine, as a flash point for potential conflict without which any consideration of nuclear use cases in the region would be incomplete.

In addition to these Northeast Asia (NEA) neighbors, an accounting of the presence of nuclear weapons and nuclear deterrence in the region would be seriously lacking without the inclusion of the roles of the third great power with nuclear weapons in the region, the United States. The

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Deployment in Northeast Asia", *NAPSNet Policy Forum*, November 07, 2022, available as https://nautilus.org/napsnet/napsnet-policy-forum/potential-implications-of-the-situation-in-ukraine-for-russias-nuclear-deployment-in-northeast-asia/, Paul K. Davis (2022), "Potential Implications of the War In Ukraine for Northeast Asia", *NAPSNet Policy Forum*, October 27, 2022, available as https://nautilus.org/napsnet/napsnet-policy-forum/potential-implications-of-the-war-in-ukraine-for-northeast-asia/; Tong Zhao (2022), "Implications of Russia's Nuclear Signaling During the Ukraine War for China's Nuclear Policy", *NAPSNet Policy Forum*, October 13, 2022, available as https://nautilus.org/napsnet/napsnet-policy-forum/implications-of-russias-nuclear-signaling-during-the-ukraine-war-for-chinas-nuclear-policy/; and Alexandre Y. Mansourov (2022), "Birds of a Feather: Thoughts on Pyongyang's Lessons from the War in Ukraine", *NAPSNet Policy Forum*, October 07, 2022, available as https://nautilus.org/napsnet/napsnet-policy-forum/birds-of-a-feather-thoughts-on-pyongyangs-lessons-from-the-war-in-ukraine/

[7] The words "Let Nagasaki be the Last!" begin the 2015 Nagasaki declaration of the Pugwash Council. See Pugwash Conferences on Science and World Affairs (2015), "2015 Nagasaki Declaration," dated November 5, 2015, and available as https://pugwash.org/2015/11/05/2015-nagasaki-declaration/

[8] See, for example, United Nations Platform for Nuclear-Weapon-Free Zones (2020), "Mongolia's nuclear-weapon-free status", available as https://www.un.org/nwfz/content/mongolias-nuclear-weapon-free-status.

United States has a number of major military bases in the region, including in the ROK, Japan, and, to the south, Guam. Although US nuclear weapons were removed from the Korean Peninsula itself in 1991, the United States extends its "nuclear umbrella" over the ROK, Japan, and quite unofficially (although meaningfully) Taiwan.

Sketches of the nuclear weapons capabilities of these states, with updates from the descriptions provided in our Year 1 project report, are provided below. [9]

- **China** is thought to possess approximately 350 to 400 nuclear weapons, based on recent estimates,[10] with delivery systems including short and long-range land-based missiles (including intercontinental ballistic missiles, or intercontinental ballistic missiles (ICBMs), that can be fired from fixed or mobile launchers, ballistic missile submarines, missiles based on ships, and bombers.[11] Most or all of these weapons are thought to be strategic nuclear weapons, that is, not developed for tactical or battlefield use. The expansion of China's nuclear forces has been underway in recent years, underscored by reports of large-scale development of what are thought to be new missile silos for ICBMs in Xinyang and Gansu provinces.[12] Starting in 1964, and ending, at least nominally,[13] with its signing of the Comprehensive Nuclear Test Ban Treaty (CTBT) in 1996, China is estimated to have conducted forty-seven nuclear tests, of which twenty-three were above-ground.[14]

- **Russia** possesses over six thousand nuclear weapons, of which 4500 are reported to be operational[15] and can be delivered via a full range of delivery systems including fixed and mobile land-based launchers, sea- and submarine-based missile systems, bombers, and air-launched ballistic missiles. Russia has on the order of 1500 non-strategic (tactical)

[9] For an overview of nuclear capabilities of regional powers, see P. Hayes, T. Kulkarni, C.I. Moon, S. Shetty (2022), *WMD in Asia-Pacific*, Asia-Pacific Leadership Network for Nuclear Non-Proliferation and Disarmament, available as https://cms.apln.network/wp-content/uploads/2022/03/WMD-in-Asia-Pacific.pdf

[10] See, for example, Idrees Ali and Phil Stewart (2022), "China likely to have 1,500 nuclear warheads by 2035: Pentagon", *Reuters*, dated November 29, 2022, and available as https://www.reuters.com/world/china-likely-have-1500-nuclear-warheads-by-2035-pentagon-2022-11-29/ ; the Federation of American Scientists (2022), "Status of World Nuclear Forces, available as https://fas.org/issues/nuclear-weapons/status-world-nuclear-forces/; and RECNA (2022), "List of World Nuclear Warheads (June 2022), (世界の核弾頭一覧（2022 年 6 月）), available as https://www.recna.nagasaki-u.ac.jp/recna/nuclear1/nuclear_list_202206

[11] See, for example, Hans M. Kristensen and Matt Korda (2020), "Chinese nuclear forces, 2020", *Bulletin of the Atomic Scientists*, Volume 76, 2020 - Issue 6 Pages 443-457, published online: 10 Dec 2020, and available as https://www.tandfonline.com/doi/full/10.1080/00963402.2020.1846432

[12] See, for example, Tong Zhao (2021), "What's Driving China's Nuclear Buildup?," Carnegie Endowment for International Peace, dated August 05, 2021, and available as https://carnegieendowment.org/2021/08/05/what-s-driving-china-s-nuclear-buildup-pub-85106

[13] Recent low-yield nuclear tests are suspected, but not proven, to have been carried out recently by China. See, for example, Julian Borger (2020), "China may have conducted low-level nuclear test, US claims," *The Guardian*, dated 15 April, 2020, and available as https://www.theguardian.com/world/2020/apr/16/china-may-have-conducted-low-level-nuclear-test-us-report-claims

[14] Atomicarchive.com (2021), "China's Nuclear Tests," available as https://www.atomicarchive.com/almanac/test-sites/prc-testing.html

[15] See, for example, Hans M. Kristensen and Matt Korda (2022), "Russian nuclear weapons, 2022," *Bulletin of the Atomic Scientists, V*olume 78, 2022, Issue 2, Pages 98-121, published online 25 February 2022, and available as https://www.tandfonline.com/doi/pdf/10.1080/00963402.2022.2038907?needAccess=true

nuclear weapons in addition to its mostly high-yield strategic warheads.[16] Russia has conducted over 700 nuclear weapons tests.

- Based on its announcements and weapons demonstrations, the **DPRK** now has nuclear weapons and delivery devices designed for different ranges, including continental range missiles that it has test-fired multiple times during 2022.[17] The DPRK has on many occasions announced its development and possession of nuclear weapons through its state media outlets and other channels. These announcements notwithstanding, the actual size of the DPRK's nuclear weapons arsenal is not known with any certainty. Analysts suggest the DPRK may possess sufficient fissile material for on the order of fifty nuclear weapons, although only a fraction of that material may have been incorporated into warheads as of 2021.[18] The DPRK has conducted six known nuclear weapons tests between 2006 and 2017.[19] The DPRK has been actively developing and testing missile systems, some of which are thought to be nuclear-capable, extending from short-range missiles to missiles with potential ICBM capabilities. The DPRK's delivery systems are mostly land-based, including a recently-demonstrated capability to fire ballistic missiles from a train, but the DPRK may also be developing the capability to fire ballistic missiles, and potentially nuclear ballistic missiles, from submarines.[20]

- **Japan** does not possess nuclear weapons, and as a signatory to the Non-Proliferation Treaty (NPT), is obliged not to develop them. Japan is, however, covered by the United States' "nuclear umbrella," an arrangement denoting US extended nuclear deterrence with the intent being the assurance of US protection, with nuclear weapons, if necessary, in the event of a conflict. This arrangement is also designed to prevent the development of nuclear weapons by Japan and/or by other states also covered by US extended nuclear deterrence.[21] Although the nuclear umbrella is not a formal legal or treaty commitment, rather a "political assurance," it has sufficed thus far, along with national laws and moral positions born out of being the only nation in history to have suffered a nuclear attack, to keep Japan and other "umbrella" states from developing nuclear weapons. That said, and as indicated in one of the use cases presented in our Year 1 Report, Japan certainly does have the technical wherewithal to develop nuclear weapons, probably in a matter of

[16] Matt Korda (2021), *Nuclear Weapons and Delivery Systems that Might be Implicated in Nuclear Use Involving the Korean Peninsula*, paper prepared for the Reducing the Risk of Nuclear Weapons Use in Northeast Asia project, September 2021 (publication forthcoming).

[17] See, for example, Carlotta Dotto, Brad Lendon and Jessie Yeung, "North Korea's record year of missile testing is putting the world on edge", *CNN*, dated December 26, 2022, available as https://www.cnn.com/2022/12/26/asia/north-korea-missile-testing-year-end-intl-hnk/index.html

[18] See, for example, *38 North*, "Estimating North Korea's Nuclear Stockpiles: An Interview With Siegfried Hecker," dated April 30, 2021, and available as https://www.38north.org/2021/04/estimating-north-koreas-nuclear-stockpiles-an-interview-with-siegfried-hecker/

[19] Nuclear Threat Initiative (2020), "North Korea," last updated October 2020, and available as https://www.nti.org/learn/countries/north-korea/

[20] Korda (2021), ibid.

[21] Gregory Kulacki (2021), "The US Doesn't Need to Worry About Japan (or Any Other Ally) Going Nuclear," *The Diplomat*, dated February 05, 2021, and available as https://thediplomat.com/2021/02/the-us-doesnt-need-to-worry-about-japan-or-any-other-ally-going-nuclear/, described the US "nuclear umbrella" as follows: "At the dawn of the nuclear age, to encourage friendly countries to refrain from building nuclear weapons, the United States promised to protect them with U.S. nuclear weapons. This arrangement came to be called the nuclear umbrella. The experts call it extended nuclear deterrence."

months, in the unlikely event that concerns about the reliability of the US nuclear umbrella rise to the level that might lead it to do so. Such a breakout likely would be an abrogation of its obligations as a signatory to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The late Shinzo Abe, Japan's former prime minister, following the Russian invasion of Ukraine in February of 2022, suggested the discussion of a NATO-style "nuclear sharing" approach for Japan, which raised concerns in China and elsewhere, although the nuclear sharing option was quickly rejected as unacceptable by Japan's current prime minister, Fumio Kishida.[22] Japan has both small-scale uranium enrichment facilities (used to produce low-enriched uranium)[23] and a full-scale reprocessing plant (at Rokkasho), still waiting for an operating license to separate plutonium for use in "mixed oxide" reactor fuel. And, most importantly, Japan has ownership of over 45 tonnes of separated plutonium (Pu), of which 9.3 tonnes are in storage in Japan, with the rest in Europe and the United Kingdom (14.8 tonnes in France and 21.8 tonnes in the United Kingdom).[24] The amount of Pu in storage in Japan alone is sufficient to make on the order of a thousand or more nuclear warheads.[25]

- The **ROK** is also covered by US extended nuclear deterrence, is a signatory of the NPT, and is thus also unlikely for those reasons to develop nuclear weapons, although the election of a more pro-nuclear (energy and weapons) government in 2022, headed by President Yoon Suk Yeol, has intensified the debate over whether the country should acquire nuclear weapons, with remarks by President Yoon in early 2023, although described as discussing only a hypothetical scenario, raising the profile of the discussion of nuclear weapons acquisition by the ROK.[26] The ROK, unlike Japan does not possess, as a condition of its nuclear energy agreement with the United States, either facilities for uranium enrichment or for spent fuel reprocessing. It has, however, attempted to obtain nuclear weapons and related delivery systems in the 1970s-early 1980s and dabbled in clandestine research on reprocessing and other "dual use" technologies in the recent past, and it has been suggested that ROK proliferation activity research has been one of the

[22] See, for example, Sayuri Romei (2022), "The legacy of Shinzo Abe: a Japan divided about nuclear weapons", *Bulletin of the Atomic Scientists*, dated August 24, 2022, available as https://thebulletin.org/2022/08/the-legacy-of-shinzo-abe-a-japan-divided-about-nuclear-weapons/; and Justin McCurry (2022), "China rattled by calls for Japan to host US nuclear weapons", The Guardian, dated 1 Mar 2022, and available as

[23] The World Nuclear Association (2021), "Japan's Nuclear Fuel Cycle," updated January, 2021, and available as https://world-nuclear.org/focus/fukushima-daiichi-accident/japan-nuclear-fuel-cycle.aspx

[24] Japan Atomic Energy Commission (2022), *The Status Report of Plutonium Management in Japan—2021* Office of Atomic Energy Policy, Cabinet Office, dated July, 12, 2022, and available as http://www.aec.go.jp/jicst/NC/sitemap/pdf/kanri220712_e.pdf

[25] Assumes about eight (8) kg reactor-grade Pu required per weapon. See, for example, Union of Concerned Scientists (2009), "Weapon Materials Basics," published July 18, 2009, and available as https://www.ucsusa.org/resources/weapon-materials-basics; and V. Fortakov (1998), "Nuclear Verification: What It Is, How It Works, the Assurances It Can Provide," p. 41-51 in International Atomic Energy Agency, *Technical workshop on safeguards, verification technologies, and other related experience*, 253 p, 11-13 May 1998, available as https://inis.iaea.org/collection/NCLCollectionStore/_Public/30/050/30050964.pdf?r=1

[26] See, for example, William Gallo (2023), "Why South Korea's President is Talking About Nuclear Weapons", *Voice of America*, dated January 16, 2023, and available as https://www.voanews.com/a/why-south-korea-s-president-is-talking-about-nuclear-weapons/6919962.html

considerations that led the DPRK's to begin its pursuit of nuclear weapons.[27] The ROK, like Japan, is highly advanced technologically, and there is little doubt that it could produce nuclear weapons-capable technologies quite rapidly, in the unlikely event that it made the decision to do so.

- **Taiwan** is in a similar position to the ROK, with thousands of tonnes of spent nuclear fuel in storage and advanced technologies that could readily be used for "nuclear breakout" in the (again unlikely, unless international circumstances change markedly) event the decision was made to pursue nuclear weapons. Like the ROK, it too previously sought to develop its own nuclear weapons. Though it is not—because it is not officially a state—a signatory to the NPT or related agreements, it has said that it will abide by those agreements.[28] Taiwan is also, at least tacitly and unofficially, covered by US extended nuclear deterrence, although the United States' commitment to defend Taiwan is the subject of "strategic ambiguity."[29]

- **The United States**, though not a Northeast Asian country, has great influence in the region, both as the guarantor of security for Japan, the ROK, and (tacitly) Taiwan, and as a major and continuing military presence in the region. The United States had nuclear weapons deployed on the Korean Peninsula (in the ROK) from 1958 until 1991, when they were removed.[30] The United States also had nuclear weapons stored on Okinawa from 1954 until 1972. The presence of these weapons on territory that was returned to Japan in the 1960s was covered under a secret agreement between the United States and Japan in which neither state would publicly confirm any introduction of nuclear weapons into Japan's territory. The agreement did, however, appear to violate Japan's "three non-nuclear principles" (promises "not to process, produce, or permit the introduction of nuclear weapons into Japan") formalized in 1967.[31] The United States continues to project nuclear deterrence for the ROK and for the region as a whole from submarines, ships, bombers, and missiles based elsewhere, including on US territory and from bases in Japan and elsewhere. The United States has a full range of nuclear missile technologies, including missiles designed for both tactical and strategic delivery of

[27] Anastasia Barannikova (2022), "Korean Peninsula Nuclear Issue: Challenges and Prospects", *Journal for Peace and Nuclear Disarmament*, Volume 5, 2022 - Issue sup1: Reducing the Risk of Nuclear Weapons Use in Northeast Asia, dated 20 March, 2022, and available as https://www.tandfonline.com/doi/full/10.1080/25751654.2022.2053409

[28] Monte Bullard (2005), "Taiwan and Nonproliferation," the Nuclear Treat Initiative, dated May 1, 2005, and available as https://www.nti.org/analysis/articles/taiwan-and-nonproliferation/

[29] David Brunnstrom (2021), "U.S. position on Taiwan unchanged despite Biden comment – official," *Reuters*, dated August 20, 2021, and available as https://www.reuters.com/world/asia-pacific/us-position-taiwan-unchanged-despite-biden-comment-official-2021-08-19/ See also Sheryn Lee (2021), *Avoiding Nuclear War in the Taiwan Strait*, prepared for the Reducing the Risk of Nuclear Weapons Use in Northeast Asia project, September 2021. On a US State Department website, the relationship is described as a "…U.S. commitment to assist Taiwan in maintaining its defensive capability" (U.S. Relations With Taiwan, Bilateral Relations Fact Sheet," dated August 18, 2018, and available as https://www.state.gov/u-s-relations-with-taiwan/

[30] See, for example, Hans M. Kristensen and Robert S. Norris (2017), "A history of US nuclear weapons in South Korea," *Bulletin of the Atomic Scientists*, Volume 73, 2017 - Issue 6, Pages 349-357, published online: 26 Oct 2017, and available as https://www.tandfonline.com/doi/full/10.1080/00963402.2017.1388656

[31] See, for example, Mercedes Trent (2019), "The History of U.S. Decision-making on Nuclear Weapons in Japan," Federation of American Scientists, dated August 21, 2019, and available as https://fas.org/blogs/security/2019/08/the-history-of-u-s-decision-making-on-nuclear-weapons-in-japan/

nuclear warheads. The United States has all available delivery systems, and like Russia has thousands of warheads of different types and sizes. The Intermediate-Range Nuclear Forces (INF) Treaty, signed by the United States and the Soviet Union (USSR) in 1987, "required the United States and the Soviet Union to eliminate and permanently forswear all of their nuclear and conventional ground-launched ballistic and cruise missiles with ranges of 500 to 5,500 kilometers."[32] The United States, however, withdrew from the INF treaty in 2019, and implied that it might deploy intermediate cruise missiles in the Asia-Pacific Region,[33] although without nuclear warheads. It would, however, be difficult to verify whether the warheads used on these missiles are conventional or nuclear.

A map of Northeast Asia is presented for reference in Figure 2-1, showing the distance from the demilitarized zone (DMZ) dividing the nations of the Korean Peninsula, the key (but not the only) locus of conflict in the region.[34]

[32] See, for example, Arms Control Association (2019), "The Intermediate-Range Nuclear Forces (INF) Treaty at a Glance," last reviewed August 2019, and available as https://www.armscontrol.org/factsheets/INFtreaty

[33] See, for example, Idrees Ali (2019), "U.S. Defense Secretary says he favors placing missiles in Asia," *Reuters*, dated August 3, 2019, and available as https://www.reuters.com/article/us-usa-asia-inf/u-s-defense-secretary-says-he-favors-placing-missiles-in-asia-idUSKCN1UT098

[34] Prepared based on a map downloaded from Google Earth, January 7, 2022. The red circles on the map show, for reference, the approximate distance from the demilitarized zone (DMZ) that divides the Korean Peninsula.

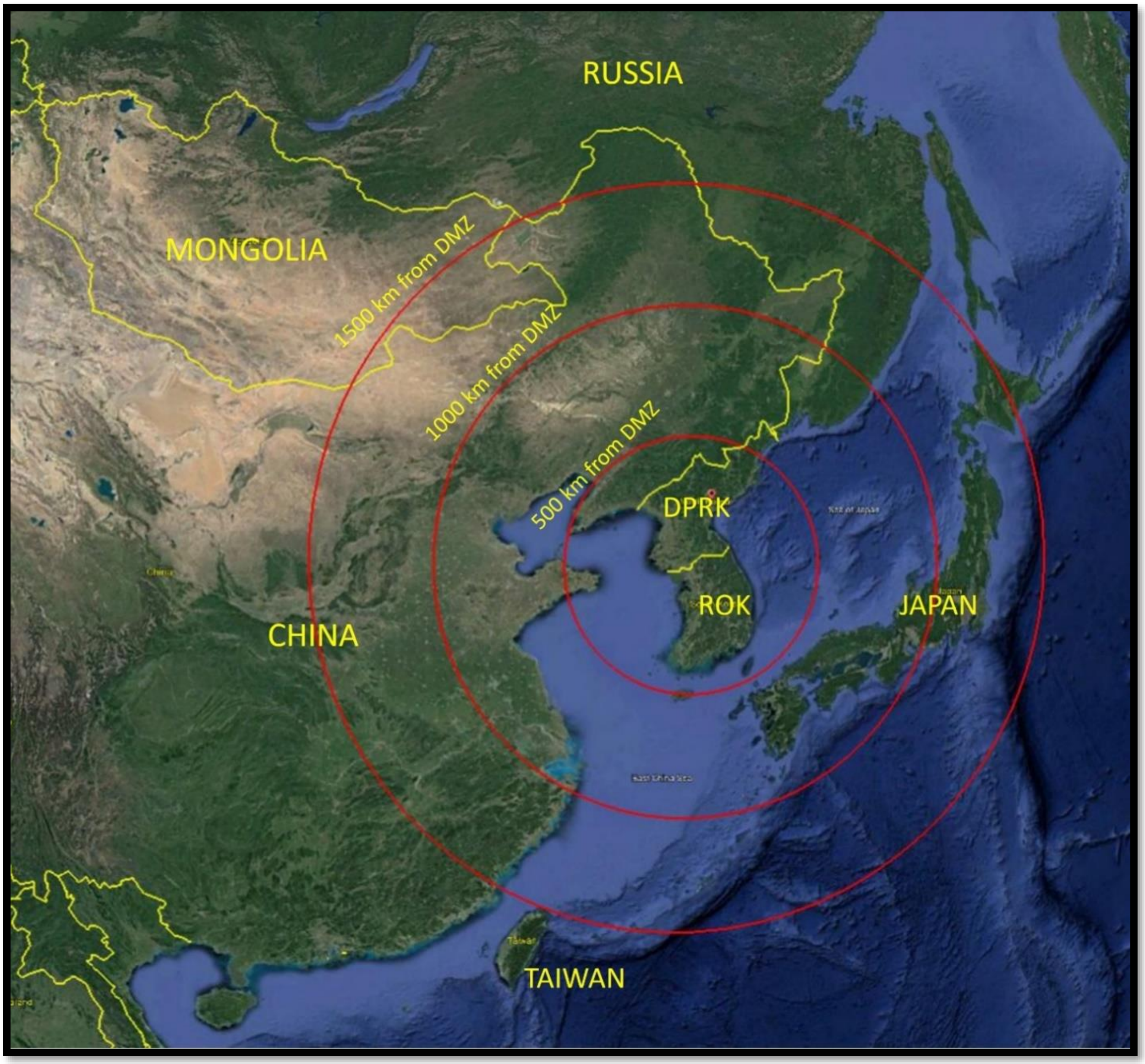

Figure 2-1: Map of Northeast Asia.

In addition to these state "actors," it is conceivable that nuclear weapons or nuclear devices, such as weapons designed to spread radioactivity via a non-nuclear explosion, could be used in an attack in Northeast Asia by non-state groups, such as terrorist organizations. Attacks on nuclear energy facilities, including reactors and spent fuel storage facilities in the ROK, Japan, or Taiwan, could also be carried out, and such attacks might have significant consequences for nearby populations, including plumes of radioactive material capable of causing acute and chronic health impacts, depending on factors such as distance and dilution.[35]

In sum, the existing, under-development, and (potentially) nascent nuclear weapons capabilities of actors in Northeast Asia make it crucial to find ways to reduce the risk of nuclear weapons use, as well as of the conflicts that might precipitate nuclear weapons use. These nuclear weapons capabilities, combined with simmering territorial and other disputes, and, of course, the longstanding state of war—albeit restrained for nearly 70 years by an Armistice to the point that it is now a "cold peace"—on the Korean Peninsula, make reduction in the risk of nuclear weapons detonation a key goal for our time.

2.3 Summary of project goals, approaches/methods, and organization

The overall goal of the "Reducing the Risk of Nuclear Weapons Use in Northeast Asia" project continues to be the reduction and minimization of the risk that nuclear weapons will be used in Northeast Asia. To achieve this goal, the project is designed to assist in developing better understandings of the processes that could lead to the first use of nuclear weapons and the potential outcomes of such nuclear weapons use. Improved understandings of the potential paths to and impacts of nuclear weapons use will help to inform the development and implementation of policies designed to reduce the risks of nuclear weapons detonation. To repeat, our strategic goal is to prevent any use of nuclear weapons in the region and, ultimately, to avoid armed aggression or war.

To understand the risk of nuclear weapons use and to develop policies to lower that risk, the Reducing the Risk of Nuclear Weapons Use in Northeast Asia project has as its basic objectives to address the risk of nuclear use by answering the following questions:

1) Under what conditions might nuclear weapons be used (with or without intention) in NEA and by whom? How might such first use of nuclear weapons escalate to a larger scale of nuclear war? And which states might respond to a first nuclear use with nuclear weapons use of their own?
2) What are the possible consequences (fatalities, physical damages to key infrastructure, environmental damages, climate impacts, and more) of potential nuclear weapons use in NEA?
3) What are the possible measures to reduce the possibility of use of nuclear weapons in the region? That is, what lessons do analyses of use cases offer for the development and deployment of policies that will help to avoid nuclear weapons use?

Step 1 of this process, the development of nuclear use cases involving, though not necessarily restricted to the Korean Peninsula, was the focus of our Year 1 Report, and has continued in year 2 with the addition of three more cases created based on consideration of changes that the Ukraine conflict has brought about.

[35] See, for example, David von Hippel and Peter Hayes (2018), *Radiological Risk from Accident or Attack at Nuclear Energy Facilities in China*, NAPSNet Special Reports, February 22, 2018, available as https://nautilus.org/napsnet/napsnet-special-reports/radiological-risk-from-accident-or-attack-at-nuclear-energy-facilities-in-china/; and Peter Hayes (2018), *Non-State Terrorism and Inadvertent Nuclear War*", NAPSNet Special Reports, January 18, 2018, available as https://nautilus.org/napsnet/napsnet-special-reports/non-state-terrorism-and-inadvertent-nuclear-war/

It should be emphasized that in developing these nuclear use cases—which represent only a small sampling of the vast universe of possible ways that nuclear conflict could start and evolve—we do not intend in any way to imply that one use case is more likely than another—which is unknowable—or to unintentionally will any of these use cases even one iota closer to reality. Our intention, rather, is and has been to posit these cases to learn from them and by so doing, anticipate and avoid such outcomes.

In Year 2 of the NU-NEA project, our focus has been on the evaluation of the results of selected use cases, focusing on the fatalities caused by blast overpressure, heat, and, to an approximate extent, by the firestorms that history indicates will result from nuclear use (Nagasaki and Hiroshima in 1945, but also the extensive bombing of cities during World War II) and will outstrip the damage caused by blast overpressure and thermal radiation alone. We also track the immediate (prompt) and longer-term (from fallout) radioactive emissions caused by each detonation in each of the selected use cases and estimate their effects on human health. Use cases evaluated were selected to span a range of places, nuclear actors, detonation types, and extents of nuclear conflict.

As noted above, the overall goal of the "Reducing the Risk of Nuclear Weapons Use in Northeast Asia" project is to reduce and minimize the risk that nuclear weapons will be used in the region. This is being accomplished by developing better understandings of the processes that could lead to the first use of nuclear weapons, and of the potential outcomes of such nuclear weapons use, of the consequences of nuclear weapons use, and of the policies that might—or rather, looking back from a case posited to happen in the future, might have—reduced the risks of nuclear weapons detonation. The cases posited for analysis are defined to take place between 2025 and 2030.

2.3.1 Approaches and methods, by project year

With the above questions in mind, the project identifies three basic tasks to meet the above objectives, with each task being the primary focus of each of the three project years:

1. **Development of possible nuclear use case.** This first task, which was the focus in project Year 1, and the results of which are provided in the Year 1 Report was to develop multiple cases that involve possible and plausible nuclear weapon use in the region, including possible escalation to a larger scale of nuclear war through counterstrikes, and retaliation, with a focus on use cases involving the Korean Peninsula in a regional and global geo-strategic context. Given the global context, some posited cases involve actual weapons use in places other than the Korea Peninsula. The objective of our Year 1 work was to provide enough specificity in the definition of the use cases to sufficiently inform the estimates of the impacts of those cases to allow modeling of the cases to move forward during the second year of the project.
2. **Simulation of nuclear use cases.** This second task, undertaken in Year 2 and described in this report, has been to develop computer simulations, including the use of the HYSPLIT tool for estimating the movement and severity of radioactive fallout,[36] and

[36] HYSPLIT is a computational model described as a tool to "… simulate the dispersion and trajectory of substances transported and dispersed through our atmosphere, over local to global scales." See United States Department of Commerce National Oceanic and Atmospheric Administration (NOAA, 2022), "HYSPLIT," available as https://www.arl.noaa.gov/hysplit/

other analysis, including of blast overpressure and heat emissions in the seconds following nuclear detonation. These calculations have been applied to selected examples of the nuclear use cases assembled during task 1 above, with each of the selected cases first elaborated to provide the specific inputs—timing, weapon type and yield, height of weapon burst, and other parameters—needed to undertake quantitative analyses. Although it has not been possible to elaborate and model all of the use cases developed in Year 1, the goal of Year 2 has been to assess the potential consequences of nuclear use cases spanning a range of places, nuclear actors, detonation types, and extents of nuclear conflict. Task 2 includes evaluating selected key nuclear impacts quantitively, including the areas affected directly by nuclear detonations, the areas affected by radioactive fallout, and the human casualties and radiation health impacts implied by those quantitative results, while identifying a range of other possible consequences, for which qualitative discussions of impacts and/or descriptions of the methods available to further evaluate those impacts, including, for example, economic and environmental damages, and the possible climate impacts of nuclear use, some of which will be addressed in Year 3 of the project.

3. **Development of policy recommendations to reduce the risk of nuclear war in NEA**. Based on the results of task 1 and 2, above, task 3 will focus on assessing current nuclear policies in the region and developing policy measures to reduce the risks that nuclear weapons will be used in the region.

2.3.2 Project organization

The Research Center for Nuclear Weapons Abolition, Nagasaki University (RECNA), Nautilus Institute, and the Asia Pacific Leadership Network for Nuclear non-proliferation and Disarmament (APLN), with the cooperation of the Panel on Peace and Security of Northeast Asia (PSNA), are hosting this project. RECNA, Nautilus Institute, and APLN have set up a Steering Committee as a project management organization. PSNA serves as an Advisory Group to the Project, and key members of PSNA are involved in each task. A Consultative Group of experts in various disciplines related to the project was assembled to provide input to and review of use cases in Year 1, with some Consultative Group members also commissioned to prepare background papers, published on the websites of the project partners, to inform the development and analysis of nuclear weapons use cases. In Year 2 of the project, contributing authors were commissioned to provide input to a synthesis paper (in process as of this writing) on the impact of the Ukraine conflict on nuclear postures and policies in Northeast Asia. Some of these contributions have been published on the project partners' websites as short papers.

3 Selecting Nuclear Weapons Use Cases for Analysis

3.1 Summary definitions and applications of use cases

3.1.1 What defines a use case?

For the purposes of this project, and as described in our Year 1 Report, a "use case" is defined as starting with the detonation of one or more nuclear weapons in an attack or counterattack against a military opponent. As such, this definition excludes, the "use" that nuclear weapons have been put to in the more than 75 years since the Hiroshima and Nagasaki bombings of 1945, which is to provide deterrence of a potential enemy's attack on a state or its territories, allies, or the military assets of either using either conventional or nuclear weapons. This definition also therefore excludes the detonation of nuclear weapons as part of tests that do not involve attacks, and the detonation of nuclear explosives—so-called "peaceful nuclear explosions"—for purposes such as civil engineering, as has been discussed in the past, tested in many instances (by the United States and the Soviet Union) but actually carried out (by the Soviet Union) in only a handful of cases.[39]

Nuclear use cases as defined in this project follow the general considerations, as described in our Year 1 Report, that the detonations will occur between 2025 and 2030, and that they will involve (if not necessarily start on) the Korean Peninsula. For the purposes of impact modeling and other analyses, attributes for each use case were specified including:

1. **Who** are the **possible** users of nuclear weapons?
    - Which state uses nuclear weapons first?
2. **Why** does the nuclear use happen? That is, what combination of events, and what political, economic, environmental, social and/or military circumstances, induce the designated actors to pursue nuclear weapons use? This would include consideration of **triggering events** such as (but certainly not limited to) accidental first use, pre-emptive strikes, or responses to terrorism (including both physical and cyber-attacks).
    - What perceived advantage and/or perceived vulnerability led to the use of nuclear weapons, and how did the situation arise? That is, what is the "back story" of the conflict that makes it potentially realistic?
3. **Which state responds** to nuclear first use with nuclear weapons and/or conventional forces?
4. **What and where** are the targets of nuclear weapons in each case, and **when** does the attack occur? What is the target for the first nuclear strike, including location, timing (what season of the year, and what time of day or night[40]) and type of detonation?

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[39] Tests of peaceful nuclear explosions "spanned 1957-75 in the USA and 1965-89 in the USSR." These tests will be banned by the Comprehensive Test Ban Treaty when the latter comes into force. See World Nuclear Organization (2018), "Peaceful Nuclear Explosions," updated December 2018, and available as https://world-nuclear.org/information-library/non-power-nuclear-applications/industry/peaceful-nuclear-explosions.aspx

[40] To model dispersion of radioactive particles from a nuclear use incident, it has been necessary to specify both a location and approximate timing to obtain weather data representative of the time and place of weapons use. The same information is needed to calculate other modeling results, for example, human exposure.

- What are the targets for subsequent or retaliatory strikes, including the number of counterstrikes and the types of targets (military or civilian) involved?

5. **How** are the first strikes and subsequent nuclear attacks carried out?
   - What size (yield) and type of weapon (uranium, plutonium, hydrogen) is used in each case?[41]
   - What delivery and targeting systems are used? Information on these elements helps to determine how likely weapons are to reach their targets and to cause collateral damage.
6. How **plausible** is the nuclear use case, and how significant are its impacts likely to be?
   - To pose cases that are of relevance to policymakers, they should be judged to be possible within the universe of all possible nuclear use cases in the region, and
   - They should have a large enough potential impact — in terms of human lives lost, economic damage, political repercussions, environmental and/or ecological damage — to capture the interest of policymakers.

3.1.2 Applications of use cases

In their paper prepared for in Year 1 of this project, Paul K. Davis and Bruce Bennett list the following applications of use cases:[42]

- "Education [of] analysts, scholars, policymakers, military officers, staffs, students
- Communication among scholars and practitioners; with public; in negotiations
- Assessing strategic balances from different perspectives and with different assumptions
- Assessing arms control options by governments and outside groups
- Understanding potential outcomes of nuclear war in terms of relative and absolute military gains and losses, and more broadly

[41] The size of the weapon used, along with at what level (ground level or in the atmosphere) it is detonated, are inputs to determine the size and shape (height above the ground, width, and height of "cap") of the mushroom cloud resulting from the nuclear explosion, which in turn is an input to the distribution of the sources of radioactive particles that make up fallout. The location (latitude and longitude) of detonation also may play a role in the composition of fallout based on the local soil types (or water bodies) and any man-made structures destroyed in the detonation area, although incorporation of these details has in part been beyond the scope of the work in project Year 2.

[42] Paul K. Davis and Bruce Wm. Bennett (2021), *Nuclear-Use Cases for Contemplating Crisis and Conflict in East Asia*, paper prepared for the Reducing the Risk of Nuclear Weapons Use in Northeast Asia project, 9 December, 2021, and available as APLN, RECNA, PSNA, and Nautilus Institute Special Reports at https://www.apln.network/projects/nuclear-weapon-use-risk-reduction/nuclear-use-cases-for-contemplating-crisis-and-conflict-on-the-korean-peninsula, https://www.recna.nagasaki-u.ac.jp/recna/topics/29469, https://www.recna.nagasaki-u.ac.jp/recna/psnanews/29485, and https://nautilus.org/napsnet/napsnet-special-reports/nuclear-use-cases-for-contemplating-crisis-and-conflict-on-the-korean-peninsula/

- Identifying problems and opportunities in avoiding or mitigating nuclear war noting particular weaknesses of deterrence and ways to improve it
- Planning force planning, operational planning, and crisis planning"

Virtually all of these roles for use cases, with the possible exception of detailed force and operational planning, factor into the applications for the use cases developed during this project, as all of these applications can be thought of as elements in developing and refining policies designed to reduce the risk that nuclear weapons use will occur.

3.1.3 Objectives in assembling and evaluating a range of use cases

History, as we noted in our Year 1 Report, is strewn with events that failed to be considered by those responsible for planning. In some cases, these oversights were because those events had not happened before. In other cases, the events were simply considered to be "unthinkable" for reasons varying from the events being thought to be "unlikely" to the foibles of human hubris. As such, the goal of this project has been to initially assemble as broad a range of use cases as is practicable. Given the many actors in NEA, and the almost limitless number of potential triggers for conflict in the region, there are literally an unlimited number of use cases that might have been produced. Limits on the amount of time and human resources that can go into developing, and subsequently, as in the Year 2 analyses reported on below, evaluating such use cases mean that only a limited set of use cases can be assembled and analyzed. Our objectives in doing so have been to assemble a set of use cases that includes all of the potential actors in the use of nuclear weapons in NEA in general and involving the Korean Peninsula in particular, that include multiple modes of nuclear weapons use, for example, against different types of targets, in different types of detonations, and at different levels of yield, and to explore a range of triggering events. The objective in assembling and, subsequently, analyzing this breadth of use cases is to identify and test policy solutions that reduce the risk of nuclear war from a range of different angles in order to find policy solutions that can be used to address—and are "robust" responses to—different ways in which nuclear war might arise.

To analyze the use cases, again mindful of both the time and other resources required to carry out use case evaluation, we selected a subset of the 27 use cases and use case variants developed during Year 1, plus one of the three additional use cases (and variants) developed this year with Russia as the first user (see Annex 1), for further analysis during Year 2.

3.1.4 Criteria for selecting use cases for further analysis

Criteria in selecting this group of use cases were that the group of cases selected as a whole should:

- Include a range of first users of nuclear weapons.
- Include a range of targets of nuclear weapons use—military, urban, rural—although in practice most of the nations that might be first users would likely, given existing doctrines for nuclear weapons use, attack military targets. Note, however, that many military targets in NEA are surrounded by civilian areas.
- Include a range of extents of nuclear conflict (single detonation, limited exchange, extensive exchange).

- Include multiple delivery systems, heights of burst, and sizes (nuclear yield) of weapons, although the former may not be as important in determining the results of detonations.
- Be sufficiently limited to allow analysis within the constraints of project resources, and to avoid significant repetition of analyses of individual detonations.

With these criteria in mind, NU-NEA project staff and leaders reviewed summaries of the 30 use cases assembled and settled on a set of use cases to move forward to quantitative and other further analyses.

3.2 Use Cases Evaluated

Based on application of the criteria above, five use cases were selected for quantitative analysis in Year 2 of the NU-NEA project:

- "We're Still Here" Variant 1, in which the DPRK used nuclear weapons first (evaluated as **Use Case 1**).
- "US Leadership Hubris" in which the first use of nuclear weapons is by the United States (evaluated **Use Case 2**).
- "Terrorist" Variant 1, in which a terrorist attack is the first (and in this case, only) use of nuclear weapons (evaluated as **Use Case 3**).
- "Conflict from Ukraine Spreads East "in which Russia carries out the first use of nuclear weapons (evaluated as **Use Case 4**).
- "Not Going Well in Taiwan", in which China detonates the first weapon of the conflict (evaluated as **Use Case 5**).

Full descriptions of these use cases are available in the Year 1 Report or in Annex 1 to this Report, and summaries are provided in Table 3-1. In this table, and in the text and graphics shown in sections below, "FUD" stands for "First Use Detonations," attacks with nuclear weapons by first users, "RD" stands for "Response Detonations," and "AD" stands for "Additional Detonations."

Table 3-1: Overview of Parameters for Evaluated Use Cases

Evaluated Use Case	First User	Responding User(s)	Types of Targets	Weapon Types/Sizes	Total Detonations
#1: "We're Still Here" Variant 1	DPRK	United States	**FUD**: "Demonstration" Target in ROK **RD**: DPRK Nuclear Infrastructure	**FUD**: Fission, 10 kT **RD**: 2-stage H-bombs, 8 kT	**3**
#2: "US Leadership Hubris"	United States	DPRK, China	**FUD**: DPRK nuclear weapons infrastructure **RD**: US military base in ROK, ROK/Japan industrial targets **AD**: US and Chinese military targets	**FUD**: 2-stage H-bombs, 8 kT **RD**: Fission, 20, 10 kT **AD**: 2-stage H-bombs 50, 200, 300 kT	**18**
#3: "Terrorist" Variant 1	Terrorist	[None]	**FUD**: Transit and commercial hub in Tokyo	**FUD**: Fission, 10 kT	**1**
#4: "Conflict from Ukraine Spreads East"	Russia	United States	**FUD**: US military bases in Japan and warships at sea **RD**: Russian naval and submarine bases	**FUD**: 2-stage H-bombs, 150, 200 kT **RD**: H-bomb, 8 kT	**8**
#5: "Not Going Well in Taiwan"	China	United States, China	**FUD**: US military bases in Japan and Guam **RD**: Chinese military targets **AD**: US military bases, Chinese military bases	**FUD**: 2-stage H-bombs, 250 kT **RD**: 2-stage H-bombs, 8 and 50 kT **AD**: 2-stage H-bombs 250, 300 kT	**24**

3.3 Elaboration of use cases for quantitative evaluation

Descriptions of the five selected use cases listed above were elaborated to provide inputs for the modeling in project Year 2, including:

- Developing the **narrative** of each use case describing in greater detail how the use case plays out.
- Stipulating the **yields of the weapons used** (in kilotons, or kT) and the **height of burst** (HOB—point of detonation of the weapon either above the ground or at or slightly below ground level), in meters. These details were developed based on consideration of factors such as weapons arsenals reportedly held by each actor, the nature of the target of each detonation, and assumptions as to how those planning a nuclear attack on each particular target might do so. Weapons yield and HOB were stipulated for each first use detonation (FUD), response detonation (RD), and additional detonation (AD) included in the Use Case.
- Defining the **precise targets** (expressed as latitude/longitude coordinates) for each detonation.
- Deciding a precise **date and time** for each detonation to enable the use of historical weather data,[43] such as the wind speed and direction that would carry radioactive particles downwind (nuclear fallout), the air transparency at the time of the detonation, which affects the distance that thermal radiation can travel, and other parameters.
- Identifying the type of weapon and delivery system used, including whether the weapon is a fission, thermonuclear, of hybrid weapon to specify the "fission fraction" of the detonation for the purposes of determining prompt and fallout radiation.

The results of these elaborations are provided in Annex 2: Use Case Elaborations to this Report.

[43] There is, of course, no guarantee that the weather on, for example, March 1, 2026, will be the same as recorded on March 1, 2021. As such, there is considerable and unavoidable uncertainty as to which direction fallout from a nuclear detonation will travel, and the extent to which it will affect any given location. This uncertainty cannot be fully avoided, but sensitivity analysis considering other possible/probable weather patterns in selected locations can help to identify when and where fallout impacts might be particularly significant.

4 Evaluation of Use Cases—Impacts Considered

4.1 Introduction: Impacts of nuclear weapons use

Nuclear weapons detonations have a wide range of destructive impacts on humans, structures, the environment, and society. Some of these impacts occur within seconds or minutes—or indeed, fractions of a second—while some take days, months, years, decades, or even longer to fully manifest. It would be impossible to catalog and evaluate all of these impacts, but we have attempted to prepare quantitative estimates of a range of key impacts of the nuclear detonations in the use cases described above, with additional impacts receiving qualitative treatment, and some left for further analyses in Year 3 of the NU-NEA project.

The **physical** impacts of nuclear weapons detonation, with a focus on human casualties, include:

- **Thermal fluence**, or thermal radiation from the nuclear fireball, depending on the distance from the fireball and other factors, causes skin burns to exposed flesh, and causes combustible materials, from fuel to building materials to clothing, to ignite.
- The damage from potential **firestorms** started by the thermal fluence from the nuclear detonation. Although the thermal fluence from nuclear explosions sets fires at various distances by causing combustible materials to burn, and additional fires can stem from buildings and vehicles destroyed by overpressure, firestorms are a special case in that they represent an entire area lit aflame essentially at once, creating gale-force winds in the direction of the fire/ground zero in all direction, burning for hours, and nearly impossible to escape or survive.
- **Blast overpressure**, the blast wave from the explosion, destroys buildings and other structures, with destruction complete near "ground zero" (the point on the ground at which or over which a detonation occurs) and decreasing with distance. People and animals within the blast wave area are typically killed or injured as buildings collapse and by flying debris.
- **Prompt (or immediate) radiation exposure** from the nuclear explosion, reaching affected victims within ranges of hundreds of meters to kilometers of ground zero in a matter of seconds.
- **Radiation exposure from fallout** as radioactive materials from the blast are lifted into the air, dispersed, and deposited downwind. Severe radiation exposure from fallout occurs within a few hours to days following a nuclear detonation, and typically near ground zero, but radioactive materials can travel downwind for tens or even hundreds of kilometers, and exposure can continue for months as the decay of radioactive elements occurs in fallout zones.
- Human health impacts result from **exposure to both prompt radiation and nuclear fallout**. Severe exposure can be lethal in a matter of hours to weeks or inhibit the healing of burns and physical injuries by weakening the human immune system. Less severe radiation exposure can cause autoimmune illnesses and cancer, which often appears years or decades after exposure.

Each of these impacts have been evaluated quantitatively during Year 2 of the NU-NEA project. Discussions of each of these impacts are provided in the remaining subsections of this section, the methods used to evaluate each of these impacts are described in Section 5 of this Report, and the results of the applications of those methods are presented in Section 6.

Except for fallout radiation dispersed by wind, the direct impacts of nuclear detonations overlap to simultaneously affect populations in the areas around ground zero. An individual exposed to severe radiation levels may also suffer physical injuries and/or burns or be trapped in a firestorm zone. Those whose immune systems are weakened by radiation exposure are more susceptible to succumbing from overpressure-related injuries or burns, and burn injuries inhibit the healing of other physical injuries.

Additional impacts of nuclear detonations on humans, society, the economy, and the environment result from the direct impacts described above. These include:

- The economic costs of deaths and health impacts of nuclear detonation and radiation exposure, starting with the costs of treating the sick and injured, but also including other related costs to the economy.
- The costs of infrastructure rebuilding following a nuclear detonation.
- The costs of environmental contamination with radioactivity.
- The costs of ecological impacts of nuclear detonations.
- The potential impacts of nuclear detonations on global climate.
- The social and political consequences of nuclear use.

These impacts are not addressed directly in this Report, but some of these impacts will be evaluated in Year 3 of the NU-NEA project, subject to ongoing decisions about Year 3 activities. Year 3 of the project will, as noted above, focus on identification of policies for reducing the risk of nuclear weapons use.

4.2 Thermal fluence (radiative heat)

Thermal fluence measures the radiative heat from the nuclear fireball resulting from detonation. Thermal fluence is typically measured in units of calories per square centimeter ($cal/cm^{2)}$ of surface area at specific distances or "ranges" from ground zero. Heat radiation from a nuclear detonation, as noted above, can burn skin, fuel, fabric, flammable building materials, and other fuels encountered in the line of sight from the nuclear blast. With respect to impacts on human health, thermal fluence of about 8 to 10 cal/cm^2 , for the range of nuclear weapon yields considered in the use cases above, will cause third degree burns on exposed skin in essentially all individuals not taking evasive action, with 5 to 7 cal/cm^2 causing second degree burns, as shown in Figure 4-1.[44] Wood will ignite at 10-20 cal/cm^2, many fabrics will ignite at 10 cal/cm^2, and paper ignites at around 5 cal/cm^2, with ignition depending on conditions including the presence or absence of humidity or wind. Thermal fluence can have a range of impacts, depending on, for example, how a person is dressed. Sufficiently high thermal fluence values can cause significant burns even through heavy clothing, as described in Table 4-1, which focuses on burn thresholds

[44] Figure is from page 565 of the seminal 1977 US Department of Defense publication, The Effects of Nuclear Weapons, 3rd Edition, compiled and edited by Samuel Glasstone and Philip J. Dolan, available as https://www.osti.gov/servlets/purl/6852629

for soldiers equipped with various types of uniforms.[45] Examples of burns suffered by the nuclear bombings in Japan in 1945 are shown in Figure 4-2.[46]

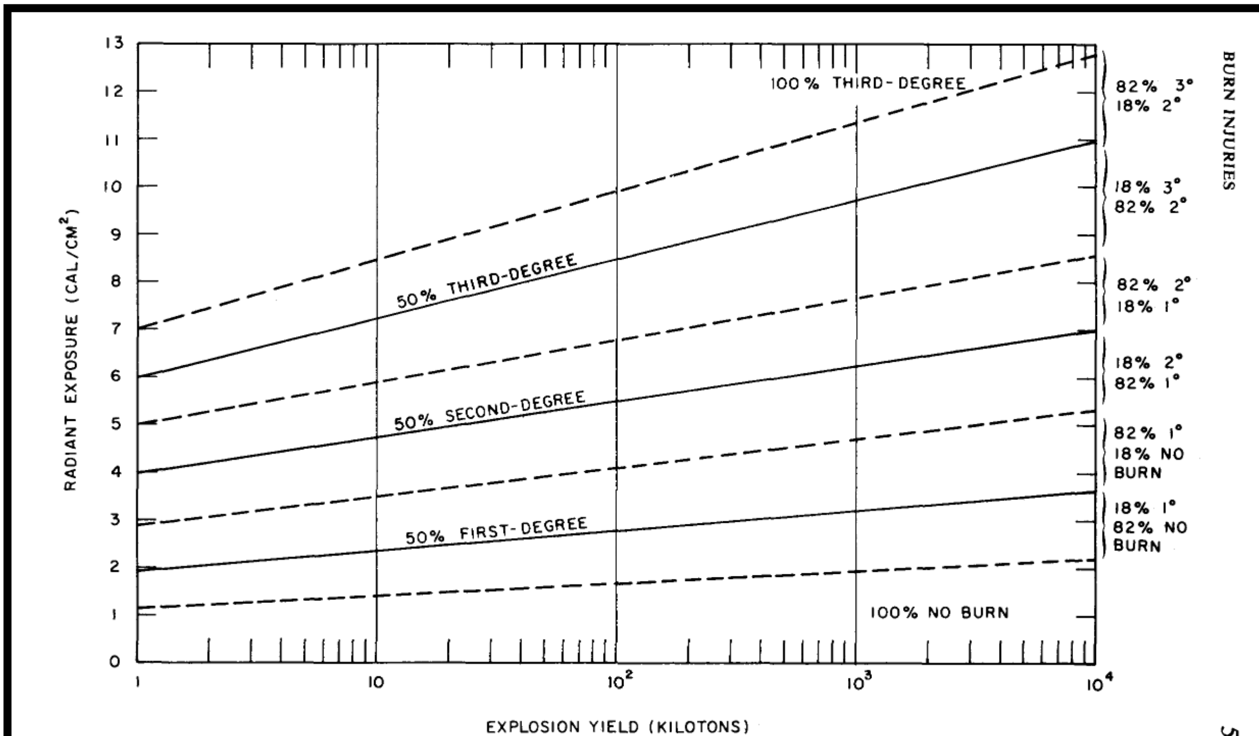

Figure 12.65. Skin burn probabilities for an average unshielded population taking no evasive action as a function of explosion yield and radiant exposure.

Figure 4-1: Probability of First- through Third-Degree Burns and Radiant Exposure as a Function of Nuclear Weapons Yield.

[45] From Carl A. Curling and Samantha Todd (2017), Parameters for Estimation of Casualties from First and Third Degree Flash Burns, institute for Defense Analysis, dated March 2017, and available as https://apps.dtic.mil/sti/pdfs/AD1123338.pdf

[46] Images from https://www.atomicarchive.com/media/photographs/human/medical.html (left) and from https://www.archives.gov/files/research/military/ww2/photos/images/ww2-164.jpg (right). The latter image also appears in Glasstone and Dolan (1977), ibid.

Table 4-1: Thermal Fluence Thresholds for Burns with Clothing of Various Types

Thermal Fluence Threshold (Q_t) Values for Various Burns and Uniform Types

Uniform/Clothing	1st Degree Burns [Cal/cm2]	1st Degree Burns [kJ/m2]	2nd Degree Burns [Cal/cm2]	2nd Degree Burns [kJ/m2]	3rd Degree Burns [Cal/cm2]	3rd Degree Burns [kJ/m2]
Bare Skin	2.08	87.2	2.61	109	3.98	167
Battledress Uniform (BDU) + T-shirt	5.93	248	7.41	310	11.3	474
BDU + T-shirt + Airspace†	12.0	504	15.1	630	23.0	963
Battledress Overgarment (BDO)	8.03	336	10.0	420	15.3	642
BDO + Airspace†	12.8	536	16.0	670	24.5	1,020
BDO + BDU + T-shirt	24.9	1,040	31.1	1,300	47.5	1,990
BDO + BDU + T-shirt + Airspace†	38.4	1,610	48.0	2,010	73.5	3,070

† Airspace indicates looser clothing (i.e., clothing with airspace between the body and the garment), as opposed to fitted clothing.[3]

Figure 4-2: Examples of Flash Burns Suffered by Victims of Nuclear Weapons in Japan, including Burns Suffered through Clothing.

4.3 Firestorms

A nuclear detonation in any area where fuels are present will start fires. Potential fuels for fires include wood used in construction, plastics, rubber, fabric, vegetation and other biomass, and stores of combustibles at scales ranging from gasoline cans in garages and automobile fuel tanks to huge fuel storage tanks at depots. In some cases, these fires will be started by thermal fluence from the nuclear blast at many different, dispersed points, and burn out in those areas. In some cases, large fires will be started by thermal fluence, and, driven by ambient winds and/or topography, grow in a particular direction. Line fires, as are common in forest fires and as occurred in some of the historic urban fires of the past,[47] are an example of this type of conflagration. The nuclear attack on Nagasaki in August of 1945 created a mass fire when the hills surrounding the city, with relatively little fuel of their own to burn, acted as a constraint on the fire area and as a flue, with hot air rising from the fire pulling cooler air from the ocean behind it, and driving the fire up the slope through the city.

Firestorms are also mass fires but have particular characteristics. In a firestorm, a large enough contiguous area is set aflame, effectively at once, that the fire creates its own wind patterns. As heat from the fire rises, winds arise on all sides traveling toward the fire, sometimes at gale-force velocities of up to 90 miles per hour (about 40 meters/second). In some cases, the generation of a firestorm may be prevented by the surrounding geography. For example, although the fires resulting from the attack on Nagasaki were devastating, the large-scale firestorm effect was mitigated by the mountainous geography of the region. Figure 4-3 shows how firestorm wind circulation patterns arise and are perpetuated as the firestorm proceeds.[48] These winds both act as a limit to the growth of the fire—although secondary blazes can start outside the fire area from embers of the firestorm—and cause the fierce, and for all practical purposes, impossible to escape, nature of the firestorm. The thermal fluence from a nuclear weapons detonation can, if atmospheric, fuel loading, and topographic conditions are suitable, cause mass fires to start in a matter of minutes. Firestorms can burn out an entire area many square kilometers in extent in a matter of hours and are essentially impossible for humans trapped inside the fire zone to escape or survive. Even if some within the firestorm are able to retreat to, for example, protected sub-basements or subway tunnels, the combination of the intense heat from the fires above, as it penetrates down, coupled with the consumption of oxygen and smoke and toxins from burning materials, would cause even those who escaped the initial flames to perish in hours or days.

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[47] Examples of such line fires include "…the great urban fires that destroyed London (1666), Chicago (1871), and San Francisco (1906)….," as well as more recent first such as those that have caused devastation in the North American west and in many other places in recent years. See, for example, Lynn Eden (2004), *Whole World on Fire: Organizations, Knowledge, & Nuclear Weapons Devastation*, Cornell University Press, Ithaca and London (quote shown is from page 28 of this volume).

[48] Source of this information and Figure 4-3 is Theodore A. Postol (1986), "Possible Fatalities from Superfires Following Nuclear Attacks in or near Urban Areas," paper included (pages 15-72) in *The Medical Implications of Nuclear War*, Fred Solomon and Robert Q. Marston, Editors, National Academies Press, available from https://nap.nationalacademies.org/catalog/940/the-medical-implications-of-nuclear-war

The description of the schematic in Postol's paper reads, "The drawings show how a mass fire that bums simultaneously over a large area can generate high ground winds. In A, buoyantly rising air from a fire zone pushes air at higher altitudes upward and outward. Eventually this action can result in the establishment of a macroscopic flow field of enormous power and extent (B). If the heat output per unit area from combustion is reduced, but the area over which the heat output is produced is increased, such a large circulating pattern might still occur. Thus, predictions of ground winds and air temperatures from mass fires must consider both the scale of the fire and the heat input per unit area in the region where such fires bum."

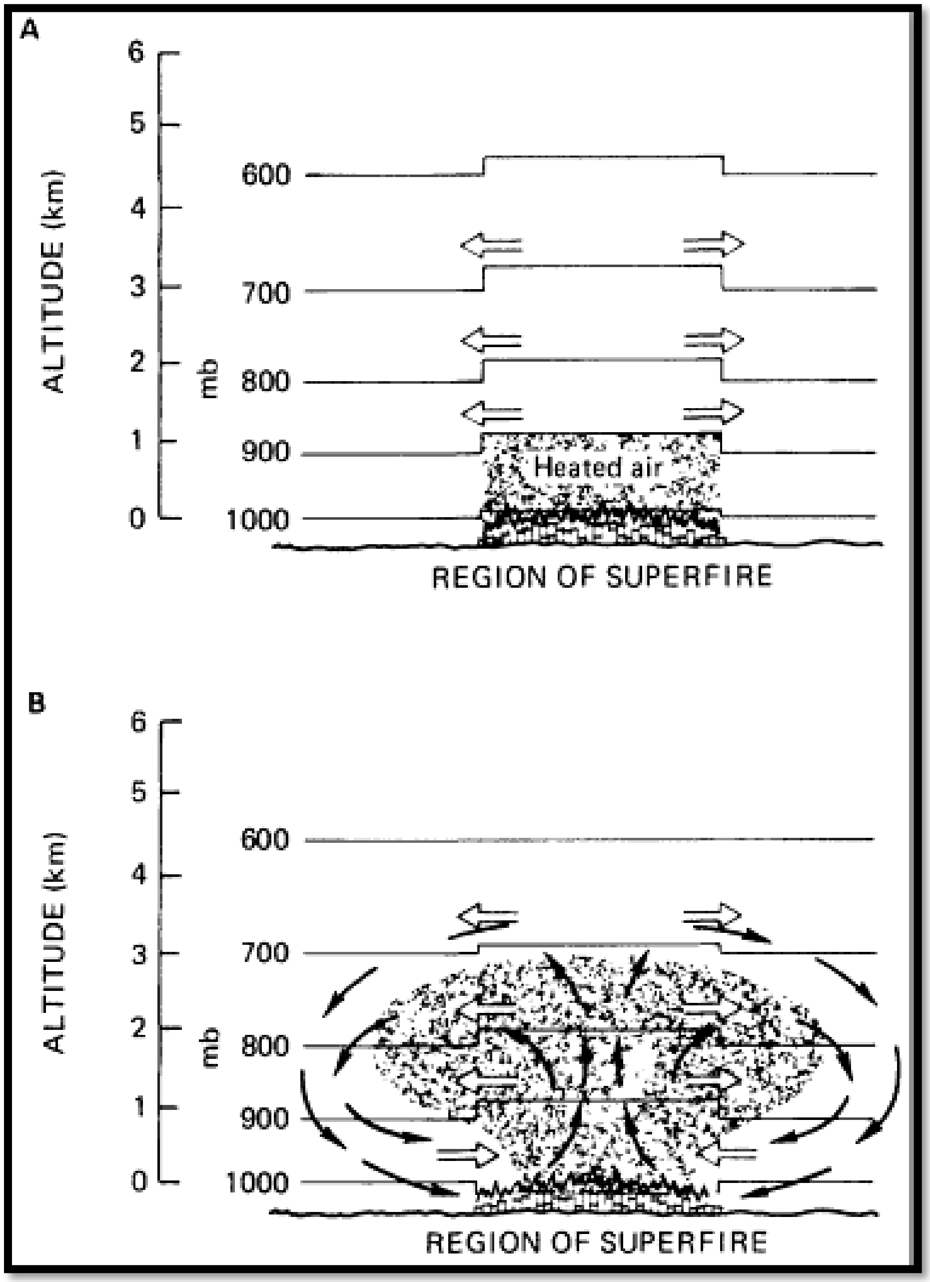

Figure 4-3: Schematic of the Initiation and Progress of a Firestorm (or "Superfire").

The city of Hiroshima, when attacked with nuclear weapons in August of 1945, was a city on a relatively flat plain, made up of houses made mostly of wood. The thermal fluence from the nuclear weapon detonated over the city, coupled with the results of the blast overpressure, caused a firestorm to a radius of about 1.5 to 2 km from ground zero, destroying virtually everything within that radius (see Figure 4-4).

In many cases, depending in part upon factors such as weapons yield and topography, the casualties from a nuclear detonation-caused firestorm will effectively overwhelm and subsume the impacts on people of overpressure, thermal fluence, and initial radiation, as well as fallout, although all of these impacts combine to reduce survivability. The importance of firestorms to the overall impacts of nuclear weapons is shown in the results of some of the use cases evaluated in this report (see section 6), but has often been omitted in past simulation studies of nuclear detonations.

Fires outside the firestorm radius may still be set due to overpressure and/or thermal damage to gas and electric infrastructure or ignition of building materials or vehicle or fuels, causing additional damage.

Figure 4-4: Firestorms Ignited by Nuclear Detonations in Hiroshima, 1945. [49]

Firestorms ignited by nuclear detonations are qualitatively different in their initiation from those ignited by conventional weapons. World War II featured a number of devastating fires, deliberately set by combatants though aerial bombardment in order to destroy war industry

[49] Source of image, Atomicarchive.com, available as https://www.atomicarchive.com/media/photographs/hiroshima/image-17.html
Caption of image in source: "The ruins of Hiroshima. Almost all wooden houses to a radius of 4,750–6,330 feet (1,450–1,930 meters) from the hypocenter were crushed instantly. Fire then swept through them, either from the heat of the blast or from cooking fires, until they were engulfed by the firestorm."

infrastructure and, perhaps at least equally, to demoralize opponents. Some of these fires also became firestorms. Although firestorms were ignited in the non-nuclear bombing of cities during World War II, those firestorms were caused by targeted application of thousands of high-explosive bombs and incendiary devices from hundreds of planes, and thus present a very different situation relative to the firestorm damage that can be caused by a single nuclear weapon.

Consideration of firestorm damage has in the past been largely omitted from weapons damage/targeting analysis by official United States military planners, and likely by planners from other nuclear nations as well. These omissions have potential international legal implications, as noted briefly in section 1.2 of this Report.

This omission has been brought to the attention of the public through the work of Lynn Eden,[50] Theodore Postol, and others. The work of Lynn Eden and Theodore Postol builds in part on decades of work by H. L. Brode and his colleagues, who explored the physics of firestorms from the 1950s through the 1990s.[51]

4.4 Blast overpressure

Blast overpressure denotes a shock wave, propagated from the nuclear blast and traveling at approximately the speed of sound, that causes physical destruction. Although humans are surprisingly resilient to overpressure, structures are not, and the shock wave from the nuclear detonation reaches a structure, typically in a matter of seconds, many structures will be destroyed, depending on their composition and distance from ground zero. When these structures fail, fatal and non-fatal injuries to persons in and near them result.

A publication on emergency planning and response to a nuclear detonation developed by a US federal inter-agency committee (led by National Security staff and the Office of Science and Technology Policy) provides the following description of the blast effects of a nuclear detonation:[52]

> "Initially, blast causes the most casualties in a ground level urban nuclear explosion. Blast effects consist of overpressure and dynamic pressure waves ... The human body is remarkably resistant to overpressure, particularly when compared with rigid structures such as buildings. Although many would survive the blast overpressure itself, they will not easily survive the high velocity winds, or the crushing injuries incurred during the collapse of buildings from the blast overpressure or the impact of high velocity shrapnel (e.g., flying debris and glass) ... Blast injuries, such as lung and eardrum damage, will likely be

[50] Lynne Eden (2004), ibid.

[51] As just one example of Brode's extensive work, see H.L. Brode, Ph.D., and R.D. Small (1986), "A Review of the Physics of Large Urban Fires," paper included (pages 73-95) in *The Medical Implications of Nuclear War*, Fred Solomon and Robert Q. Marston, Editors, National Academies Press, available from https://nap.nationalacademies.org/catalog/940/the-medical-implications-of-nuclear-war

[52] United States National Security Staff Interagency Policy Coordination Subcommittee for Preparedness & Response to Radiological and Nuclear Threats (2010), *Planning Guidance for Response to a Nuclear Detonation, 2nd Edition*, dated June 2010, and available as https://nepis.epa.gov/Exe/ZyPDF.cgi/P100C9X6.PDF?Dockey=P100C9X6.PDF. A new *Third Edition* of the same document, published in May of 2022 by the (US) Federal Emergency Management Agency (FEMA) is available as https://www.fema.gov/sites/default/files/documents/fema_nuc-detonation-planning-guide.pdf

overshadowed by injuries related to collapsing structures. Many of these will be fatal injuries [in the areas of moderate to severe building damage]. Further out [from ground zero], flying debris injuries will prevail ... Large windows can break at blast wave pressures as low as 0.1 psi, and people will be subject to injury from the glass falling from damaged tall buildings."

Units given for overpressure are typically pounds per square inch (psi) at distances or "ranges" from ground zero. In SI units, one psi is equal to approximately 6.9 kPa (kilo Pascals), and one Pa is defined as one Newton (N) of force per square meter. Overpressures of 10 psi generate maximum wind speeds of nearly 300 miles per hour (480 km per hour), or on the order of two or more times higher than peak wind speeds experienced in even the most violent typhoons and hurricanes. Depending on the distance from ground zero, the pressure wave and hurricane-force winds will arrive seconds to minutes after the detonation and last for fractions of a second to seconds depending on the weapon yield. The initial pressure wave is followed by a negative phase pressure, as depicted in Figure 4-5.[53] Table 4-2 summarizes the deaths and casualties associated with different levels of overpressure.[54] Figure 4-6 shows examples of destruction from nuclear blast overpressure on a typical house built to test blast effects at the US nuclear test site in Nevada and on a concrete building in Hiroshima.[55]

[53] Figure from Chapter 3 of U.S. Army, Navy, and Air Force (1996), FM 8-9, *NATO Handbook on the Medical Aspects of NBC Defensive Operations AMedP-6(B)*, dated 1 February 1996, and available as https://nuke.fas.org/guide/usa/doctrine/dod/fm8-9/1ch3.htm

[54] Table from Atomicarchive.com (undated), "Overpressure," and available as https://www.atomicarchive.com/science/effects/overpressure.html

[55] Images from Atomicarchive.com, https://www.atomicarchive.com/media/photographs/blast-wave/index.html and https://www.atomicarchive.com/science/effects/blast-effects-humans.html

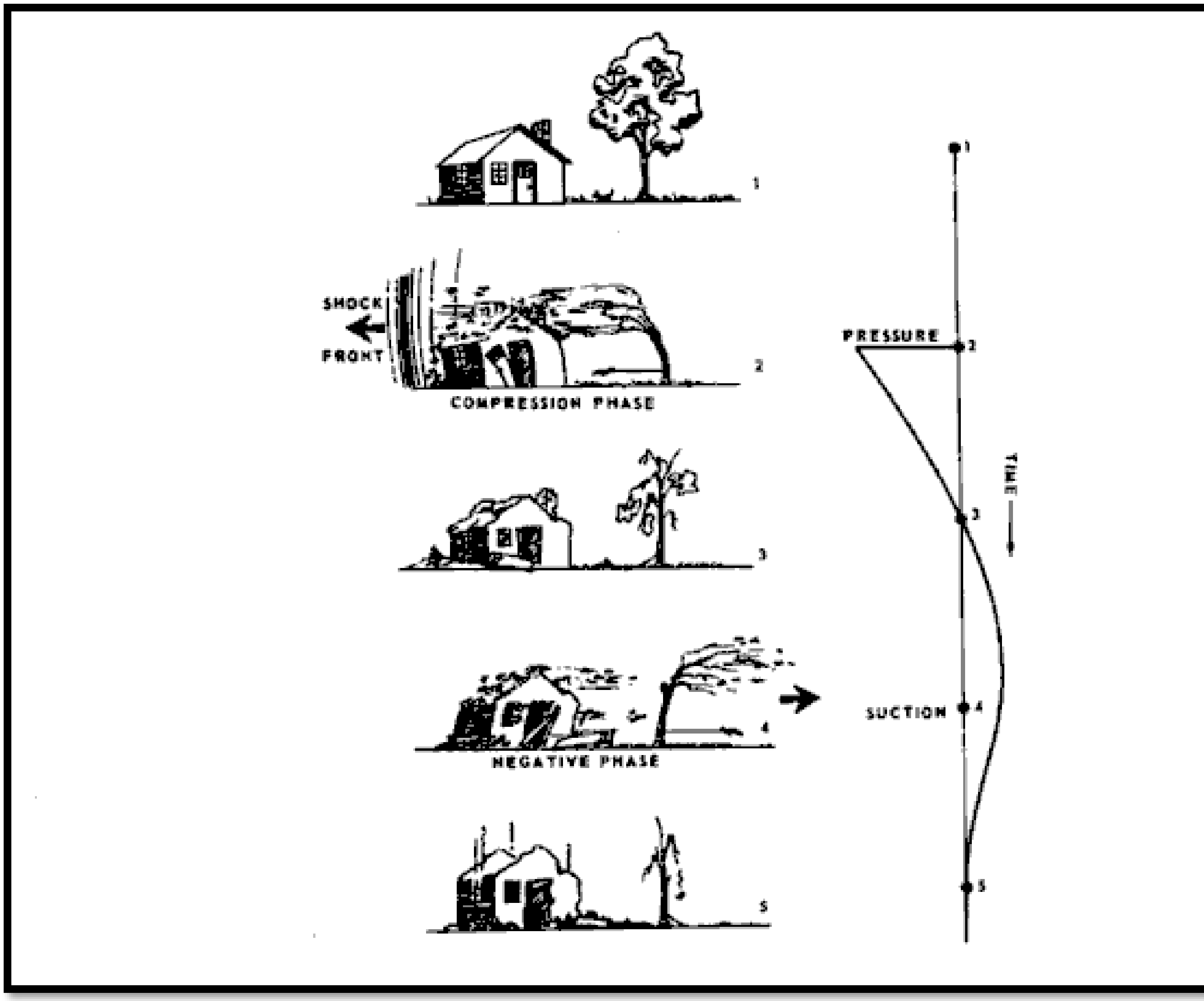

Figure 4-5: Variations of Blast Effects of a Nuclear Detonation Associated with Positive and Negative Phase Pressures with Time.

Table 4-2: Deaths and Casualties Associated with Different Levels of Overpressure

Overpressure	Physical Effects
20 psi	Heavily built concrete buildings are severely damaged or demolished.
10 psi	Reinforced concrete buildings are severely damaged or demolished. Most people are killed.
5 psi	Most buildings collapse. Injuries are universal, fatalities are widespread.
3 psi	Residential structures collapse. Serious injuries are common, fatalities may occur.
1 psi	Window glass shatters Light injuries from fragments occur.

Figure 4-6: Impacts of Nuclear Blast on Wood-Framed House at Nevada Nuclear Weapons Test Site (5 psi) and on a Concrete Building at Hiroshima.

4.5 Prompt radiation exposure

Prompt radiation is nuclear radiation occurring within the first minute after a nuclear detonation (as opposed to fallout, which occurs later). The primary radiation types emitted are gamma and neutron radiation, the energy from which is absorbed in tissues and causes damage depending on the dose of radiation received.[56]

Units for prompt radiation dose thresholds are often given in rem ("Roentgen equivalent man"), with one rem equal to 0.01 Sievert (Sv) or 10 millisievert (mSv).[57] [58] A dose of 200 rem or more is considered fatal or near-fatal, with doses between 50 and 200 rem considered high but survivable, and doses of 10-50 rem potentially causing medium- and long-term health impacts, as shown in Table 4-3.[59]

Table 4-3: Health Effects of Ionizing Radiation Doses[60]

Dose (rem)	0.1	5	10	50	100	200	600	1000
Significance	USNRC annual dose limit to the public	USNRC annual dose limit for radiation workers	Statistical increase in cancer incidence	Considered high dose by USNRC	High dose with high survivability	Survival chance highly dependent on medical care	Almost no survival even with intense medical care	Lethal within days
Symptoms Possible			Onset of cancer	Acute radiation symptoms	Moderate decrease in white blood cell count	Severe decrease in white blood cell count, Skin hemorrhage/blood spot, hemorrhage, infection, hair loss		Diarrhea, fever, fatal electrolyte imbalance
Death occurs within						2-12 weeks	1-6 weeks	<2-14 days
Cause of Death						Hemorrhage, Infection		Circulatory, respiratory collapse

56 See, for example, Atomicarchive.com (undated), "Nuclear Radiation," available as https://www.atomicarchive.com/science/effects/radiation.html

57 In this Report we have used a mixture of SI units (International System of Units) such as Sieverts, and non-SI units such as rem or pounds per square inch (psi) for overpressure. We do so because much of the literature on nuclear blast effects, and thus many of the examples of such effects, dates back to research commissioned by the United States military in the latter half of the 1900s, and we felt that retaining these units makes is easier to compare our methods and results with those from the older literature.

58 The online *Encyclopaedia Britannica* (2022), in https://www.britannica.com/technology/sievert, describes the sievert (Sv) as a "…unit of radiation absorption in the International System of Units (SI). The sievert takes into account the relative biological effectiveness (RBE) of ionizing radiation, since each form of such radiation—e.g., X-rays, gamma rays, neutrons—has a slightly different effect on living tissue. Accordingly, one sievert is generally defined as the amount of radiation roughly equivalent in biological effectiveness to one gray (or 100 rads) of gamma radiation." One Gray, in SI units, is the absorption of one Joule of radiation energy per kilogram of matter.

59 See also Atomicarchive.com (undated), "Radiation Effects on Humans", available as https://www.atomicarchive.com/science/effects/radiation-effects-human.html

60 Source of Table 4-3: Glasstone and Dolan (1977), ibid, Table 12.108, p. 580.

4.6 Radiation exposure from fallout

Radiation exposure to fallout comes from nuclear materials/contaminated debris sent airborne and deposited downwind by the nuclear detonation. Fallout exposure, measured in the same units and with the same overall health consequences per unit dose as those for prompt radiation, above, comes from a combination of materials suspended in the atmosphere (cloudshine) and materials deposited on the ground and other surfaces (groundshine). Airborne nuclear materials are transported by ambient winds and deposited as dry particles or combined with precipitation.

As is the case with prompt radiation, though with greater potential impacts due to the distances that airborne radiation from nuclear detonations can be transported, exposures above background levels, such as exposures below 5 rem/50 mSv may have limited health impacts but significant political impacts, particularly when international cross-border contamination is considered.

4.7 Delayed health effects from radiation exposure

In addition to the prompt lethal and near-lethal effects of high doses of radiation exposure described in Table 4-3, lower doses of radiation increase the risk of developing certain cancers, often many years or even decades after exposure. Tissues at the highest risk of developing radiation-induced cancers are bone marrow, female breasts, salivary glands, and the thyroid, while the bladder, colon, stomach, liver, lung, kidney, ovaries, and skin are at a moderate risk of radiation-induced cancer.[61] There is a statistical increase in cancer incidence in a population that has absorbed a radiation dose of at least 10 rem (0.1 Sv). Below 10 rem, the linear-non-threshold (LNT) model hypothesizes that there is also a per Sv increase in cancer incidence in a population. Whether or not, however, exposures below 10 rem increase the individual risk of radiation-induced cancer is a matter of continued debate.[62] In this project, it was assumed that radiation-induced cancer incidence can be estimated in populations that receive a dose of 10 rem or higher.

[61] See, for example, Fred A Mettler (2012), "Medical effects and risks of exposure to ionising Radiation," Journal of Radiological Protection. 32 (2012) N9–N13, available from https://pubmed.ncbi.nlm.nih.gov/22395124/

[62] The International Commission on Radiological Protection (ICRO) defines the Linear-non-threshold (LNT) model as "A dose-response model which is based on the assumption that, in the low dose range, radiation doses greater than zero will increase the risk of excess cancer and/or heritable disease in a simple proportionate manner." ICRP (2007), Annals of the ICRP PUBLICATION 103, The 2007 Recommendations of the International Commission on Radiological Protection, Editor J. Valentin, available as https://journals.sagepub.com/doi/pdf/10.1177/ANIB_37_2-4

5 Methods Used to Estimate Impacts of Nuclear Detonations

5.1 Introduction

The direct effects of nuclear weapons described in Section 4—prompt radiation, thermal fluence, overpressure, and fallout—and their physical impacts scale based on the yield, type of weapon, and the height of burst of the detonation. The extent of firestorms is determined by thermal fluence and conditions on the ground at the site of detonation. The level of radioactivity and distribution of fallout from each detonation depends on the detonation parameters and on weather conditions. For the most part, these impacts occur within seconds to days of the time of detonation, and have overlapping areas of effect, with the exception of biological radiation dose health effects from prompt and fallout radiation, which cause cancer over a period of years or decades.

To evaluate the potential consequences of five use cases, we first calculated the extent of various levels of impact for each detonation and displayed the results on maps. Then, population databases and geographic information systems (GIS) mapping software were used to estimate the number of people exposed to each level of physical impact. To estimate excess cancer risk and the number of resulting cancer deaths, a cancer incidence factor was applied based on the level of radiation exposure to the population.

Our primary objective has been to estimate the number of short-term deaths and the number of long-term radiation-induced cancer deaths resulting from the detonations in each use case. This grim task was undertaken to illustrate the significant impacts that nuclear conflicts, whether limited or extensive, would have on human populations and to show why the risks of such conflicts must be minimized.

In the rest of Section 5, the procedures used to quantitatively estimate the impacts of nuclear weapons on human populations are described. The section ends with a description of how the estimates of each impact were combined to yield a total estimate of likely deaths resulting from each of the use cases, the results of which are presented in Section 6.

5.2 Evaluation of thermal fluence impacts

The impact of thermal fluence from each nuclear detonation on victims in the blast area was evaluated in two steps: calculating the size of fluence "contours" relative to ground zero and estimating the populations within each contour.

The distances from ground zero of thermal fluence thresholds were calculated at 20, 15, 10, 5, and 3 cal/cm^2 using the declassified U.S. Defense Nuclear Agency (now the Defense Special Weapons Agency) "Weapon Effects Calculator" software.[63] This tool, released in 1984, was written to run under MS DOS, predating Windows. As a result, it requires an emulator such as "DOSBox" to run on a Windows operating system. A screenshot of the "Weapon Effects Calculator" opening screen is provided in Figure 5-1.

[63] This and other similar software tools are available from Nuclearweaponsarchive.org (undated), "Repository of Nuclear Effects Computer Simulations and Models," at https://nuclearweaponarchive.org/Library/Nukesims.html

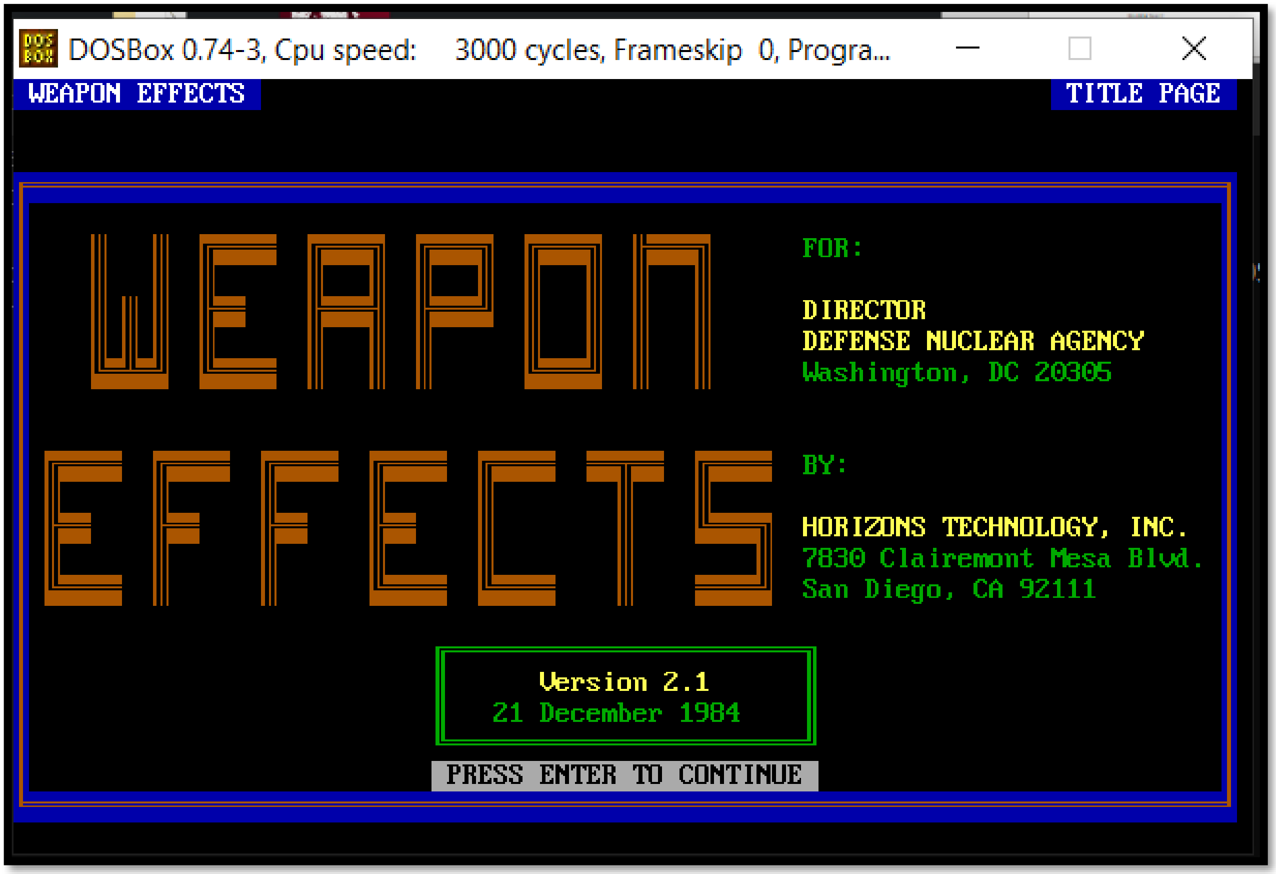

Figure 5-1: Opening Screen of Defense Nuclear Agency "Weapon Effects" Program.

The weapon yield, height of burst, visibility (in km), and thermal fluence values were entered into the Weapon Effects tool to back-calculate the corresponding "ranges" (distances from ground zero) for each detonation. Thermal fluence from nuclear detonations is attenuated when visibility is limited by humidity or particles in the air. A visibility of 10 km (10,000 meters) representing less-than-ideal visibility (which would be closer to 50 km) was assumed when calculating the range of each thermal fluence contour. Tests in selected detonations found that the difference in range between 10 km and 50 km visibility was relatively small—a few percent to about 20 percent lower for 10 km visibility than for 50 km. Lower visibility of 10 km was selected for all use cases, resulting in a slight underestimate of each thermal fluence range. The results of each "backward calculation" were plotted as circular thermal fluence contours on a Google Earth-based map projection using the open source "QGIS" GIS software.[64] Figure 5-2 shows an example of the projected thermal fluence contours on a satellite image of the target area.

[64] QGIS software is available from QGIS (2023), "QGIS: A Free and Open Source Geographic Information System," at https://www.qgis.org/en/site/

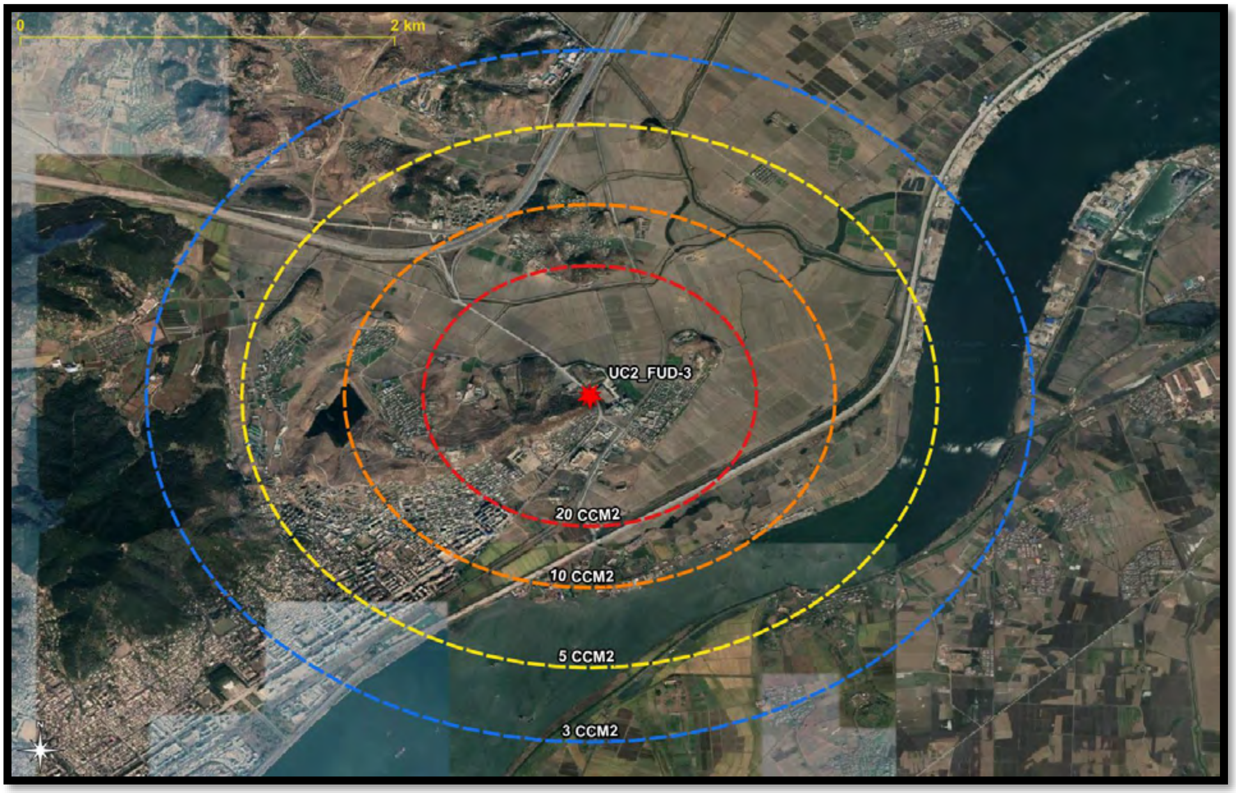

Figure 5-2: Example of Plot of Thermal Fluence Contours in QGIS: Use Case 2, First Use Detonation 3 (DPRK).

The population within each thermal fluence zone was counted in QGIS by overlaying the contour rings with the LandScan 2021 (landscan global-2021) and GPW (gpw_v4_population_count_rev11_2020_30_sec) population databases, each of which uses a global resolution of 30 arc-seconds.[65] The population estimates obtained using each database varied slightly from one detonation to another, up to around a factor of two. However, both population databases produced results consistently on the same order of magnitude. Final results were calculated using the LandScan 2021 database.

5.3 Evaluation of firestorm impacts

Of the two unspeakably horrific uses of nuclear weapons against the territory of a military adversary, only the nuclear bomb dropped on Hiroshima by the United States in 1945 resulted in the large-scale occurrence of a what is technically called a firestorm. Although much has been learned from that one example, despite many decades of research by nuclear weapons experts, the factors that predict whether a nuclear detonation will result in a firestorm are not thoroughly understood. Urban firestorms caused by the intensive use of thousands of conventional weapons

[65] LandScan data downloaded from Oak Ridge National Laboratory (ORNL, probably 2022), "LandScan Global," https://landscan.ornl.gov/. GPW data downloaded from Socioeconomic Data and Applications Center (SEDAC, probably 2021), "Gridded Population of the World (GPW), v4", available from https://sedac.ciesin.columbia.edu/data/collection/gpw-v4/sets/browse

in World War II have been studied as analogs to glean information on potential nuclear weapon-ignited firestorms, but they are an imperfect model.

What **is** clearly understood about nuclear weapons and firestorms includes the following:

- Above a certain level of thermal fluence from a nuclear weapon, many fires, and potentially mass fires, will almost certainly ignite almost immediately and concurrently in the area affected by a nuclear weapon, if the fuel exists to be burned. Whether those fires will coalesce into a firestorm depends on a number of factors related to the location and timing of the nuclear detonation, some of them not necessarily knowable in advance of an attack.
- In an urban environment, multiple fires ignited concurrently will grow into larger fires within 15 to 30 minutes.[66] These large fires will generate large volumes of rising air over the entire area. Rising air will in turn pull cooler air and more oxygen into the fire in its wake, further increasing the intensity of the fire.
- The radius of the firestorm will be self-limited by the potentially gale-force winds that will rush towards the fire from all sides.
- Once started, a firestorm will result in the destruction of everything within its perimeter, and, barring a small handful of miracles,[67] the death of everyone within the firestorm radius.

Considering these sobering characteristics, the potential impacts of firestorms resulting from nuclear detonations were estimated by attempting to discern whether a firestorm will occur, the range out to which it will spread, and how many victims will perish in the blaze.

The general consensus on the minimum conditions necessary to support a firestorm is discussed in the seminal 1977 work compiled by Glasstone and Dolan, which reads as follows:[68]

> "….Nevertheless, based on World War II experience with mass fires resulting from air raids on Germany and Japan, the minimum requirements for a fire storm to develop are considered some authorities to be the following: (1) at least 8 pounds of combustibles per square foot of fire area, (2) at least half of the structures in the area on fire simultaneously, (3) a wind of less than 8 miles per hour at the time, and (4) a minimum burning area of about half a square mile. High-rise buildings do not lend themselves to formation of firestorms because of the vertical dispersion of the combustible material and the baffle effects of the structures."

As definitive as the above sounds, it should be noted that the two sentences in Glasstone and Dolan immediately preceding the passage above acknowledge the considerable uncertainties:

> "…Apart from a description of the observed phenomena, there is as yet no generally accepted definition of a firestorm. Furthermore, the conditions, e.g., weather, ignition-point density, fuel density, etc., under which a firestorm may be expected are not known."

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[66] See, for example, United States Government Printing Office (1946), United States Strategic Bombing Survey: The Effects of Atomic Bombs on Hiroshima and Nagasaki, dated June 30, 1946, and available as https://docs.rwu.edu/cgi/viewcontent.cgi?article=1000&context=rwu_ebooks

[67] Some survivors of the firestorm following the bombing of Hiroshima, for example, survived in part by taking refuge in l the rivers that flow through the city; Atomicarchive.com, "Eyewitness Account of Hiroshima By Father John A. Siemes," available as https://www.atomicarchive.com/resources/documents/hiroshima-nagasaki/hiroshima-siemes.html

[68] Glasstone and Dolan (1977), ibid, pages 299 and 300.

Of the four conditions for firestorms described by Glasstone and Dolan, number (2) is easily satisfied for all of the detonations in our five use cases, as all include yields that are above the threshold where the radius of thermal fluence sufficient to ignite materials will produce a burning area of over a half a square mile (about 1.3 km^2) in extent. Similarly, by definition, the thermal fluence values above the threshold will ignite virtually all exposed burnable materials within that radius at once, satisfying Glasstone and Dolan's condition (4). Whether or not an ambient wind of 8 miles per hour (3.6 meters/second) is present (condition (3) will depend on the weather at the detonation site at the time, which can be estimated based on past weather patterns, but does not affect the **potential** for a firestorm to occur.

This account leaves condition (1), a fuel loading of 8 pounds of combustibles per square foot (about 39 kilograms per square meter), for further consideration. This threshold is a relatively high bar for the development of a firestorm. By comparison, a 1991 study of fuel loads in cities in the United States found that although residential and commercial buildings themselves had fuel loads at or above this level (123 to 150 kg/m^2 for residential buildings, and 39 to 273 kg/m^2 for non-residential), the average fuel load over an "average US urban area" ranged from 14 to 21 kg/m^2.[69] An average urban area would likely include relatively open space at its periphery, reducing the overall average, but even considering a reasonably dense suburb with houses covering one-third of their lot areas, plus streets and sidewalks, fuel loadings might well not reach 39 kg/m^2. Asian cities, which tend to be more dense on average than in the United States, might raise the potential for fuel loadings to be higher, but many Asian cities make more use of concrete and brick construction than is typical in the United States. Shifting to consideration of rural detonations, a minimum fuel loading of 39 kg/m^2 would all but eliminate the potential of firestorms in forests, as even the most dense forests barely reach that level of fuel loading.[70]

Although the Glasstone and Dolan conditions for firestorm formation are frequently quoted in other literature on nuclear weapon effects, the original source of the information is unclear. The source may well have been anecdotal. There is a large body of literature, however, on forest fires, that include descriptions of firestorm-like conditions—cyclonic winds and radial airflow in instances where fires converge in clusters.[71] These studies suggest that areas such as forests where fuel loadings are much lower than the 39 kg/m^2 indicated by Glasstone and Dolan, might equally be subject to firestorms, although it is not definitely known what the minimum conditions for a nuclear-caused firestorm should be. The fact that many large forest fires have been seen to create, in effect, their own weather through rising hot air masses above the flames,

[69] B. Bush, G. Anno, R. McCoy, R. Gaj, and R. D. Small (1991), "Fuel loads in U.S. cities," *Fire Technology*, 1991 Feb; 27(1):5-32, abstract available at https://pubmed.ncbi.nlm.nih.gov/10109450/

[70] See, for example, Raphaël Proulx, Guillaume Rheault, Laurianne Bonin, Irene Torrecilla Roca, Charles A. Martin, Louis Desrochers, and Ian Seiferling (2015), "How much biomass do plant communities pack per unit volume?" PeerJ 2015, 3: e849, published online 2015 Mar 19 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4369330/

[71] See, for example, Jason Sharples, James Hilton, Andrew Sullivan, and Rachel Badlan (2020), Fire Coalescence and Mass Spotfire Dynamics: Experimentation, Modelling and Simulation: Annual project report 2019-2020, dated 4/11/2020, REPORT NO. 625.2020m available as https://www.bnhcrc.com.au/sites/default/files/managed/downloads/nb13-sharples-ar-2019-2020_rt_0.pdf; the much older Clive M. Countryman (1964), *Mass Fires and Fire Behavior*, U.S. Forest Service Research Paper PSW-19, available as https://www.fs.usda.gov/psw/publications/documents/psw_rp019/psw_rp019.pdf; and Mark A. Finney and Sara S. McAllister (2011), "A Review of Fire Interactions and Mass Fires," *Journal of Combustion*, Volume 2011, Article ID 548328,14 pages, available as https://www.fs.usda.gov/rm/pubs_other/rmrs_2011_finney_m003.pdf

as a nuclear-caused firestorm would, suggests that the threshold for firestorms fuel loading could be significantly lower than the 8 lb/ft^2 (39 kg/m^2) value.

Navigating these uncertain criteria for firestorms, for the purposes of our analysis the following approach was used to estimate the number of deaths caused by firestorms for the five use cases presented in Section 6 of this Report:

- The radius of the **potential** firestorm zone for each detonation was assumed to occur within a thermal fluence threshold of greater than 15 cal/cm^2 for detonations with yields 50 kT and over, and greater than 10 cal/cm^2 for detonations of smaller yield.[72] Figure 5-3 shows an example of the estimated extent of a firestorm for one of the detonations in Evaluated Use Case 2.
- Weather conditions could affect firestorm formation, for example, when ambient winds are strong enough to prevent a firestorm from forming, or when snow on the ground or cloud cover multiplies thermal fluence, increasing the range from ground zero to which a firestorm perimeter could extend. We did not, however, attempt to make adjustments for potential weather conditions at the time of detonation.
- Satellite imagery of the target area for each detonation was examined to assess whether it seems possible that enough fuel is present to allow a firestorm to form. For example, detonations at desert locations, at other rural locations with highly varied topography and/or limited numbers of dwellings and biomass, at non-rural locations in which a substantial portion of the area of potential firestorm zone was covered with concrete (such as a large area of tarmac), and explosions wholly or mostly over water are assumed to result in no firestorm development. In general, nuclear detonation targets where firestorm development was assumed to be possible included built-up areas in at least portions of the targets, a large housing zone at least as dense as in a typical suburb, and/or significant fossil fuel stores, such as oil tanks.
- If a firestorm does form, effectively all of the population inside the firestorm zone will perish.
- The results presented in Section 6 acknowledge the uncertainty of firestorm formation by separating estimates of additional deaths due to firestorms—that is, deaths beyond those caused by other effects of each nuclear detonation—from estimates of deaths due to other nuclear weapons impacts.

Due in part to the large uncertainties associated with predicting firestorm occurrence and extent, nuclear weapon targeteers do not traditionally consider firestorm effects when planning nuclear attack strategies. The existence of uncertainties, however, does not mean that firestorm impacts are insignificant or negligible. On the contrary, we believe that simply ignoring firestorm impacts in an analysis of humanitarian consequences of nuclear conflict is irresponsible. In this analysis, an attempt was thus made to include an estimate of firestorm impacts in addition to the traditionally considered direct impacts.

[72] These thermal fluence limits for firestorms caused by weapons yields of different sizes were suggested by Theodore Postol, personal communication, 12-12-2022. The limit used for smaller detonations, 10 cal/cm^2, is roughly consistent with experience of areas where large numbers of fires were set in the bombings of both Hiroshima and Nagasaki.

Figure 5-3: Example Image of Potential Firestorm Zone (orange shaded area) in QGIS: Use Case 2, Response Detonation 2 (Yokohama, Japan).

5.4 Evaluation of blast overpressure impacts

The impacts of blast overpressure on the populations located near ground zero was, as with thermal fluence, evaluated in two steps: calculating the distances from ground zero affected by various overpressure thresholds, then counting the population within each contour.

The distances from ground zero of peak overpressure thresholds (that is, the highest overpressures experienced at each distance) were calculated at 10, 8, 5, 2 and 0.5 psi (in SI units, about 69, 55, 34, 14, and 3.5 kilopascals (kPa), respectively) using the declassified U.S. Defense Nuclear Agency (now the Defense Special Weapons Agency) "Weapons Effects Calculator" software.

For each detonation, the weapon yield, height of burst, and overpressure thresholds were input into the Weapon Effects Calculator and a backward calculation was run to output the distance from ground zero corresponding to each overpressure value. As with thermal fluence, the resulting circular contours of overpressure were plotted on a Google Earth-based map projection using the open source QGIS software.[73] Figure 5-4 shows an example of peak overpressure

[73] QGIS software is available from QGIS (2023), "QGIS: A Free and Open-Source Geographic Information System," at https://www.qgis.org/en/site/

contours mapped onto a satellite image of the target area. The largest contour (shown in blue) encompasses the area in which the blast wave will reach a peak overpressure of 0.5 psi or higher—enough to break the glass in windows and cause other minor damage.

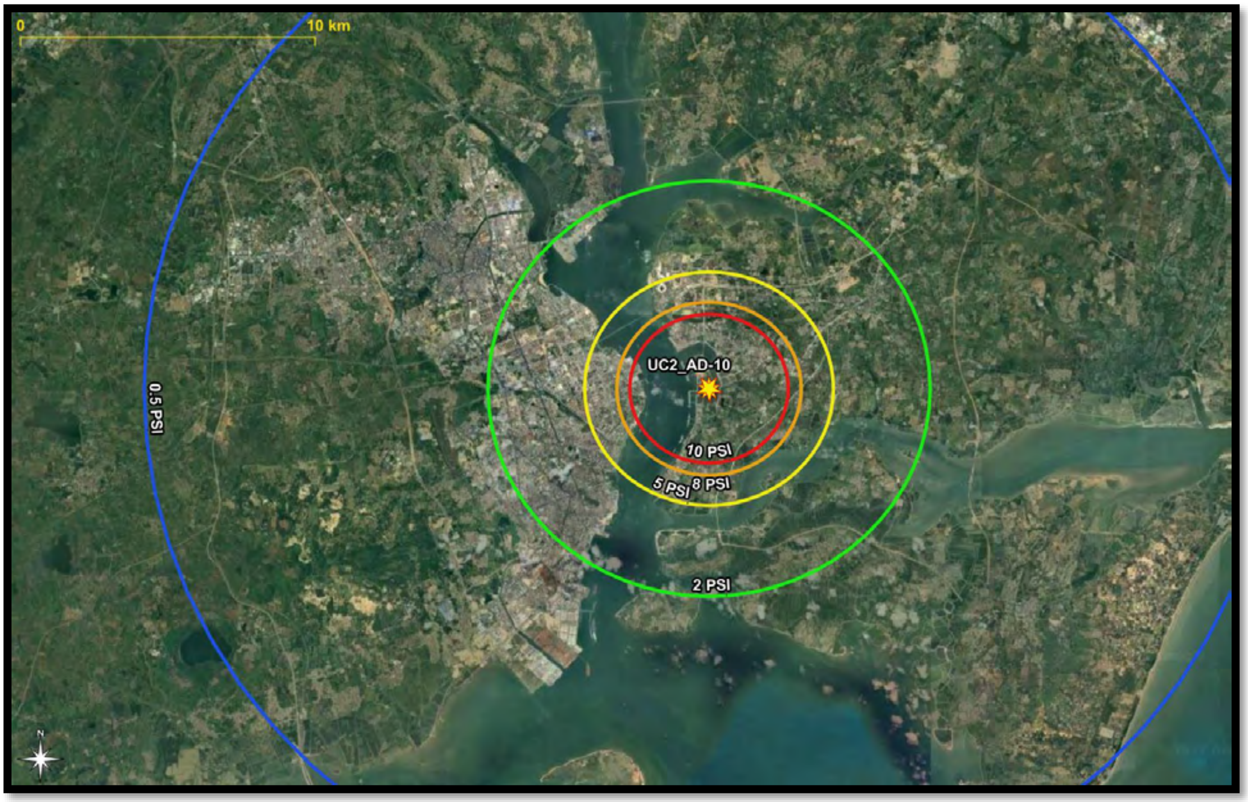

Figure 5-4: Example of Peak Blast Overpressure Contours Mapped in QGIS: Use Case 2, Additional Detonation 10 (South China).

5.5 Evaluation of prompt radiation exposure

The short and long-term health impacts on a population from prompt radiation doses, acquired instantaneously from the fission explosion itself, were evaluated in two steps: calculating the distances from ground zero corresponding to various radiation dose levels, then estimating the population within each zone.

The distances from ground zero of prompt radiation thresholds were calculated at 200, 100, 50, 25, and 10 rem (2, 1, 0.5, 0.25, and 0.1 Sv) using the declassified U.S. Defense Nuclear Agency “Weapons Effects Calculator” software.

For each detonation, the weapon yield, height of burst, weapon type (selected from 15 available options), and relative air density, and radiation dose thresholds were input into the software.

Since some kinds of radiation are attenuated in air, thus the exposure rate also depends on the air density. The relative air density was calculated using the formula

$$\text{Air Density} = e^{-\left(\frac{Altitude^{1.04}}{13000}\right)}$$

where the altitude of each target was estimated using Google Earth Pro. Then, a backward calculation was run to output the distance from ground zero corresponding to each radiation dose threshold. The resulting circular contours of prompt radiation exposure were plotted on Google Earth-based map projections using the open source QGIS software.[74] Figure 5-5 shows an example of radiation exposure contours mapped onto a satellite image of the target area.[75]

Figure 5-5: Example of Prompt Radiation Exposure Contours Mapped in QGIS: Use Case 2, Response Detonation 1 (Camp Humphries, ROK).

[74] QGIS software is available from QGIS (2023), "QGIS: A Free and Open-Source Geographic Information System," at https://www.qgis.org/en/site/

[75] Although the contours appear to be ellipses in this and later images, they are actually circular. The ellipse shape seen is an artifact of the distortion of the map itself at higher latitudes, the result of projecting the three-dimensional globe onto a two-dimensional image.

5.6 Evaluation of fallout radiation exposure

Simulations of nuclear fallout dispersion from the moment of detonation to four days after were conducted using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) Model,[76] and the resulting accumulated biological radiation dose to the exposed population was estimated. HYSPLIT results were postprocessed using Python, then contoured and analyzed according to the levels shown in Figure 5-6 using the free QGIS software described above. The population affected by each radiation dose level was estimated by overlaying the dose contours with the LandScan™ Global 2021[77] population dataset.

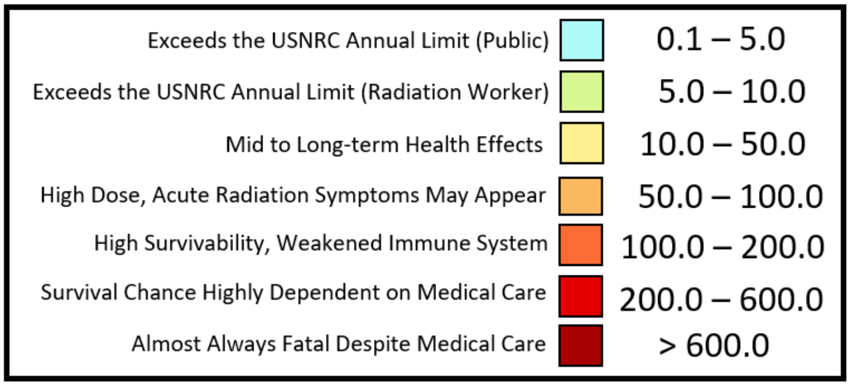

Figure 5-6: Biological Radiation Dose Levels (rem) Used to Visualize and Analyze HYSPLIT Simulation Results.

HYSPLIT is a general-purpose atmospheric transport model distributed by the U.S. National Oceanic and Atmospheric Administration's (NOAA) Air Resources Laboratory. One major limitation of HYSPLIT is its assumption of a stabilized cloud source. In reality, the dispersion of material following a nuclear weapon detonation is not stabilized, but constitutes hot, high-speed winds rising explosively in complex patterns. Current nuclear fallout codes that have been specifically developed by the US government have been found to be more accurate predictors of particle dispersion.[78] However, codes such as these that simulate more complex source terms have become government-classified and are no longer accessible to the public. Therefore, although there is a learning curve to using it, HYSPLIT has been selected for this project because it is a free and publicly accessible tool. Affiliation with a research or corporate organization may facilitate the acquisition of some files and resources for prospective users of HYSPLIT.

HYSPLIT can be used to simulate the forward or backward trajectories of pollutant dispersion based on a known input source or downwind measurement (in the case of an unknown source).

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[76] Stein, A.F., Draxler, R.R, Rolph, G.D., Stunder, B.J.B., Cohen, M.D., and Ngan, F., (2015). "NOAA's HYSPLIT atmospheric transport and dispersion modeling system," *Bull. Amer. Meteor. Soc.*, 96, 2059-2077, http://dx.doi.org/10.1175/BAMSD-14-00110.1

[77] LandScan 2021 downloaded from ORNL (2022), ibid.

[78] Jerrad P. Auxier, John D. Auxier, Howard L. Hall (2017), *Review of current nuclear fallout codes*, Journal of Environmental Radioactivity, Volume 171, Pages 246-252, ISSN 0265-931X, https://doi.org/10.1016/j.jenvrad.2017.02.010

The model includes a built-in function that converts ground or air concentrations to biological radiation dose, utilizing an input file that lists Becquerel (Bq) to rem (or Sv) conversion factors for a list of nuclear isotopes. The radiation dose conversion factor input file used in this analysis contains around 200 isotopes and is now provided by the October 2022 HYSPLIT tutorial on radionuclide applications.[79]

HYSPLIT uses real-world historical or forecast meteorological data in its particle dispersion simulation. Meteorological data were downloaded directly from the NOAA Real-time Environmental Applications and Display sYstems (READY) website,[80] the same website that provides HYSPLIT for public use. The Global Forecast System weather data,[81] which includes wind speed, direction, and precipitation information, was used with a grid resolution of 0.25-degree spatial intervals.

Several key assumptions were made to model the cloud of radioactive material produced by a nuclear detonation, known as the HYSPLIT "source term." In reality, the nuclear cloud attains its maximum height after about 10 minutes, continuing to grow laterally to a mushroom shape as it is dispersed by atmospheric winds.[82] In the HYSPLIT simulation, however, the source term (the cloud of radioactive materials) was modeled as a line source at its stabilized cloud height. A discussion on HYSPLIT fallout simulation assuming a stabilized nuclear cloud can be found in Rolph et al.[83] It is also necessary to define a particle-size distribution and altitude-dependent radioactivity distribution. These distributions were selected from the work done by Philippe et al.[84]

The simulation parameters used to run nuclear fallout simulations in this project are summarized in Table 5-1. Italicized and underlined values vary based on the detonation, and values from first-use detonations #2 and #3 from Use Case 2 are provided as an example. Figure 5-7 shows an example projection of HYSPLIT fallout contour results for a detonation in evaluated Use Case 2.

[79] Hysplit.com (undated); "Simulation of the Smoky Nuclear Test," available as https://hysplit.com/html/smoky_test.html

[80] NOAA Air Resources Laboratory (undated), "READY (Real-time Environmental Applications and Display sYstem)," available as https://www.ready.noaa.gov/index.php

[81] NOAA (undated), "Global Forecast System (GFS)," available as https://www.emc.ncep.noaa.gov/emc/pages/numerical_forecast_systems/gfs.php

[82] Glasstone and Dolan (1977), ibid, section 2.15.

[83] G.D Rolph, F. Ngan, and R.R. Draxler (2014), "Modeling the Fallout from Stabilized Nuclear Clouds using the HYSPLIT Atmospheric Dispersion Model*", Journal of Environmental Radioactivity*, Volume 136, October 2014, Pages 41-55 available as https://www.sciencedirect.com/science/article/pii/S0265931X14001453

[84] Sébastien Philippe, Sonya Schoenberger, and Nabil Ahmed (2022), "Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia," *Science & Global Security,* vol. 30, Issue 2 (2022), 1-33, available as https://doi.org/10.48550/arXiv.2103.06128

Table 5-1: HYSPLIT Simulation Parameters (*italicized, underlined* values are variable based on detonation)

Simulation Parameter	Surface-burst	Airburst
Meteorology Data	Global Forecast System (0.25 deg)	" "
Simulation Run Time	96 hours	" "
Weapon Yield	*8 kT*	" "
Detonation Date / Time	*2021 09 30 17 10 UTC*	*2021 09 30 18 00 UTC*
Ground Zero Location	*40.83, 128.56*	*38.96, 125.61*
Height of Burst (HOB)	0 m	*450 m*
# Cloud Layer Heights[85]	4	*Surface-burst heights raised by HOB
Source Release Duration	6 min	" "
Activity Distribution[86] (cap/skirt/stem)	0.775 / 0.15 / 0.075	0.9712 / 0.0283 / 0.0005
# Particle Sizes	100	" "
Particle Size Distribution / **Moment of Distribution**[87]	X ~ LogN (d=0.407 μm, σ=4) 2.5	X ~ LogN (d=0.150 μm, σ=2) 3
Particle Density	2.5 g/cm^3	4.8 g/cm3
Output Concentration Heights	0, 500 m	" "
Output Grid Resolution	0.05 deg	" "

[85] Specific height of each cloud layer was estimated based on Glasstone and Dolan Figure 9.96, "Altitudes of the stabilized cloud top and bottom as a function of total energy yield for surface or low air bursts," p. 431, and Philippe et al. at https://doi.org/10.48550/arXiv.2103.06128

[86] Philippe et al., "Radiation Exposures and Compensation of Victims of French Atmospheric Nuclear Tests in Polynesia," p. 24, https://doi.org/10.48550/arXiv.2103.06128

[87] Defense Technical Information Center (1979), DELFIC: Department of Defense Fallout Prediction System. Volume I – Fundamentals, Final Report 16, January -31 December 1979, available from https://apps.dtic.mil/sti/citations/ADA088367

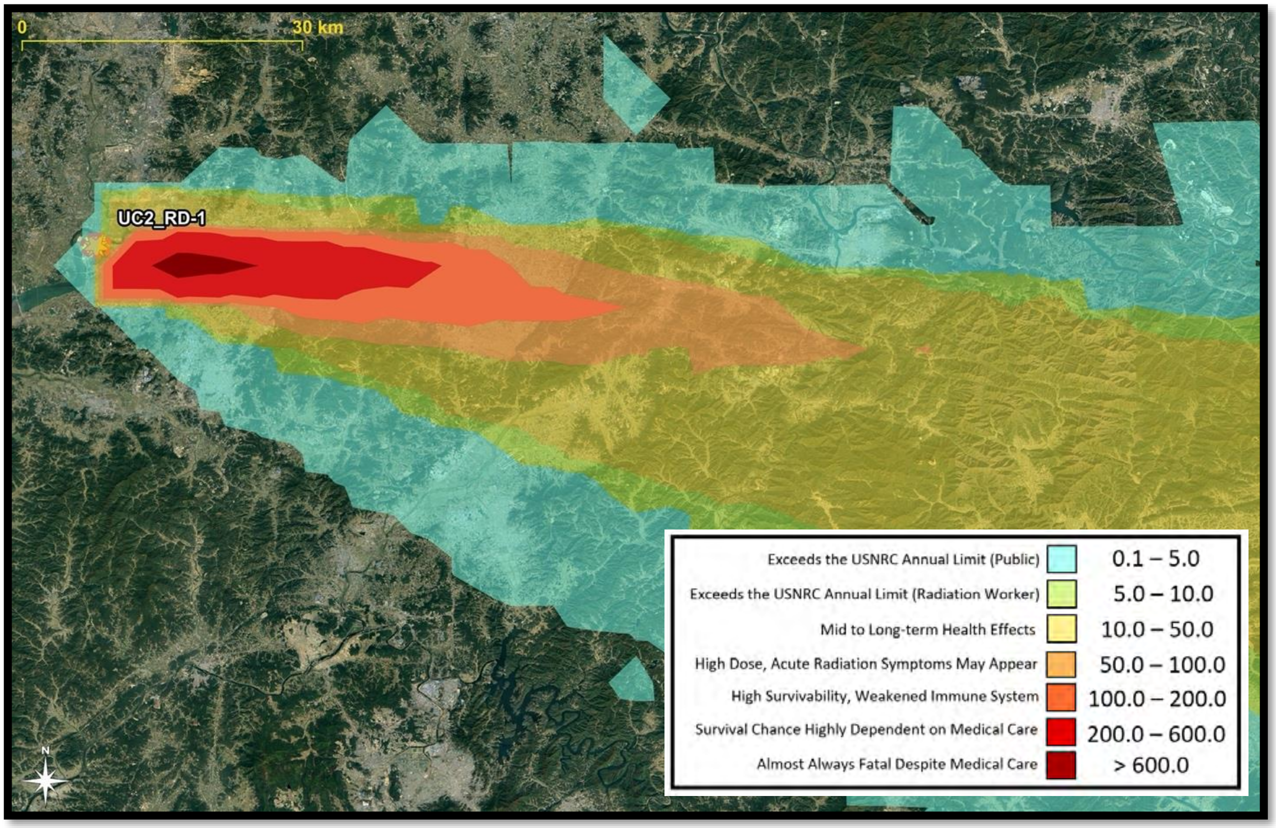

Figure 5-7: Example Fallout Radiation Exposure Map as Simulated using HYSPLIT and Projected in QGIS: Use Case 2, Response Detonation 1 (Camp Humphries, ROK).

HYSPLIT simulation results provide an indicative example of the direction and distance fallout from a nuclear detonation might travel and possible ground and air concentrations at the location of deposition. These results highly depend on weather conditions and can vary widely. Selecting the time of a nuclear attack that is just days or hours different may result in a decidedly different pattern of deposition, and different levels of radiation exposure to the populace. To gain a numerical understanding of the likelihood of fallout deposition patterns, many more simulations would need to be run. Thus, the HYSPLIT simulations in this report provide only an indicative example of what might happen under one real-world weather pattern.

5.7 Estimation of radiation-induced cancers from exposure to prompt and fallout radiation dose

Estimates of radiation-induced cancer deaths, defined as the number of additional cancer deaths in the lifetime of a population due to widespread exposure to nuclear radiation, were calculated based on the estimated exposure to prompt and fallout radiation and a statistical dose-response factor. Starting with the radiation dose contours and corresponding population estimates counted using the method described above, the number of long-term radiation-induced cancer deaths was estimated using the following method:

1. Counting the population within three exposure zones: 10–50 rem, 50–100 rem, and 100–200 rem (10 rem = 100 mSv). Both prompt and fallout radiation zones were considered if they were not already subsumed by a more deadly health effect.
2. Calculating an upper and lower estimate of the total dose received by the population in person-Sv. The upper estimate assumed dose exposures of 50, 100, and 200 rem in each zone, and the lower estimate assumed dose exposures of 10, 50, and 100 rem in each zone.
3. Multiplying the person-Sv values by 0.055—the estimated additional number of cancer deaths in a population per Sv —to estimate the number of radiation-induced cancer deaths in each exposure zone.[88]
4. Populations in radiation exposure zones below 10 rem were not included in the calculation of additional cancer deaths based on the assumption that "quantification of cancer risk at doses of less than 0.1 Gy [10 rem of gamma radiation] remains problematic."[89] We also do not estimate cancer deaths in populations exposed to over 200 rem (2 Sv) of radiation, as any acute dose above 200 rem is likely to result in short-term health complications leading to death before cancer develops.
5. Summing the radiation-induced cancer deaths estimated in step 3 over all prompt and fallout radiation exposure zones to yield the total number of estimated cancer deaths resulting from each nuclear detonation.[90]

5.8 Estimation of the aggregate impact of the effects of nuclear detonations

The detonation of a nuclear weapon would cause mayhem, destruction, injury, sickness, and death to those in the afflicted area. The distribution of physical, socioeconomical, financial, cultural, and political outcomes is uncertain and difficult to predict. Of the various metrics used to understand the consequences of a nuclear attack, the number of deaths is the most concerning to society and most physically understandable to policymakers. Therefore, an attempt has been made to develop a methodology to estimate the number of deaths resulting from the nuclear attacks in Use Cases 1 through 5.[91] Future work should also include more thorough discussions of the less quantitative but undeniably devastating effects of nuclear detonations on society.

Before describing our methods for combining each separate impact into one estimate of the total deaths resulting from each nuclear use, two points must be emphasized.

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[88] 0.055 (or 5.5 percent) additional cancer deaths per Sv of radiation exposure taken from Fred A Mettler (2012), "Medical effects and risks of exposure to ionizing radiation," Journal of Radiological Protection. 32 (2012) N9–N13, available from https://pubmed.ncbi.nlm.nih.gov/22395124/

[89] Fred A Mettler (2012), ibid.

[90] The protocol for estimating excess cancer deaths described here was prepared with much-appreciated assistance and input From Professor Noboru Takamura of Nagasaki University (personal communications, 1-27-2023).

[91] Using deaths not only does not capture all of the physical effects on the populations affected by nuclear detonations, but also does not capture the psychological and culturally annihilative effects of nuclear attack on survivors at Hiroshima and Nagasaki, effects described using the term "psychic numbing" by Robert Jay Lifton, in *Death in Life: Survivors of Hiroshima*, Random House, 1968.

First, for each of the individual impacts considered, the fraction of the population killed in the affected area by any level of prompt or fallout radiation exposure, by thermal fluence, by overpressure, or, in future decades, by cancer, is subject to many uncertainties. These uncertainties include (but are certainly not limited to):

- Weather, which can affect the impacts of a nuclear attack in many ways, from attenuating thermal fluence on foggy or hazy days to amplifying it when clouds or snow is present, to preventing the formation of firestorms when it is windy, but potentially fanning the flames of fires set by thermal fluence and from fuel sources within blast-affected areas. Weather patterns also affect where fallout is deposited via rain or wind and can impede efforts to rescue and provide medical care for survivors. The weather on the day of the nuclear attack may make populations more or less vulnerable by affecting where they are at the time of the nuclear explosion, and thus how exposed or protected they are.
- The degree to which a target is destroyed by overpressure and thermal fluence at any given distance from ground zero depends on how resilient the infrastructure is to those forces, which in turn affects the survivability of those protected (or not) by resilient infrastructure.
- Where fires will ignite, which affects both mortality and the ability of blast victims to escape to safer locations, and uncertainty as to whether a large-scale firestorm will develop and where it will spread.
- The organization or lack of emergency services in the immediate aftermath of a detonation. The availability and timeliness of medical care will in part determine whether victims of the immediate attack will survive their wounds. The ability of emergency responders to access the affected area from surrounding towns, provinces, and even countries may be impeded by ongoing conflicts.
- The affected population's ability to use intended or impromptu shelters to shield themselves from overpressure, thermal fluence, and radiation exposure, which will also have a significant impact on survival chance.
- The fraction of survivors who will succumb to their injuries or secondary health impacts such as infections in the days, weeks, or months following the initial attack.

Second, since the impacts of nuclear detonations have overlapping areas of effect, the numbers of deaths resulting from each individual impact are not additive. Specifically, as prompt radiation exposure, thermal fluence, and overpressure are concentric with ground zero of the detonation, substantially overlapping, the impacts of those three effects cannot be simply summed to yield total deaths from all three. Instead, each of the three impacts contributes to reducing victims' survivability. If a firestorm occurs, there will be essentially no survivors within the radius of the firestorm. If the firestorm radius exceeds the lethal radius of other impacts, as in many high-yield weapon detonations, the deaths from firestorms will subsume most or all of the deaths from other impacts. Radiation doses acquired from fallout primarily do not overlap with other impacts, mostly occurring outside the range of prompt radiation, thermal fluence, and overpressure. Therefore, except in instances where the zones of highest fallout overlap the lethal zones of other impacts, fallout deaths are additive to prompt deaths. Radiation-induced cancer deaths, occurring years or decades after the detonation, are also additive to total short-term deaths from other effects.

Considering these uncertainties and overlapping impacts, the number of "likely deaths" resulting from nuclear detonations in each Use Case was estimated under the following assumptions:

1. A lethal prompt and fallout **radiation dose** threshold of 200 rem (2 Sv) was assumed. The survivability of victims exposed to 200 rem of radiation or higher greatly depends on prompt and ongoing access to quality medical care, and the availability of medical care following a nuclear attack is difficult to predict.
2. The lethal threshold of **thermal fluence** was assumed to be 20 cal/cm^2. For exposed individuals, this level of thermal fluence will produce third degree burns even through many types of clothing, and will cause most combustible materials to ignite, meaning that even those sheltered from exposure to the initial pulse of heat will likely be trapped by fire.
3. The 100% lethal **peak blast overpressure** threshold was assumed to be 5 psi, which is sufficient to destroy wood-framed buildings and severely damage most other buildings. Individuals not trapped in buildings as they collapse may be injured or killed by flying debris and subject to fires that ignite when electrical lines, gas piping, or vehicles are damaged. In addition to the severe damage zone (5 psi), a death rate of 14% prompt and 18% short-term was considered in the moderate damage zone (2 psi) and 8% / 14% in the light damage zone (0.5 psi).[92] It was assumed that all victims suffering serious injuries and requiring hospitalization would succumb to their wounds within a year of the attack due to a combination of physical injuries, burns, and radiation dose exposure, lack of survival morale, and insufficient medical care.
4. For targets where a **firestorm** is considered possible, it was assumed that 100% of the population within the firestorm zone, estimated as in Section 5.3, would perish.
5. Total estimated likely deaths were calculated in several steps, as summarized in Figure 5-8. First, prompt and short-term deaths due to thermal fluence, overpressure, and prompt radiation levels were calculated based on the procedures shown in Figure 5-9. Then, for locations where a firestorm is likely, the 100% lethality firestorm zone was inserted, and population counts in other zones adjusted accordingly.
6. Next, if the range of 10 – 200 rem prompt radiation exposure was greater than any 100% lethality zone, low and high estimates of the number of long-term radiation-induced cancer deaths were calculated without adjusting for the impact zone overlap with moderate and light damage zones. Finally, short-term deaths due to high doses of fallout radiation and long-term radiation-induced cancer deaths occurring outside of the 100% lethality zones were estimated using the methods described in Section 5.7.
7. For each use case, we summed the total estimated prompt and short-term deaths for each detonation, calculated as above, and separately listed the number of estimated deaths added due to the occurrence of firestorms. The estimated number of short-term deaths resulting from fallout radiation and cancer deaths are also reported separately.

[92] Glasstone and Dolan (1977) ibid, Table 12.21, "Casualties in Reinforced-Concrete Buildings in Japan Related to Structural Damage."

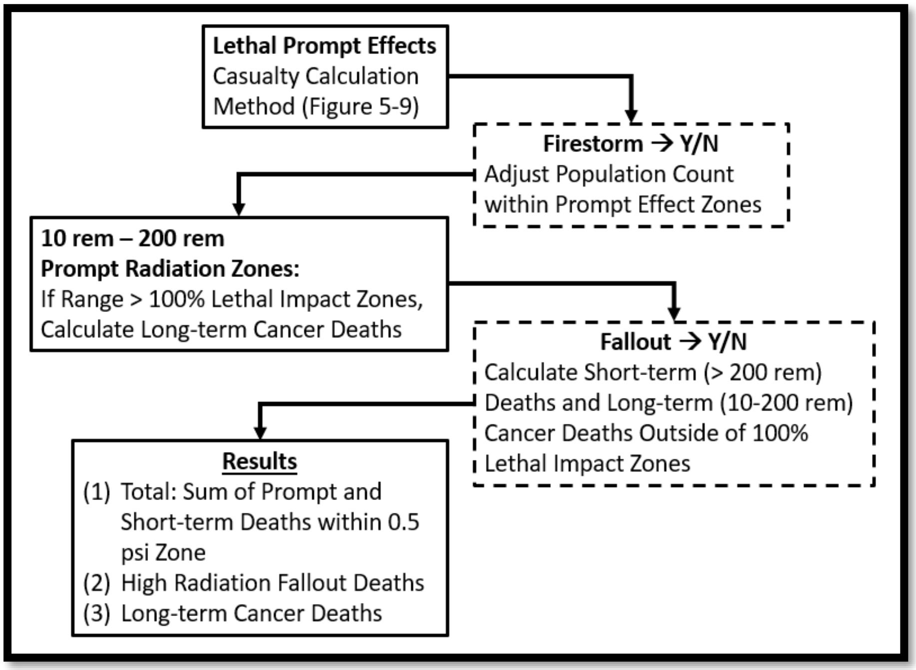


Figure 5-8: Overall Calculation Flow to Estimate the Fatalities caused by Nuclear Detonations.

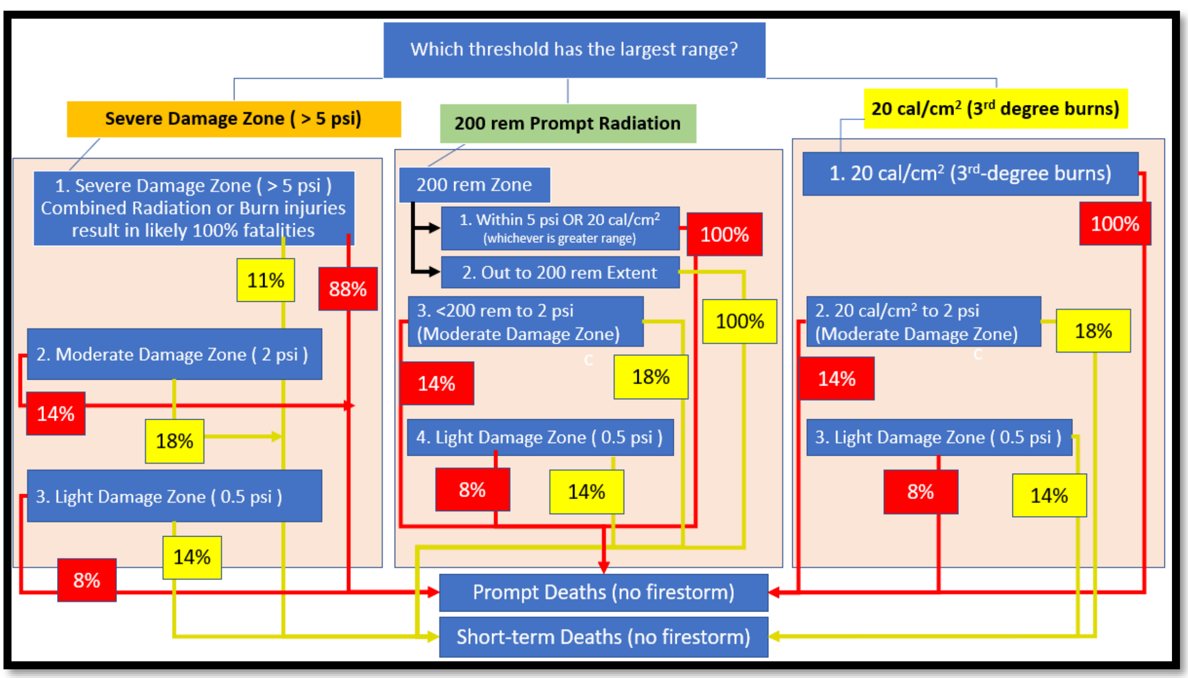


Figure 5-9: Nuclear Detonation Fatality Estimation Method based on Blast Overpressure, Prompt Radiation, and Thermal Fluence.

6 Estimated Fatalities Due to Nuclear Detonation Impacts

This section presents the simulation results of evaluated Use Cases 1 through 5. For each use case, the number of prompt, short-term, and cancer fatalities resulting from nuclear detonation impacts was estimated. Tables of key inputs and summarized narrative descriptions of each use case are provided, followed by maps and tables depicting the quantitative results of the simulations. Detailed narratives illustrating the evolution of each use case are included in Annex 2. Finally, this section provides overviews and discusses implications of the estimated impacts of each use case. More detailed results, including analytical descriptions of individual detonations, are provided in Annex 3.

6.1 Use Case 1: "We're Still Here"

In this use case, the DPRK, facing internal and external economic pressures, undertakes what can be thought of as a "demonstration" nuclear attack on a small ROK coastal community for the main purpose of driving the United States, the ROK, and the international community to the bargaining table. To retain consistency with a policy of using nuclear weapons only in defense, it is possible that the DPRK justifies the attack by contending that the ROK community was host to an ROK Navy or Coast Guard contingent that has transgressed into DPRK territory and threatened DPRK citizens. Spurred by the ROK, the United States responds using conventional weapons to mount an attack on the DPRK's artillery units near the DMZ and two low-yield nuclear weapons on buried targets thought to conceal ICBMs and other nuclear assets capable of threatening the United States and its allies. Further nuclear conflict is averted by intensive diplomacy. Table 6-1 lists the key parameters used to model the detonations in this use case.

Table 6-1: Use Case 1 Nuclear Detonation Parameters[93]

Use Case	**"We're Still Here" V1**					
First User	DPRK					
First Use Targets	Village on ROK East Coast					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	128.430	700	10	Fission	KN-23	14:00
First Responder	United States					
First Response	Nuclear missile bases in DPRK					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	39.662, 125.347	0	8	2-stage H bomb	SBN W76-2	2/16/2023, 03:00
#2	128.555	0	8	bomb	2	03:00

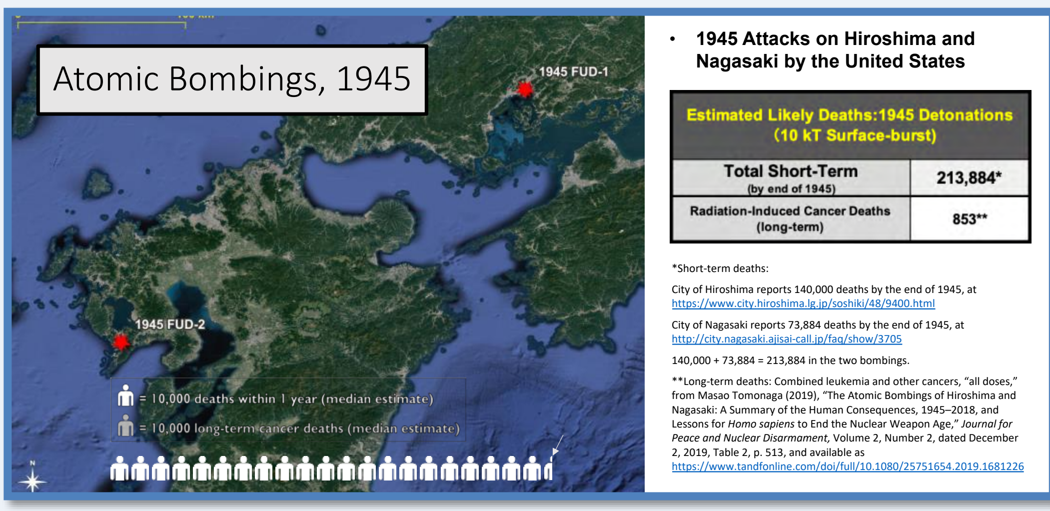
[93] In this Table and similar tables for each use case presented in this section, "Date and Time of Attack" is given as the local time at each target.

Figure 6-1 summarizes the results of the Use Case 1 simulation. Even though the targets are fairly remote, far from population centers, and the exchange of nuclear weapons is limited to three detonations, it was estimated that approximately 5,500 people would be killed within days or weeks of the attack, with another 5,600 victims within the following year. An estimated 16,000 to 36,000 could be victims of radiation-induced cancer death in the decades that follow, due to fallout radiation exposure.

In this use case, the occurrence of firestorms is unlikely due to the remote location of each detonation. The first nuclear weapon is detonated offshore by the DPRK. Much of the affected area around ground zero is covered by ocean, where the occurrence of a firestorm is not possible. The areas around the other two detonations are characterized by low to medium-density forests and fields over rugged terrain, likely insufficient to fuel the development of a firestorm. However, forest fires are probable.

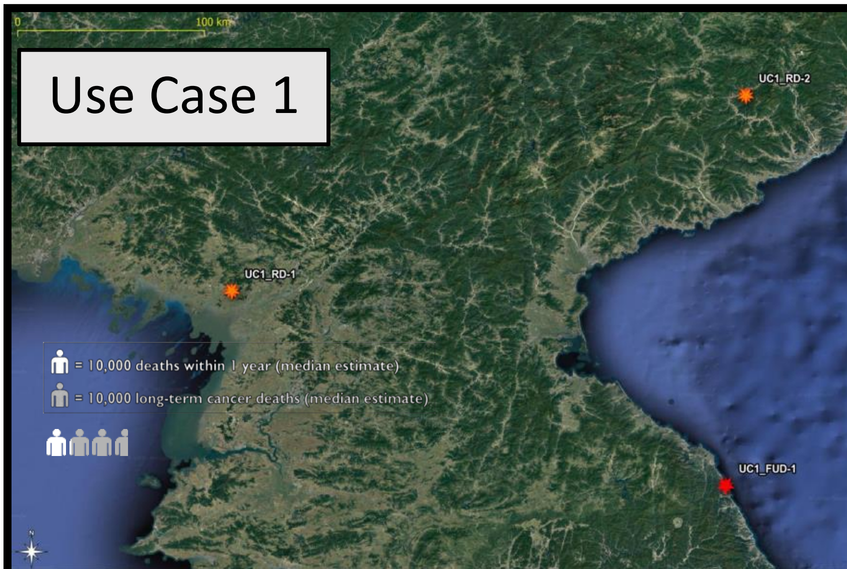
Out of the 41,000 people living within the 0.5 psi overpressure zones of the detonations included in this use case, roughly 11,000 or 27% are likely to die within the year following the attack. In some cases, survivability is highly dependent on medical care and hospital capacity.

A note about the person icons in the figures that follow in this section:



To help readers quickly grasp the magnitude of calamity represented by the nuclear explosions in the illustrated use cases, we have added icons to images in this section showing, at a glance, the median estimated deaths projected in the first year after the use of nuclear weapons (white icons), and over the longer term from nuclear-induced cancers (grey icons). The purpose of these icons is to give the reader an impressionistic sense; for more-specific figures, see the tables and text.

The figure shown above as an example illustrates estimated numbers of deaths from the Hiroshima and Nagasaki bombings on August 6 and 9, 1945. The white icons represent 213,884 deaths within one year (21⅓ icons, each representing 10,000 deaths) and the small grey sliver of the rightmost icon (arrow) represents 853 long-term cancer deaths. *These figures are very rough approximations,* but should give a sense of how the deaths projected in various use cases discussed in this report compare with the scale of the Hiroshima and Nagasaki bombings.



- Attack by DPRK on remote ROK target
- Response Detonations by US on DPRK nuclear targets
- Further attacks prevented by intensive diplomacy, restraint by other nuclear powers

Estimated Likely Deaths: Use Case 1 (8-10 kT)	
Prompt (days to weeks)	5,500
Short-Term (weeks to months)	5,600
Additional Impact: Firestorms	Firestorm Unlikely
Total (0.5 psi Zone) (Total Pop., % Lethality)	**11,000** (41,000, 27%)
High Radiation Fallout Dose (short-term)	Low Fallout
Radiation-Induced Cancer Deaths (long-term)	16,000 - 36,000

* In this figure and those that follow, "Estimated Likely Deaths" denotes populations within impact zones where one or more impacts will be lethal. These counts include "prompt" deaths that occur within days or weeks, and "short-term" deaths within about one year from injuries sustained as a result of detonations, but do not include deaths from additional eventual cancers caused by radiation (the latter are listed separately). Individual impacts may not add up to the exact Total shown due to rounding.

Figure 6-1: Targets, Estimated Likely Deaths, and Estimated Cancer Deaths Resulting from Use Case 1, All Detonations.

Figure 6-2 depicts the fallout resulting from detonations in evaluated Use Case 1. Winds carrying the radioactive particles to the southeast of the two detonations in the DPRK cause significant exposure to radiation in the affected populations. There is no fallout from the first detonation on the east coast of the ROK due to the relatively low yield of 10 kT detonated at a relatively high height-of-burst (HOB) of 700 meters. To limit the simulation time, the longitudinal range simulated was limited. In reality, the fallout appears to spread even further into northern Japan than depicted in Figure 6-2.

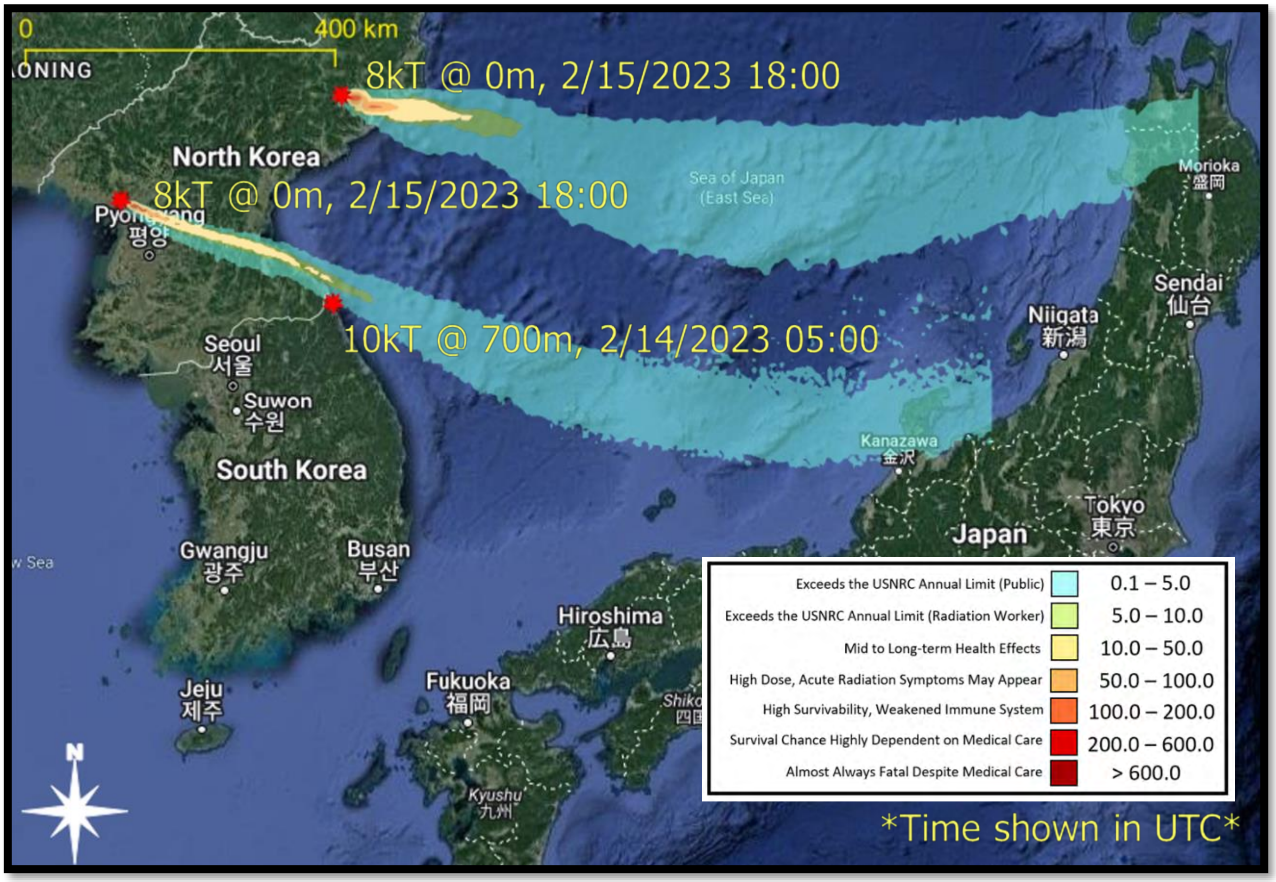


Figure 6-2: Nuclear Fallout Simulation Results for Use Case 1, Radiation Dose Units in rem.

Even though short and long-term health impacts, including estimated cancer deaths, are limited to the Korean Peninsula, the fallout simulation shows that if relatively low-yield weapons (8 kT) are detonated at surface-level on the Korean Peninsula, significant levels of fallout may spread across the East Sea and be detected as far away as northern Japan. People in some regions may acquire a radiation dose exceeding 0.1 rem, the United States Nuclear Regulatory Commission (USNRC) Annual Radiation Dose Limit to the Public, within four days.

Although there will likely be no direct health impacts resulting from this low level of exposure, Use Case 1 may have significant political impacts in Northeast Asia by dragging Japan, Russia, and China into the conflict over concern about nuclear fallout levels. Residents of the ROK may fear that nuclear fallout from American attacks has inadvertently spread into their country as well, causing critics to lose faith in the benefits of the "nuclear umbrella" or even any alliance with the United States. In addition, since the attacks by the United States resulted in cross-border nuclear fallout but the attack by the DPRK did not, this could be seen as a political victory for the DPRK, smearing the United States' international reputation.

<u>Use Case 1 Implications</u>: Even if relatively low-yield, nuclear weapons detonated on or near the surface can result in international cross-border nuclear fallout, unintentionally dragging allies and adversaries into the conflict, which can have severe political consequences, decrease trust in alliances, and spread fear in members of the public due to a lack of understanding of nuclear fallout and the biological effects of radiation.

6.2 Use Case 2: "US Leadership Hubris"

In this use case, overconfidence—in both offensive nuclear weapons capabilities and missile defense systems—on the part of the US president and the advisors that surround him or her, plus political pressures at home, leads the president to order, and the United States to mount an attack on the DPRK's nuclear and missile systems using conventional and nuclear weapons, with only partial success. The United States is thus the party to use nuclear weapons in this use case.

The DPRK responds with a nuclear missile attack on a US base in the ROK, and DPRK Special Forces attack mixed industrial targets in the Incheon (ROK) and Yokohama (Japan) areas with hand-carried nuclear devices.

The United States counters with additional nuclear attacks on DPRK nuclear and leadership targets, causing China to attack US bases in the region, followed by additional US and Chinese attacks on key military installations in each country. In total, 18 nuclear weapons are detonated in Use Case 2, the parameters for which are shown in Table 6-2.

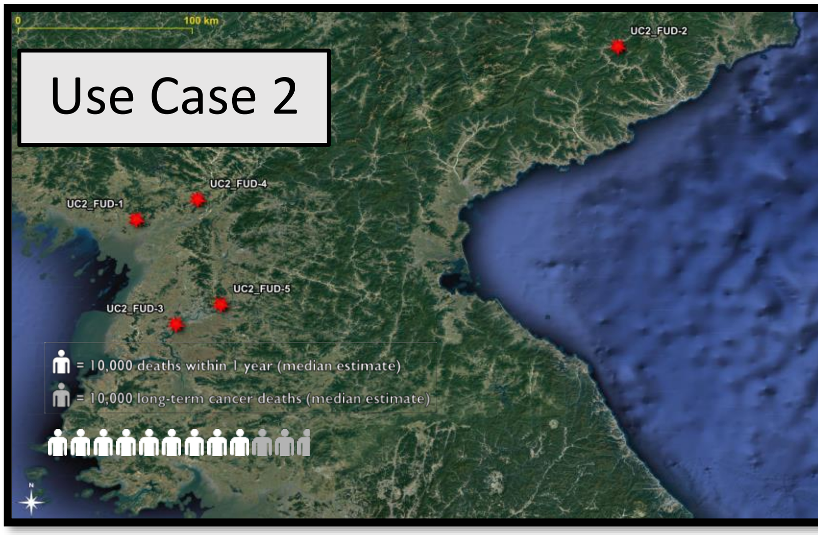
Table 6-2: Use Case 2 Nuclear Detonation Parameters

Use Case	**"US Leadership Hubris"**					
First User	United States					
First Use Targets	DPRK Nuclear Facilities					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	39.662, 125.347	0	8	2-stage H bomb	SBN W76-2	10/1/2026, 02:00
#2	40.8266, 128.555	0	8	2-stage H bomb	SBN W76-2	10/1/2026, 02:10
#3	38.957, 125.611	450	8	2-stage H bomb	SBN W76-2	10/1/2026, 3:00
#4	39.798, 125.755	450	8	2-stage H bomb	SBN W76-2	10/1/2026, 02:20
#5	39.09, 125.91	450	8	2-stage H bomb	SBN W76-2	10/1/2026, 3:10
First Responder	DPRK					
First Response Targets	US Bases and ROK/Japan Infrastructure Targets					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	36.974, 127.002	0	20	Fission	KN-23	10/1/2026, 06:00
#2	35.409, 139.630	0	10	Fission	ship	10/7/2026, 02:00
#3	37.4463, 126.607	0	10	Fission	Overland or ship	10/7/2026, 02:30
Additional Detonations	US Attacks on Pyongyang, ICBM Exchange with China					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	39.113, 125.864	-5	50	2-stage H bomb	B61-12	10/14/2026, 03:00
#2	39.124, 127.430	-5	50	2-stage H bomb	B61-12	10/14/2026, 03:10
#3	26.525, 128.046	1300	200	2-stage H bomb	DF-21 (MRBM)	10/15/2026, 04:00
#4	26.356, 127.77	1300	200	2-stage H bomb	DF-21 (MRBM)	10/15/2026, 04:10
#5	61.253, -149.77	1500	300	2-stage H bomb	DF-31 (ICBM)	10/14/2026, 11:00
#6	44.144, -103.08	1500	300	2-stage H bomb	DF-31 (ICBM)	10/14/2026, 14:30
#7	36.96, -76.3	1500	300	2-stage H bomb	DF-31 (ICBM)	10/14/2026, 15:40
#8	36.513, 103.606	1500	300	2-stage H bomb	W87 (ICBM)	10/16/2026, 03:00
#9	40.625, 115.117	1500	300	2-stage H bomb	W87 (ICBM)	10/16/2026, 03:10
#10	21.231, 110.445	1500	300	2-stage H bomb	W87 (ICBM)	10/16/2026, 03:20

Figure 6-3 through Figure 6-5 illustrate the results of the Use Case 2 simulation. Figure 6-3 shows the results after the first-use detonations, Figure 6-4 shows the cumulative results after the response detonations, and Figure 6-5 shows the results following all attacks.

The first-use detonations by the United States are unlikely to result in firestorms. Although individual fires will destroy forests and residential areas, the areas around ground zero in each case are mostly fields and sparse forest with few buildings. The overall density of this kind of terrain is likely too low to fuel a firestorm. Special consideration, however, must be given to the attack on Yongbyon, a DPRK nuclear fuel cycle facility. Depending on the kind of materials stored at the facility, fires occurring at the Yongbyon site may release additional radioactive emissions. These emissions were not considered in this simulation but should be considered by future work.

Most of the fatalities caused by the first-use attacks in Use Case 2 result from high levels of prompt radiation in the case of low-yield surface-bursts, or by far-ranging blast overpressure effects causing building damage and collapse in the case of airbursts.



- **First-Use Detonations by the US on DPRK Nuclear Arsenal and Supporting Infrastructure**

Estimated Likely Deaths: Use Case 2 First-Use Detonations (8 kT)	
Prompt (days to weeks)	42,000
Short-term (weeks to months)	42,000
Additional Impact: Firestorm	Firestorm Unlikely
Total (0.5 psi Zone) (Total Pop., % Lethality)	84,000 (290,000, 29%)
High Radiation Fallout Dose (short-term)	0 - 12,000
Radiation-Induced Cancer Deaths (long-term)	17,000 - 34,000

*Individual impacts may not add up to the exact Total shown due to rounding.

Figure 6-3: Targets, Estimated Likely Deaths, and Estimated Cancer Deaths Resulting from Use Case 2, First Use Detonations.

Response detonations by the DPRK include industrial targets that are in or near population centers, resulting in a drastic increase in the death toll of the conflict. Following the five first-use detonations, 84,000 people are killed by prompt effects. After three response detonations, the total death toll of the use case reaches an estimated 400,000 within one year, more than four times higher. Additionally, since the response detonations are detonated at surface-level, a significant number of additional fatalities may result from exposure to high doses of nuclear fallout radiation within hours to days following the attack. In the previous attack phase, up to 12,000 people are exposed to fatal levels of fallout radiation. Following the response detonations, 11,000 to 1 million people may acquire a fatal radiation dose from fallout. The long-term cancer deaths in populations affected by the response detonations could also increase by an order of magnitude due to fallout, from an estimated 17,000 to 34,000 cancers to 400,000 to 670,000 cancers.

Firestorms will likely result from two of the detonations in this phase of the conflict, although due to the far-ranging effects of prompt radiation associated with low-yield surface-bursts, radiation effects have the most significant impact on the number of fatalities in these attacks. Nevertheless, some of the areas around ground zero in these two detonations include dense housing and infrastructure, large fuel tanks that could explode, and enough fuel debris from overpressure damage that a firestorm could ignite secondary fires even outside the firestorm zone, eliminating any chance of survivability within the area of urban devastation and hindering search-and-rescue efforts.

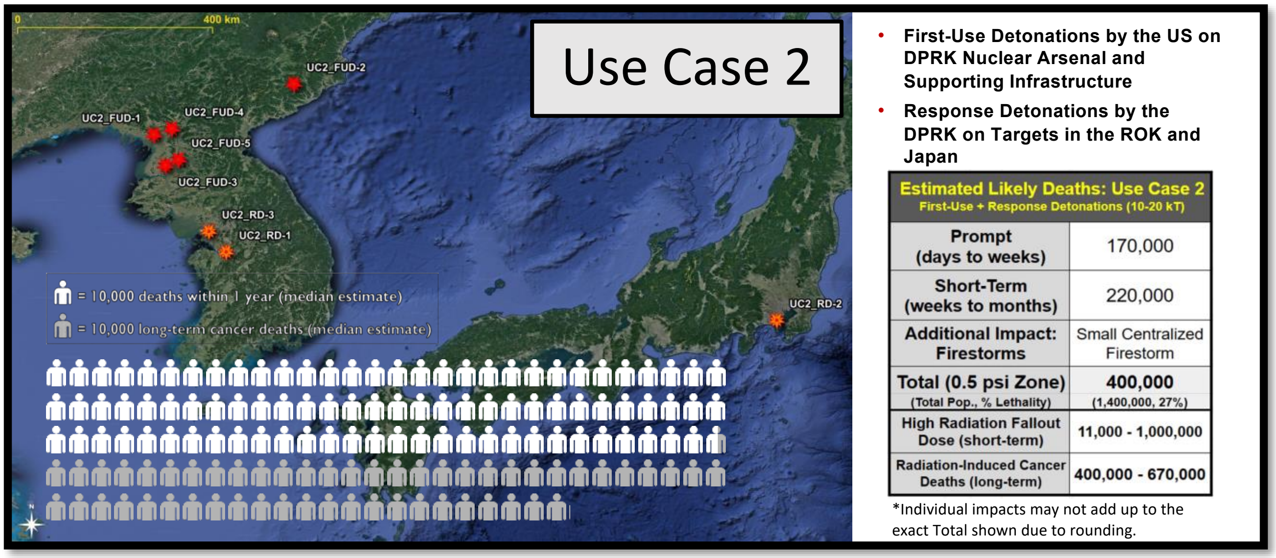


Figure 6-4: Targets, Estimated Likely Deaths, and Estimated Cancer Deaths Resulting from Use Case 2, First Use and Response Detonations.

Ensuing attacks in the escalating conflict affect the DPRK, mainland China, Okinawa, and the United States. Whereas previous detonations were limited to lower-yield surface-bursts, the ten additional nuclear weapons detonations in the escalating conflict are higher yield (200-300 kT) airbursts and 50 kT sub-surface attacks on buried targets (simulated as surface bursts). In the aftermath of the sub-surface bursts, nuclear fallout radiation, blast overpressure, and prompt radiation will have the most significant impact. In the case of high-yield airbursts, thermal fluence and large firestorms increasingly dominate as the primary cause of death. This effect can be observed in the results of the additional weapons detonations in Use Case 2. Even though the number of fatalities due to absorbed radiation doses do not increase by much in this phase of Use Case 2, the number of fatalities quintuple from 400,000 to 2.1 million, due to the impact of prompt thermal fluence and firestorms.

Firestorms will likely occur in five out of ten of the additional detonations in this use case, due to the proximity of built-up areas to ground zero in those detonations. Extensive residential areas nearby become fuel for raging firestorms when destroyed by the blast itself, and the possibility of secondary fires spreading outside the firestorm zone is significant in several cases. Several of the detonations occur on the coastline, where the firestorm zone will be limited by geography to the land areas affected by the detonations. This means that the estimate of firestorm impact in Use Case 2 could be underestimated. If the targets were further inland, the firestorm impact could be much more significant.

Due to the outsized impact of high-yield thermal fluence and firestorms, not only does the number of estimated fatalities increase, but also the relative impact of the destruction becomes greater. Following the first-use detonations in Use Case 2, around 29% of people in the 0.5 psi overpressure zone are killed; following the response detonations, around 27% are killed. As the conflict continues to escalate, the percentage of people killed within the 0.5 psi zone increases to 33% in Use Case 2, demonstrating the significance of firestorms in increasing the lethality of nuclear weapons. The impacts of firestorms can also be observed clearly in the results of Use Case 4 and Use Case 5, as explained later in this section.

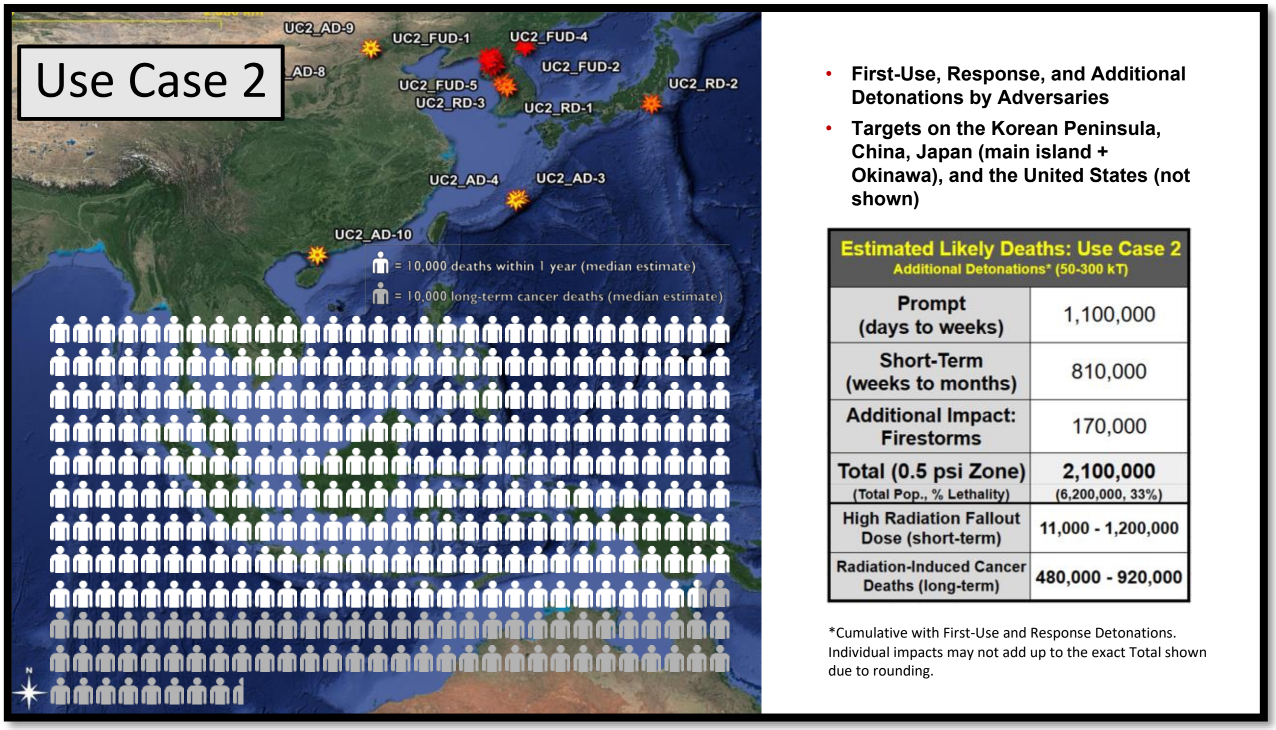


Figure 6-5: Targets, Estimated Likely Deaths, and Estimated Cancer Deaths Resulting from Use Case 2, All Detonations.

Figure 6-6 shows the deposited fallout contamination resulting from Use Case 2, escalating through each phase. When all nuclear detonation impacts are considered, up to approximately one-half of all fatalities could be caused by nuclear fallout radiation, one-quarter due to acute radiation effects and death within one year of the attack, and one-quarter due to radiation-induced cancer. The fraction of overall deaths due to fallout is highly uncertain and sensitive to prevailing weather patterns and the movement of affected populations within hours or days of the attack. The results of this simulated use case, however, show that nuclear fallout, although difficult to predict, can greatly increase the death toll and economic and societal impacts of a nuclear war.

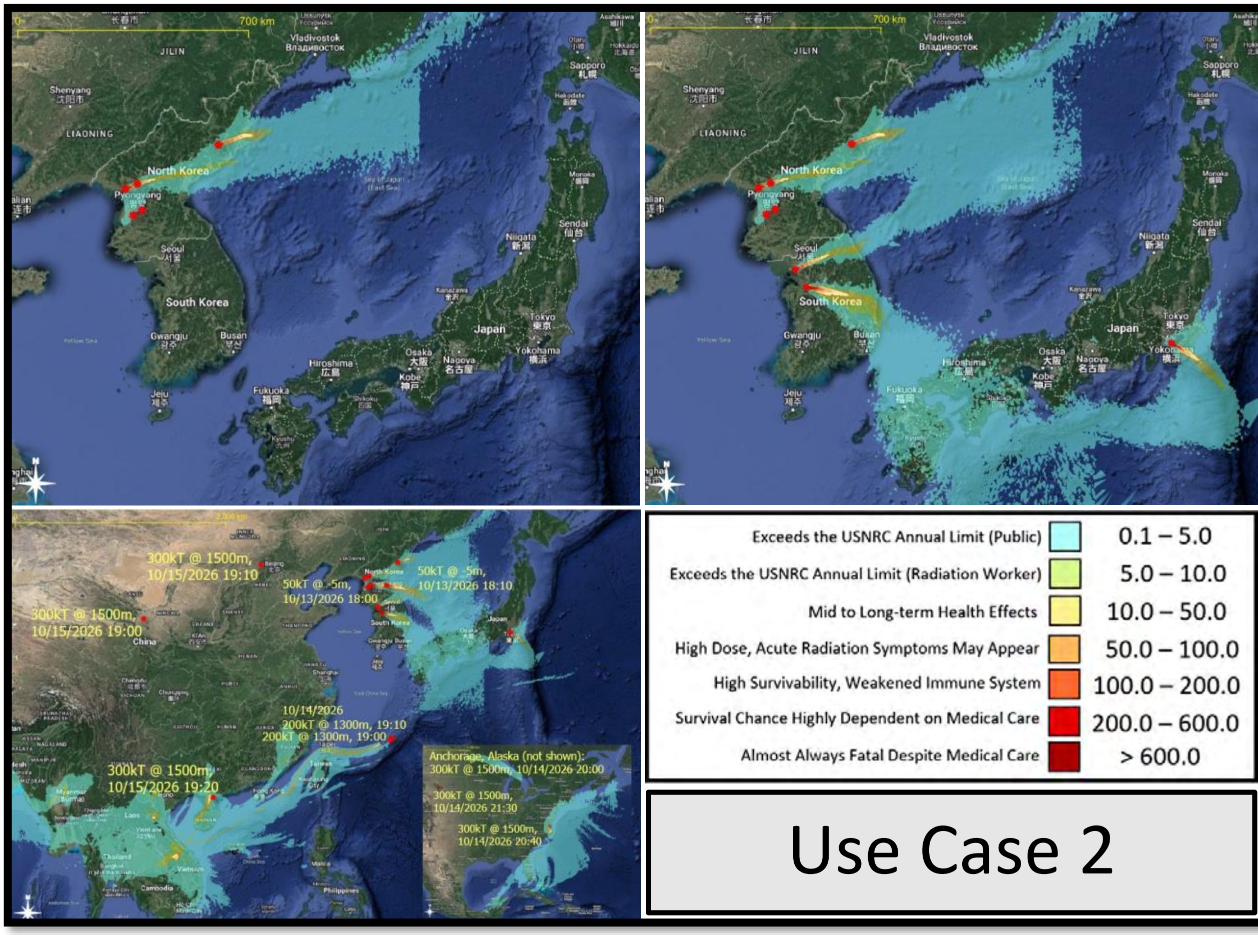


Figure 6-6: Fallout Patterns Resulting from First-Use (upper left), First-Use and Response (upper right), and All (lower left) Detonations in Use Case 2.

By the end of the conflict, most of the areas surrounding the Sea of Japan/Korean East Sea, southern China, and the Eastern Seaboard of the United States are covered by some level of nuclear fallout. Radioactive contamination even spreads to regions politically and militarily uninvolved in the conflict: southeast Asia and even the Caribbean Sea. As a result of nuclear war in Northeast Asia, these regions are affected by significant levels of nuclear fallout. Furthermore, southeast Asia and the Caribbean Sea are covered by nuclear-weapon-free treaties,[94] unlike the other regions affected. This unintended consequence of nuclear war could have significant regional and international political impacts.

[94] See map of nuclear weapons free areas in Liviu Horovitz (2009), "African Nuclear-Weapon-Free Zone Enters into Force", Middlebury Institute of International Studies at Monterey, James Martin Center for Nonproliferation Studies, dated August 12, 2009, and available as https://nonproliferation.org/african-nuclear-weapon-free-zone-enters-into-force/

Use Case 2 Implications:

- When lower-yield weapons (20 kT or less) are detonated, which are more likely to be surface-bursts, prompt radiation and high radiation from nuclear fallout can have a large impact on the death toll. If the first-response detonation is a surface-burst, it may spur the adversary to also respond with one or more surface-bursts. If the responding adversary increases the yield of their surface-burst, especially in a populated area, the death toll due to both prompt and fallout radiation can drastically increase.
- Use Case 1 and Use Case 2 both show that the attacks of responding adversaries tend to be more lethal than first-use attacks as the conflict escalates. In both cases, the fallout of the response detonations was more significant. In Use Case 2, population centers were attacked in the response detonation phase as opposed to remote targets, and weapons of larger and larger yield were increasingly detonated as the conflict escalated.
- As the weapon yield increases, the impact of firestorms increases, which disproportionately decreases the survival chance of affected populations. Not only does the fatality count increase, but also the percentage of deaths within the 0.5 psi zone, which results in even greater economic and social consequences, and makes rebuilding from the disaster even more painful and difficult for survivors.
- High-yield airbursts can result in significant levels of regional fallout that cross international borders, even dragging regions covered by nuclear-weapons-free treaties into the conflict, which can have significant political consequences and weaken international treaties.

6.3 Use Case #3: "Use by Terrorists" V1

An international or Japanese terrorist organization stages an attack meant to gain worldwide attention by detonating a smuggled-in rudimentary nuclear warhead in the Shinbashi business district of Tokyo.

Nuclear forensic analysis points to the DPRK as a source of nuclear material but is not strong enough to be unequivocal. The DPRK denies any role in the attack or in providing weapons for the attack. Responsibility for the attack is claimed by a stateless terrorist group.

Denial by the DPRK, the lack of clear evidence identifying DPRK proliferation as the source of bomb materials, the DPRK offers to assist Japan in recovery, and its general pro-engagement attitude convinces the United States not to use nuclear weapons against the DPRK, and further escalation is avoided. The key simulation parameters of this single-detonation use case are shown in Table 6-3.

Table 6-3: Use Case 3 Nuclear Detonation Parameters

Use Case	**"Use by Terrorist" V1**					
First User	Terrorist Attack					
First Use Targets	High Visibility Target in Tokyo					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	139.7587	0	10	Fission	ship	17:00
First Responder	US Response on DPRK (as possible proliferator)					
First Response Targets	[NONE--response considered, but not carried out]					
Additional Detonations	[None]					

Use Case 3 includes a single detonation of a weapon in central Tokyo. Figure 6-7 shows a satellite image of the detonation zone with rings indicating the areas within which there will be exposure to doses of 200 rem or more of prompt radiation, 5 psi or higher blast overpressure, and 10 cal/cm^2 or higher thermal fluence. The centralized firestorm zone is indicated in orange, within which there will be complete destruction and no survivors. The development of a firestorm is possible due to the high density of housing and other infrastructure, although the presence of tall buildings casts some uncertainty on the results due to a current lack of understanding as to what a firestorm might look like in a modern urban area.

Because the detonation is a relatively low-yield surface-burst, prompt radiation is estimated to have a significant impact on the fatality count. In total, an estimated 220,000 deaths or 25% of the 0.5 psi zone—not shown in Figure 6-7, but shown in Figure 6-8—will result within the days, weeks, and months following the attack, depending on the physical injuries from destroyed buildings and second and third-degree burns sustained by the victims. Around 30,000 of these victims are located within the 200-rem zone. Due to the high urban density of the Tokyo region, around 890,000 total people would be located within the 0.5 psi zone. Outside the 200-rem zone, around 190,000 of these people could suffer fatal injuries or be killed by burns, building damage due to blast overpressure, falling and flying debris, and other physical injuries. The effects of a surface-burst nuclear weapon would be somewhat shielded by a dense urban environment, but the effects of urban tunneling between skyscrapers, the behavior of the skyscrapers themselves when subjected to nuclear blast overpressure, and other factors, are not well understood, contributing large uncertainty to these results. The effects of a nuclear detonation in a highly dense urban environment should be studied further in future work.

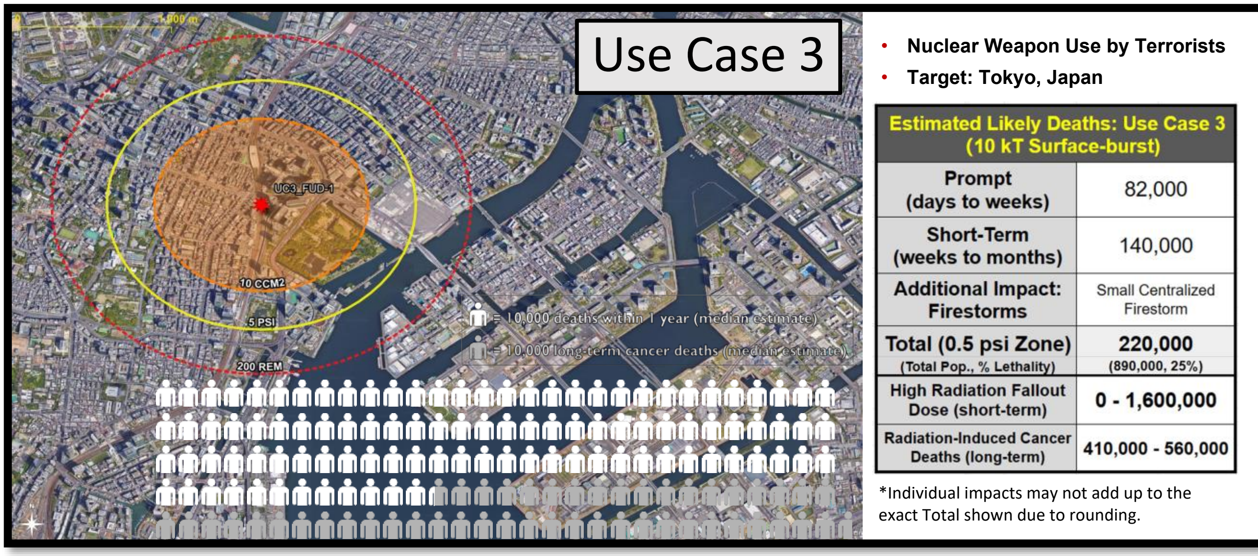


Figure 6-7: A Single, 10 kT Nuclear Detonation in Central Tokyo, Japan, Estimated Likely Deaths, and Estimated Cancers from Use Case 3.

Figure 6-8 shows the fallout simulation results for Use Case 3 on regional and local scales, respectively. Since this detonation is a relatively low-yield surface-burst, and detonated in an urban environment, fallout radiation exposure poses a large danger to the greater Tokyo region. Fallout deposition patterns are highly weather-dependent, but in this scenario, the prevailing winds blow to the east, centering on east Tokyo and reaching as far as Chiba prefecture. Within hours and over the next few days, many people who do not remain sheltered could receive lethal doses of radiation, experience acute radiation sickness, or be at a high risk of radiation-induced cancer death in their lifetime.

Under this specific weather pattern, the population within the region of Tokyo including Akihabara, Ueno Park, Asakusa, Tokyo Skytree, and much of Edogawa City would be at risk of acquiring radiation doses in the range of 200 to 600 rem within a few hours to four days of the detonation. Survival will be highly dependent on the availability and quality of medical care, and even a large city such as Tokyo would likely not have the resources or hospital capacity to treat victims outside of the areas immediately surrounding ground zero. The areas around Shibuya, Shinjuku, and Tokyo Station will also be affected by very high levels of radiation, as well as being partially located within the 0.5 psi zone (blue circle). These high levels of radiation could result in as many as 1.6 million additional deaths within the following year, and 410,000 – 580,000 radiation-induced cancer deaths in the following decades.

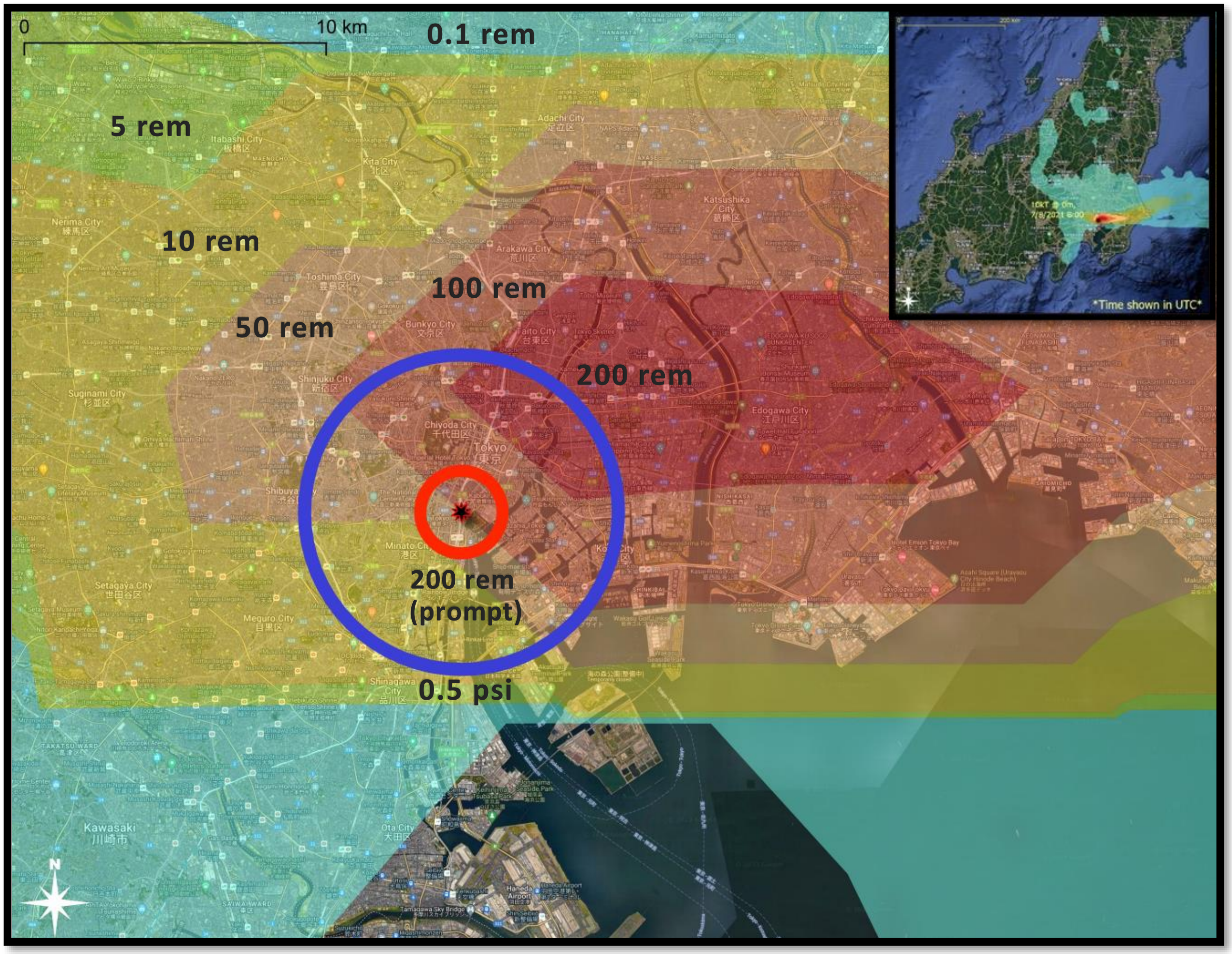


Figure 6-8: Local and Regional Fallout Patterns Resulting from the 10 kT Surface-burst Detonation in Use Case 3.

<u>Use Case 3 Implications</u>:

- In a highly dense urban environment, many of the fatalities may occur at distances further from ground zero due to flying and falling debris and to secondary fires stemming from centrally located firestorms or directly ignited by thermal fluence itself. Nuclear weapon effects in a modern urban area are not well understood, but the collapse of tall buildings or debris falling from high heights may trap survivors and hinder search and rescue efforts, as well as filling the air with dust and toxic smoke, increasing the number of fatalities even though the population may be somewhat shielded from the direct effects of the blast by the dense urban environment.
- A surface-burst detonating in a dense urban environment could result in a huge number of fatalities due to high radiation dose from fallout and could increase the number of radiation-induced cancer deaths far beyond the number of fatalities caused by impacts of the detonation in the immediate and short-term.

6.4 Use Case 4: "Conflict from Ukraine Spreads East"

The United States and its Western allies seek to restrain Russia from using nuclear weapons in Northeast Asia, but with few conventional assets to spare from the European theater, and at the urging of the ROK and Japan, the United States brings more nuclear weapons back into the region, on submarines and ships, and places more nuclear-capable bombers in the region.

The combination of US actions and political and economic troubles at home cause Russian leaders to order Russian nuclear forces in Northeast Asia, and likely Russian global nuclear forces, to go to higher alert status. Ultimately, fearing a US attack, Russia attacks US military bases in the region with nuclear weapons.

The United States responds to Russia's attacks with nuclear attacks on Russian Far Eastern nuclear bases. Further nuclear exchanges, as shown in Table 6-4, are averted by a combination of diplomacy encouraged by the ROK and Japan, war fatigue, and political changes in Russia.

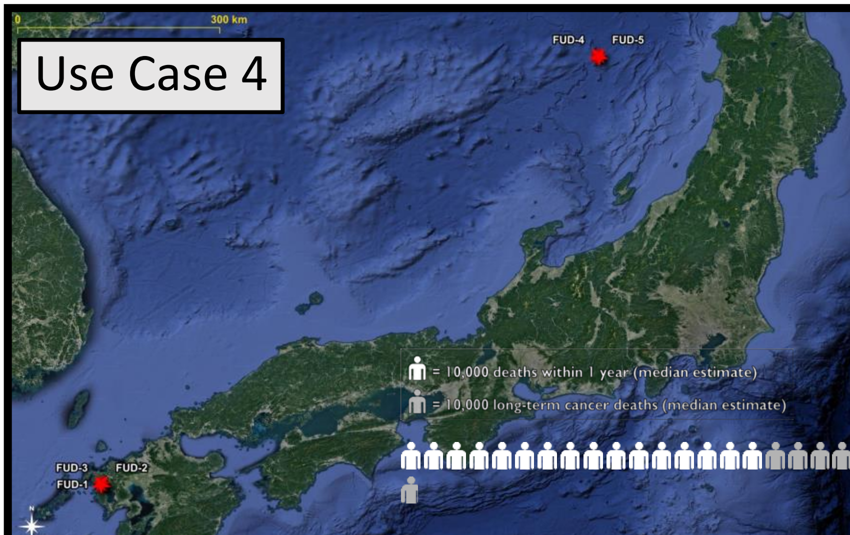
Table 6-4: Use Case 4 Nuclear Detonation Parameters

Use Case	**"Conflict from Ukraine Spreads East"**					
First User	Russia					
First Use Targets	US Naval Base and Warships					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	33.155, 129.713	1150	150	2-stage H bomb	RSM-56 Bulava	4/9/2024, 06:00
#2	33.155, 129.731	1150	150	2-stage H bomb	RSM-56 Bulava	4/9/2024, 06:01
#3	33.155, 129.700	1150	150	2-stage H bomb	RSM-56 Bulava	4/9/2024, 06:02
#4	40.27, 137.95	1300	200	2-stage H bomb	RK-55 Granat	4/9/2024, 06:00
#5	40.27, 137.98	1300	200	2-stage H bomb	RK-55 Granat	4/9/2024, 06:05
First Responder	US					
First Response Targets	Russian Naval Bases in the Far East					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	52.918, 158.49	450	8	2-stage H bomb	SBN W76-2	4/9/2024, 07:00
#2	43.111, 131.888	450	8	2-stage H bomb	SBN W76-2	4/9/2024, 07:05
#3	43.081, 131.921	450	8	2-stage H bomb	SBN W76-2	4/9/2024, 07:06
Additional Detonations	[None]					

Use Case 4 begins with attacks by Russia on US bases in southern Japan and on US and allied ships at sea. Figure 6-9 shows the number of estimated likely deaths resulting from these first use detonations. Three 150 kT hydrogen bombs are detonated at a height of 1150 meters in the vicinity of a naval base in south Japan, and two 200 kT hydrogen bombs are detonated at 1300 meters above sea level in the vicinity of a US carrier group accompanied by a number of US and allied ships. Because it is difficult to simulate a nuclear attack on ships at sea, a total personnel count of about 10,000 aboard was assumed.[95] Half of the personnel on board are assumed to perish in the attack through a combination of damage to the ships, thermal fluence, and prompt radiation exposure.

Firestorms are likely to occur following the cluster of three attacks targeting US naval bases located in a populated area of southern Japan due to the high density of housing and other buildings. The occurrence of a firestorm is not possible at sea, but individual ships in the carrier group would likely be set ablaze due to the intense heat from two high-yield fusion weapon detonations.

The first phase of Use Case 4 results in a larger fatality rate to the local population than any phase in previous use cases due to the effect of overlapping firestorm and prompt impact zones. Forty-one percent of the population are killed within hours or days, and by the end of the year following the attack. Over half of the population within the 0.5 psi zone do not survive.



- Attack by Russia on US military bases in Japan, US Navy and allies' ships at sea

Estimated Likely Deaths: Use Case 4 First-Use Detonations (150-200 kT)	
Prompt (days to weeks)	120,000
Short-Term (weeks to months)	25,000
Additional Impact: Firestorms	15,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**160,000** (290,000, 55%)
High Radiation Fallout Dose (short-term)	Low Fallout
Radiation-Induced Cancer Deaths (long-term)	14,000 - 83,000

*Individual impacts may not add up to the exact Total shown due to rounding.

Figure 6-9: Targets, Estimated Likely Deaths, and Estimated Additional Cancers from Use Case 4, First Use Detonations.

Figure 6-10 shows first-use detonations by Russia and response attacks on Russian bases by the United States, and the resulting cumulative estimated likely deaths from those attacks. The United States responds by detonating three low-yield weapons of 8 kT, which add 130,000 fatalities to the use case total, resulting in an overall likely death count of about 290,000.

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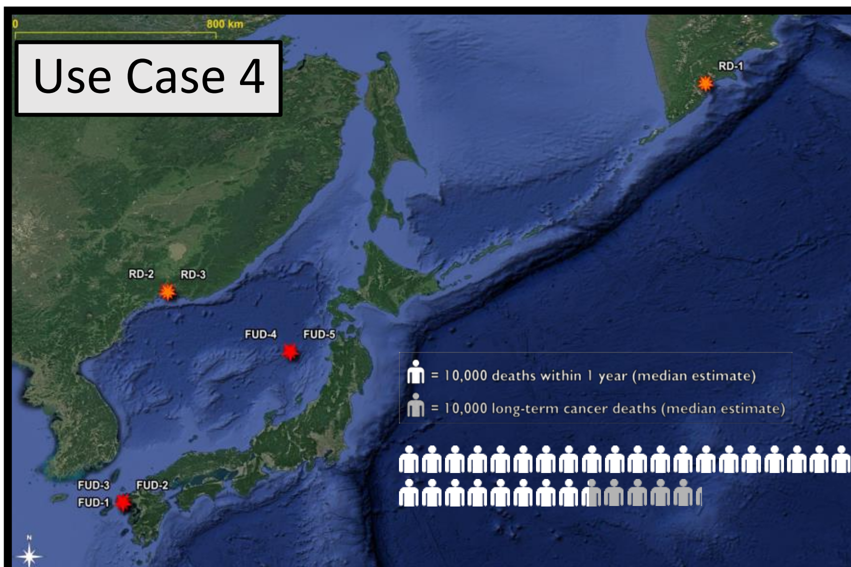
[95] Assumes attack is on a carrier battle group with some other US ships and/or allied ships also present, total of 10,000 personnel. For staffing carrier battle group, see, for example, United States Naval Reserve Intelligence Program (undated*), Ready-for-Sea Handbook: MODULE 2—CARRIER BATTLEGROUP & Amphibious Ready Group (ARG) PLATFORMS AND MISSIONS*, available as https://irp.fas.org/doddir/navy/rfs/part02.htm

In the first phase of the use case, only high-altitude, high-yield (150 kT) detonations are used over population centers, resulting in around 160,000 estimated deaths, 84% of which occur within hours or days of the attack. On the other hand, the second phase of the use case sees only the use of low-yield (8 kT) airbursts resulting in 130,000 estimated deaths, 40% of which occur within hours of days of the attack. Unexpectedly, the number of deaths in each phase of the conflict is about the same. This result can be attributed to the fact that the population size in the vicinity of the high-yield airbursts is much smaller. This result, however, also shows that the number of deaths due to a nuclear attack cannot be directly tied to the weapon yield or height-of-burst, and the death toll of a nuclear conflict can be unacceptably high even when only low-yield nuclear weapons are used.

Another significant difference between this use case and other use cases evaluated is the percentage of fatalities that occur within days as opposed to weeks or months. The high-yield weapons, causing raging firestorms and featuring high thermal fluence over a broad area, inflict instant death in a greater percentage of the victims (84%), whereas most victims of the low-yield attacks will succumb to their injuries within the span of months to a year, and their survival rate will be highly dependent on the availability of medical care. (This trend is also highly dependent on the population distribution of the area. For example, results are different if populations are clustered near ground zero or mostly located further away.



- **Attack by Russia on US military bases in Japan, US Navy and allies' ships at sea**
- **Response Detonations (3 total) by the US on Russian naval bases**

Estimated Likely Deaths: Use Case 4 First-Use + Response Detonations (8 kT Airbursts)	
Prompt (days to weeks)	170,000
Short-Term (weeks to months)	98,000
Additional Impact: Firestorms	15,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**290,000** (800,000, 36%)
High Radiation Fallout Dose (short-term)	Low Fallout
Radiation-Induced Cancer Deaths (long-term)	**14,000 - 85,000**

*Individual impacts may not add up to the exact Total shown due to rounding.

Figure 6-10: Targets, Estimated Likely Deaths, and Estimated Additional Cancers from Use Case 4, First Use and Response Detonations.

Only the first use detonations on Japan result in fallout, and the weather conditions simulated result in relatively little fallout over land, with people in the affected areas receiving relatively low doses of radioactivity, as shown in Figure 6-11. It was estimated that 14,000-85,000 people may die of radiation-induced cancer in their lifetimes. The fallout simulation resulted in a very unexpected pattern, with the radioactive material from high-yield airbursts in southwest Japan depositing onto the densely populated city of Osaka. Low levels of radioactive fallout also spread to the east coast of China in the simulation.

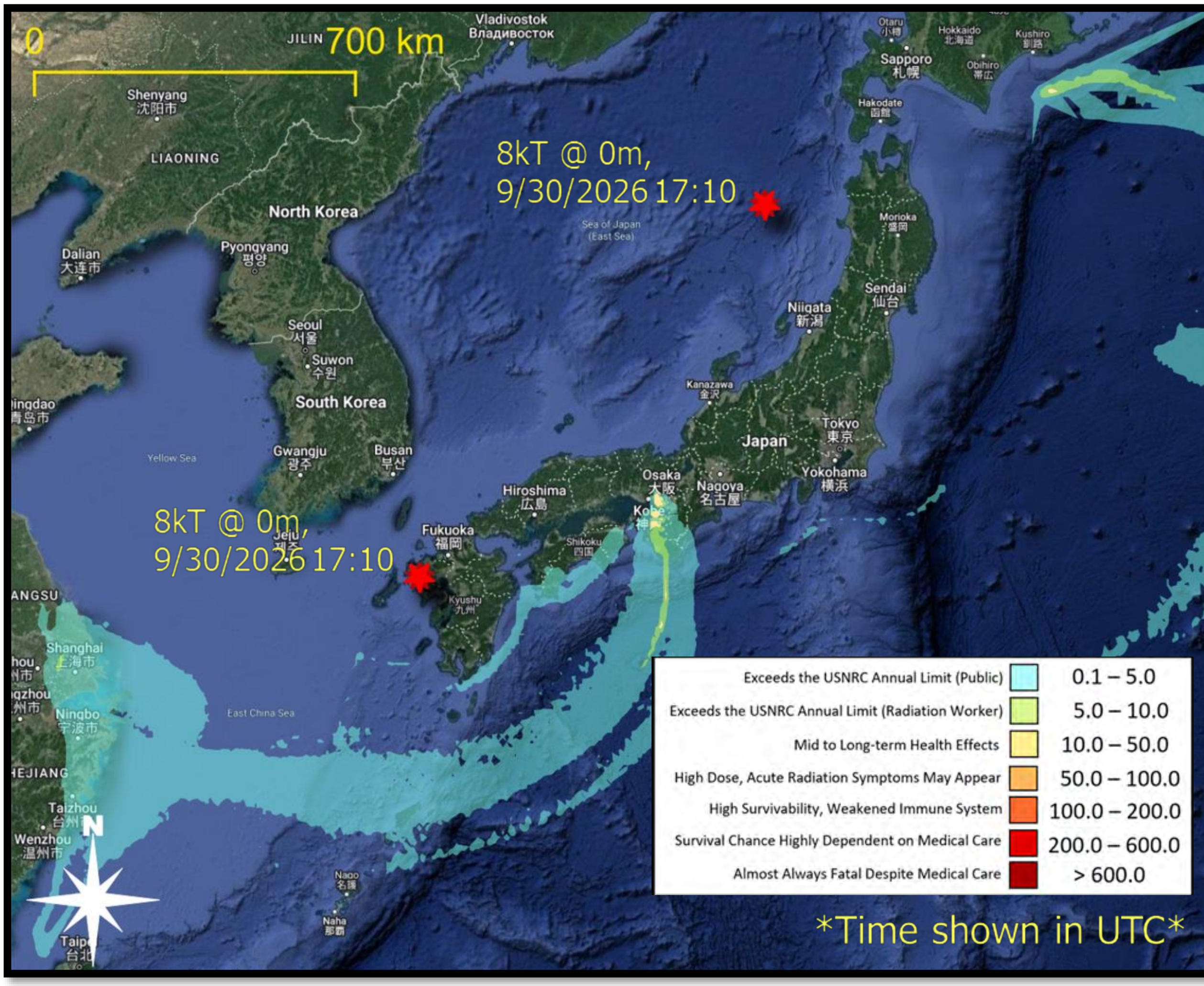


Figure 6-11: Fallout Patterns resulting from First Use Detonations in Use Case 4.

<u>Use Case 4 Implications</u>:

- Clustered nuclear attacks with overlapping impact zones have a compounding effect on the affected community; a higher percentage of the people in the affected area will not survive.
- The intense, far-ranging heat due to the huge fireball produced by high-yield, high-altitude detonations and the firestorms produced by such an attack would result in total and complete destruction of the area, likely killing over half of the population. The ability of surviving residents to heal and rebuild the community would be severely inhibited, and economic impacts to the greater region would be significant.

- Any detonation of high-yield, high-altitude weapons with devastating thermal and firestorm impacts can wipe out entire communities and have a lasting generational impact.
- Due to the variation in population size and density surrounding targets of nuclear detonations, the number of fatalities does not always directly relate to the weapon yield or height-of-burst. Since the number of people present in an area at any given time is highly variable, the death toll resulting from a nuclear conflict is highly unpredictable, regardless of the weapon yield that is used, and is unacceptably high even when only low-yield nuclear weapons are used.
- High-altitude, high-yield airbursts will result in very high prompt fatality rates—a high percentage of the victims will die within hours or days of the attack.
- Most victims of low-yield airbursts will succumb to their injuries within several weeks, months, or within a year following the attack, and their survival chance is highly dependent on the availability and quality of medical care. This would place a high emotional, social, and financial burden on the surviving members of the community and on the nation as a whole.
- High-altitude, high-yield nuclear weapon detonations can result in unpredictable and unexpected nuclear fallout patterns under certain weather conditions. Fallout can travel great distances across oceans and international borders and affect large population centers far from ground zero.

6.5 Use Case 5: "Not Going Well in Taiwan"

Changes in public opinion in an anti-leadership direction in China induce China's leaders to attempt to distract its citizens by ordering an attack on Taiwan's perimeter defenses. The United States rapidly becomes involved militarily in the conflict and China suffers significant setbacks.

Worried about further involvement of US forces in the Taiwan conflict, China first threatens, then—when threats appear to have little effect, and convinced that conventional defeat of its attack on Taiwan is imminent—attacks US bases in the region, and US ships at sea, with one or more nuclear weapons.

The United States responds with nuclear attacks on Chinese nuclear assets, including ICBM and other confirmed or suspected nuclear missile bases in China.

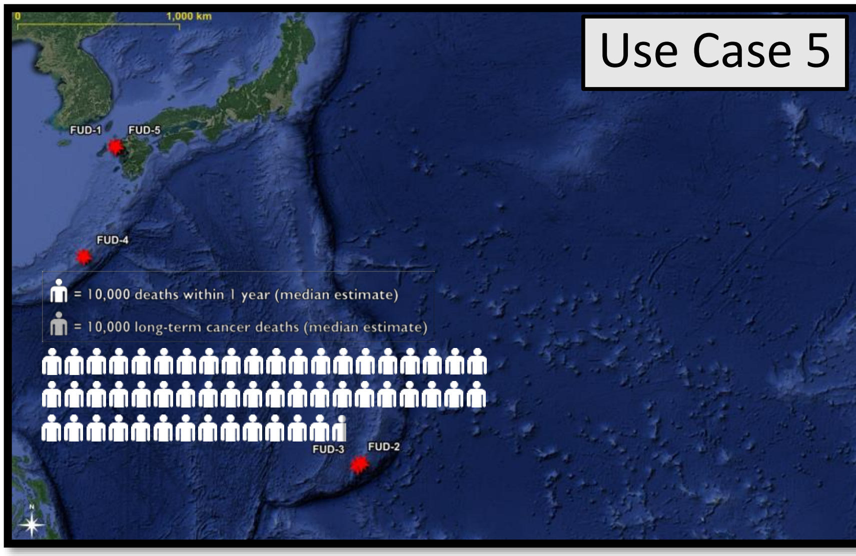
China launches counterattacks on military targets in the United States, and the United States launches additional attacks on military targets in China. In both cases, some targets are in or adjacent to urban areas. Even more extensive global nuclear war might well be considered the logical result of this use case, but the analysis of this particular conflict has been limited to 24 total detonations, as shown in Table 6-5.

Table 6-5: Key Parameters of Detonations for Use Case 5

Use Case	**"Not Going Well in Taiwan"**					
First User	China					
First Use Targets	US Naval and Air Bases					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	33.155, 129.713	1150	250	2-stage H bomb	DF-26	10/8/2023, 06:00
#2	13.59, 144.90	500	250	2-stage H bomb	DF-26	10/8/2023, 06:30
#3	13.425, 144.679	1150	250	2-stage H bomb	DF-26	10/8/2023, 06:35
#4	26.355, 127.768	1150	250	2-stage H bomb	DF-26	10/8/2023, 06:20
#5	33.156, 129.732	1150	250	2-stage H bomb	DF-26	10/8/2023, 06:10
First Responder	US					
First Response Targets	Chinese ICBM Targets and Military Bases					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	36.601, 118.482	450	8	2-stage H bomb	SBN W76-2	10/8/2023, 14:00
#2	42.290, 92.525	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
#3	42.290, 92.540	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
#4	42.282, 92.550	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
#5	42.29, 92.517	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
#6	32.1686, 114.1258	450	8	2-stage H bomb	SBN W76-2	10/8/2023, 19:30
#7	40.324, 96.45	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
#8	40.33, 96.45	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
#9	40.33, 96.455	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
#10	40.319, 96.445	-5	50	2-stage H bomb	B61-12	10/8/2023, 19:00
Additional Detonations	Chinese Attacks on Additional US Bases, ICBM Exchange with China					
	Location	***HOB (m)***	***Yield (kT)***	***Type of Weapon***	***Delivery System***	***Date and Time of Attack****
#1	35.92, 126.62	1150	250	2-stage H bomb	DF-26	06:20
#2	37.085, 127.03	1150	250	2-stage H bomb	DF-26	06:30
#3	36.513, 103.606	1500	300	2-stage H bomb	W87 (ICBM)	03:00
#4	34.06, 107.32	1500	300	2-stage H bomb	W87 (ICBM)	03:10
#5	21.231, 110.445	1500	300	2-stage H bomb	W87 (ICBM)	03:20
#6	61.253, -149.77	1500	300	2-stage H bomb	DF-5 (A or B), DF-31 (ICBM)	02:20
#7	44.144, -103.08	1500	300	2-stage H bomb	DF-5 (A or B), DF-31 (ICBM)	05:40
#8	36.96, -76.3	1500	300	2-stage H bomb	DF-5 (A or B), DF-31 (ICBM)	06:50
#9	35.290, 139.660	1300	200	2-stage H bomb	JL-1 (SBL) or DF-21 (MRBM)	21:00

Figure 6-12 indicates the target locations and estimated deaths and cancers resulting from the first use detonations in evaluated Use Case 5. In two of the attacks, two weapons were detonated close together to destroy key capabilities of close-by military bases. Hundreds of thousands of deaths in Japan and Guam were estimated to result from such attacks.

The two overlapping detonations in Sasebo Naval Base in the south of Japan will likely cause a large firestorm within the area affected by 15 cal/cm^2 or more of thermal fluence due to the high density of housing and other buildings. In Guam, the occurrence of a firestorm will likely be avoided, owing to the sparsity of infrastructure and proximity to the coast, although local fires and forest fires will occur. In Okinawa, the detonation of a 250 kT airburst will likely cause a firestorm to develop due to the high density of infrastructure in parts of the 15 cal/cm^2 zone.



- First Use Detonations: Attacks by China on US bases in Japan and the Republic of Korea

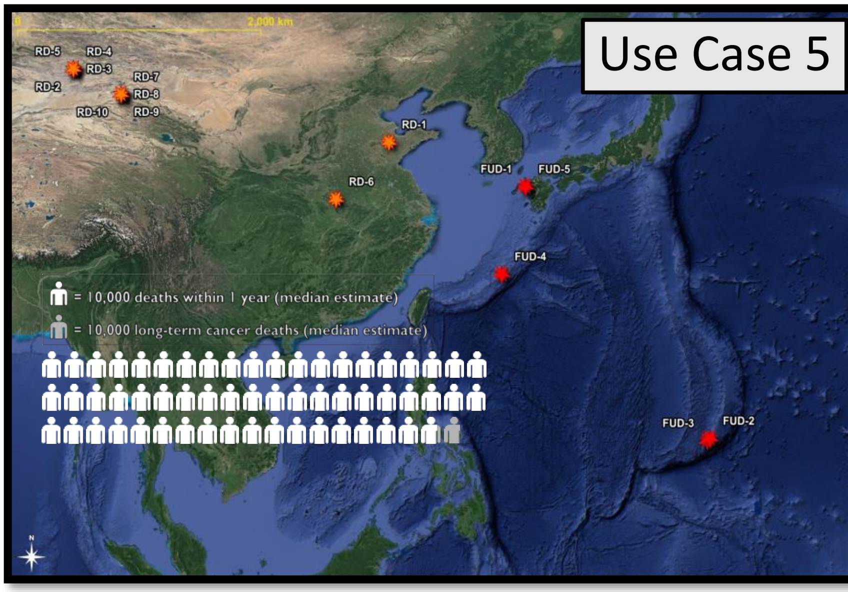
Estimated Likely Deaths: Use Case 5 First-Use Detonations (250 kT)	
Prompt (days to weeks)	350,000
Short-Term (weeks to months)	150,000
Additional Impact: Firestorms	36,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**540,000** (1,300,000, 41%)
High Radiation Fallout Dose (short-term)	Low Fallout
Radiation-Induced Cancer Deaths (long-term)	**400 - 3,000**

*Individual impacts may not add up to the exact Total shown due to rounding.

Figure 6-12: Targets, Estimated Likely Deaths, and Estimated Additional Cancers Resulting from Use Case 5, First Use Detonations.

Figure 6-13 shows the cumulative impact of both first use and response detonations in Use Case 5. Many of the response detonations target remote and unpopulated missile sites in western China, but some are in or near urban areas. An estimated 570,000 deaths would result from first use and response detonations in this use case, with an additional 400–19,000 short-term deaths due to high fallout radiation, and 5,000–15,000 long-term, radiation-induced cancer deaths. As the conflict escalates, the primary nuclear weapon impact causing an increase in the number of fatalities is nuclear fallout. Even when nuclear weapons are detonated in areas that appear to be remote, there are oftentimes nearby communities that may be severely affected by nuclear fallout levels.

Most of the attacks carried out in the response detonation phase of Use Case 5 target remote areas covered by sparse vegetation or desert. At one missile site in China, the occurrence of a firestorm is possible due to the clustering of infrastructure near ground zero.



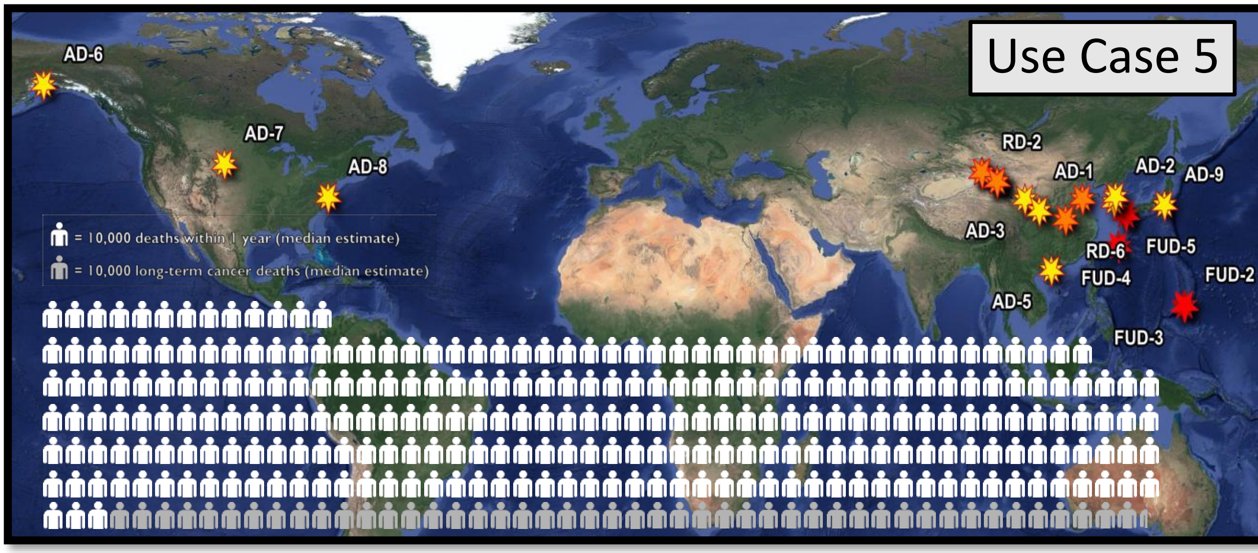
- **First Use Detonations: Attacks by China on US bases in Japan and the Republic of Korea**
- **Response Detonations: Attacks by the US on Chinese nuclear and military bases**

Estimated Likely Deaths: Use Case 5 **First-Use + Response Detonations (8-50 kT)**	
Prompt (days to weeks)	370,000
Short-Term (weeks to months)	160,000
Additional Impact: Firestorms	38,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**570,000** (1,400,000, 40%)
High Radiation Fallout Dose (short-term)	**400 - 19,000**
Radiation-Induced Cancer Deaths (long-term)	**5,000 - 15,000**

*Individual impacts may not add up to the exact Total shown due to rounding.

Figure 6-13: Targets, Estimated Likely Deaths, and Estimated Additional Cancers Resulting from Use Case 5, First Use and Response Detonations.

Finally, Figure 6-14 shows the cumulative estimated likely deaths resulting from all first use, response, and additional detonations in Use Case 5. An estimated 2.6 million victims would likely die within one year because of the immediate impacts of this global nuclear conflict, with an additional 400–19,000 short-term victims of high radiation dose exposure. Tens to hundreds of thousands more could die from radiation-induced cancers in their lifetime.



- **First Use Detonations: Attacks by China on US bases in Japan and the Republic of Korea**
- **Response Detonations: Attacks by the US on Chinese nuclear and military bases**
- **Additional Detonations: Attacks by China and the US on their adversary's nuclear and military bases**

Estimated Likely Deaths: Use Case 5 **Additional Detonations***	
Prompt (days to weeks)	1,500,000
Short-Term (weeks to months)	930,000
Additional Impact: Firestorms	190,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**2,600,000** (7,600,000, 35%)
High Radiation Fallout Dose (short-term)	**400 - 19,000**
Radiation-Induced Cancer Deaths (long-term)	**96,000 - 830,000**

*Cumulative with First-Use and Response Detonations. Individual impacts may not add up to the exact Total shown due to rounding.

Figure 6-14: Targets, Estimated Likely Deaths and Estimated Additional Cancers Resulting from Use Case 5, All Detonations.

Figure 6-15 through Figure 6-17 show simulated fallout patterns from first use, first use and response, and all detonations in Use Case 5, respectively. Radioactive material and contaminated soil particles are spread across much of south and east Asia by the end of the conflict, including to many countries politically and militarily uninvolved. South Japan, parts of China, Southeast

Asia, Taiwan, and other Pacific islands were affected by significant levels of radioactive fallout–mostly non-lethal, but enough to increase the cancer risk in some populations and will thus have far-reaching political consequences. Although covered by Nuclear-Weapon-Free treaties or self-declared nuclear-weapon-free zones, the Philippines, Mongolia, Laos, Myanmar, Thailand, Vietnam, and many Pacific islands are affected by radioactive contamination from fallout.

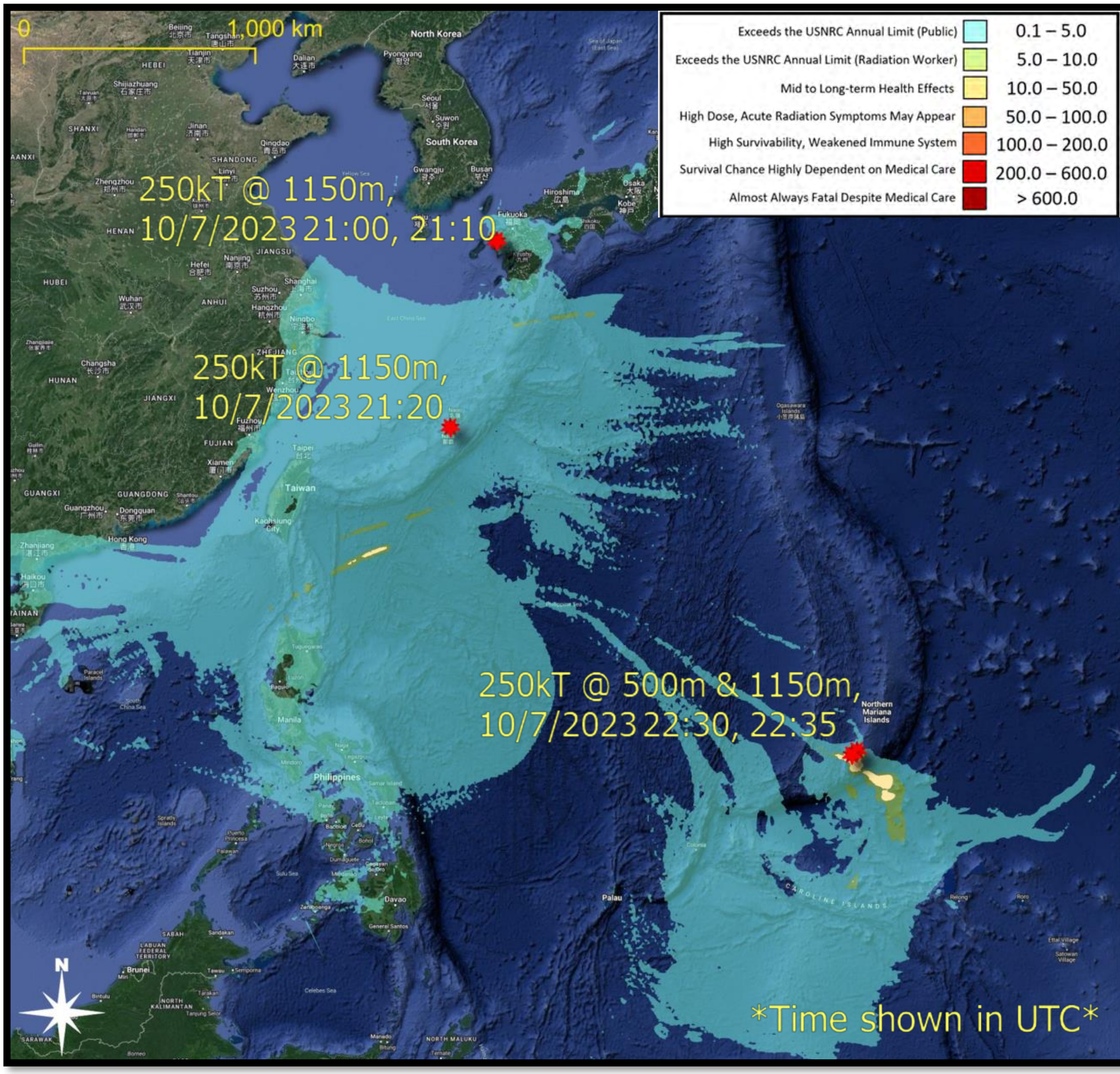


Figure 6-15: Fallout Pattens for First Use detonations in Japan and Guam in Use Case 5.

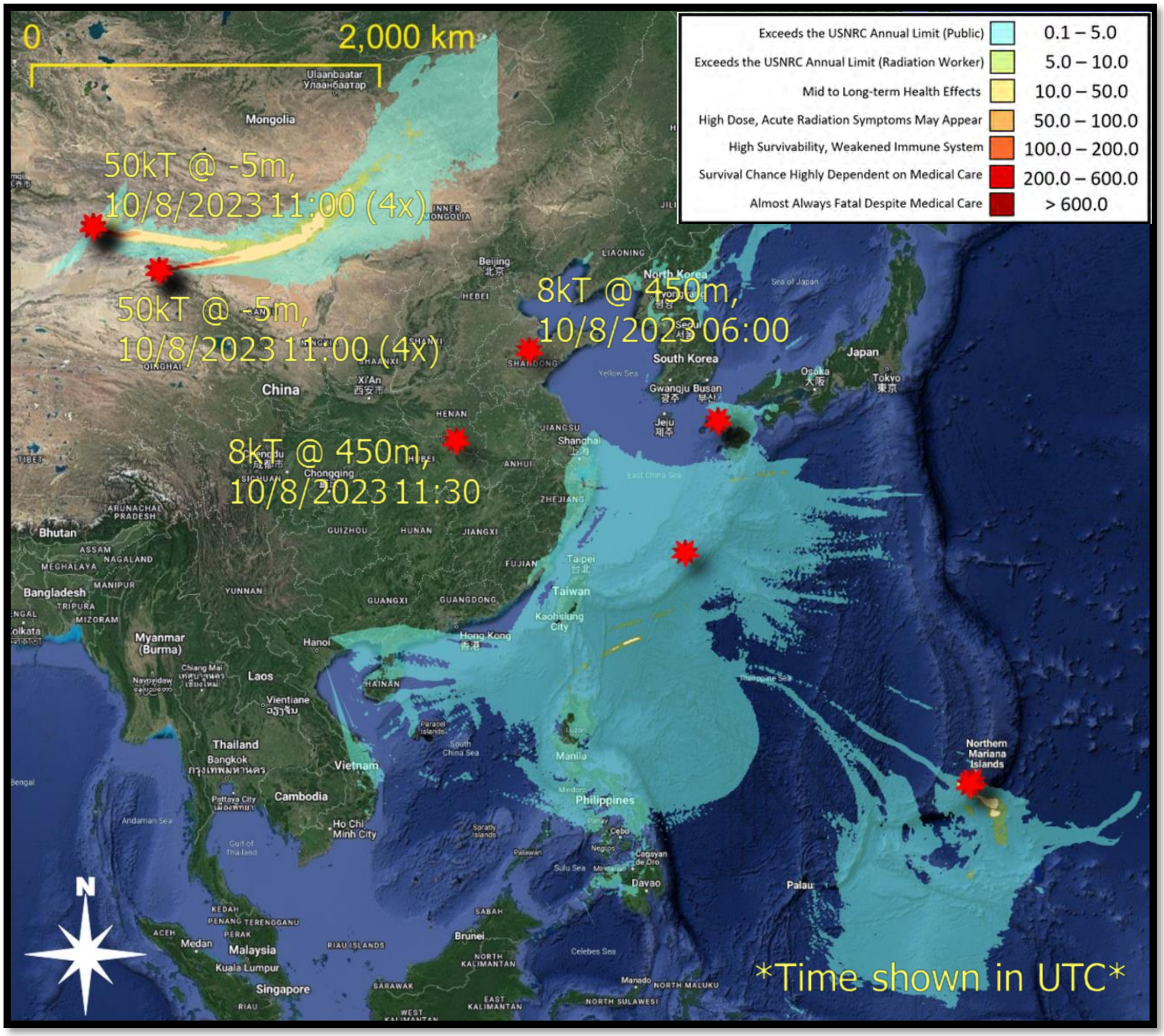


Figure 6-16: Fallout Pattens for First Use and Response Detonations in Japan, Guam, and China in Use Case 5.

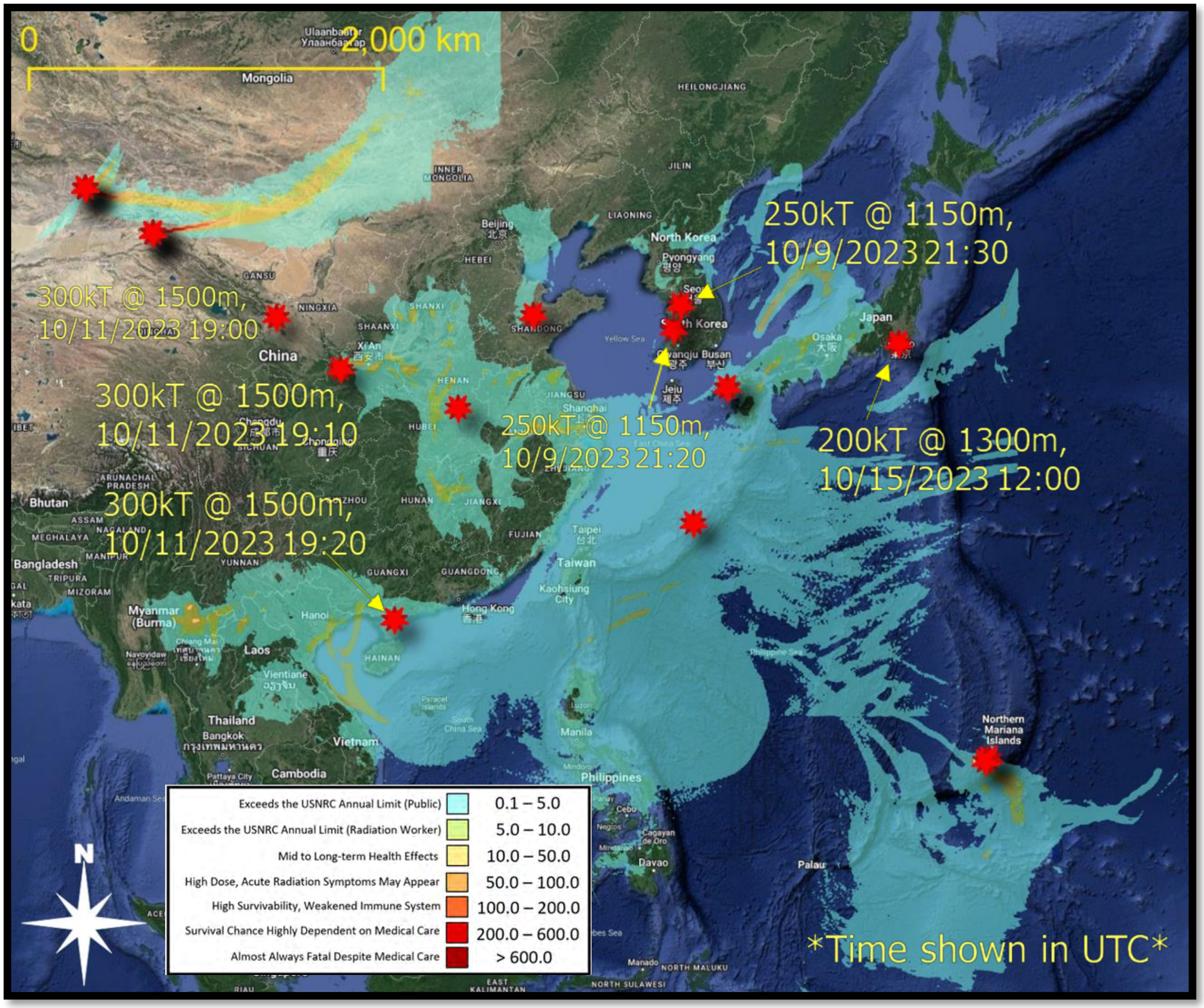


Figure 6-17: Fallout Pattens for All Detonations in Asia in Use Case 5.

<u>Use Case 5 Implications</u>:

- Even attacks in "remote" areas can have fatal effects on nearby populations due to the dispersion of highly radioactive nuclear fallout. Areas that seem remote are, in reality, home to communities of people who live far from city centers and may not have timely access to the medical care required to prevent acute radiation fatalities and treat radiation-induced leukemia and cancer.
- As a nuclear conflict escalates, even if the same number of nuclear weapons are detonated from one phase of the conflict to the next, the weapon yields used may increase, disproportionately magnifying the number of fatalities by 4-5x or even more, demonstrated by the results of the Use Case 2 and Use Case 5 simulations.

- One of the greatest unintended consequences of nuclear war is the spread of nuclear fallout. Regional nuclear conflict can escalate to global nuclear conflict when significant levels of radioactive fallout cross international borders, even dragging countries in Nuclear-Weapon-Free Zones into the conflict, which can have significant political consequences and could weaken international nuclear nonproliferation treaties.

6.6 Conclusion: Overall Summary of Simulated Use case Results and Implications

Low-Yield Nuclear Weapons (20 kT or less): Surface-burst low-yield nuclear weapons can result in international cross-border nuclear fallout, unintentionally dragging allies and adversaries into the conflict, which can have severe political consequences and spread fear in members of the public due to a lack of understanding of nuclear fallout and the biological effects of radiation. Very low-yield weapons are more likely to be surface-bursts, in which case prompt radiation and high radiation from nuclear fallout can have a large impact on the death toll of a conflict. In the case of low-yield airbursts, most victims will succumb to their injuries within several weeks, months, or a year following the attack, and their survival chance is highly dependent on the availability and quality of medical care. This would place a high emotional, social, and financial burden on the surviving members of the community and nation.

Firestorm / High-Yield Airburst Impact: As the weapon yield increases, the impact of firestorms increases, which disproportionately decreases the survival chance of affected populations. Not only does the fatality count increase as a result of firestorms, but also a higher percentage of the people located within the 0.5 psi zone surrounding the target will die, resulting in even greater economic and social consequences, making rebuilding from the disaster even more painful and difficult for survivors. In the case of clustered detonations, firestorms from high-yield, high-altitude detonations would result in total and complete destruction of the area, likely killing over half of the population within the 0.5 psi zone. The ability of surviving residents to heal and rebuild their communities would be severely inhibited, causing major economic impacts to the greater region, and possibly wiping out entire local communities and producing lasting generational impacts.

International Cross-Border Nuclear Fallout: Low-yield surface bursts and high-yield surface or airbursts can result in significant levels of regional fallout that cross international borders, even dragging regions covered by Nuclear-Weapon-Free treaties into the conflict, which can have significant political consequences and weaken international treaties. Even low levels of fallout can decrease trust in alliances and spread fear in members of the public due to a lack of understanding of nuclear fallout and the biological effects of radiation.

Conflict Escalation: The attacks of responding adversaries tend to be more lethal than first-use attacks as the conflict escalates. If the first-response detonation is a surface-burst, it may spur the adversary to also respond with one or more surface-bursts. If the responding adversary increases the yield of their surface-burst, especially in a populated area, the death toll due to both prompt and fallout radiation can drastically increase. In Use Case 2, population centers are attacked in the response detonation phase as opposed to remote targets, and weapons of increasingly larger and larger yield are detonated as the conflict escalates. As a nuclear conflict escalates, even if the same number of nuclear weapons are detonated from one phase of the conflict to the next, the weapon yields used may increase, disproportionately magnifying the number of fatalities by a factor of four to five or even more.

Urban Targets: In a highly dense urban environment, many fatalities may occur at distances further from ground zero due to flying and falling debris and to secondary fires stemming from centrally-located firestorms. The collapse of tall buildings or debris falling from high heights may trap survivors and hinder search and rescue efforts, as well as filling the air with dust and toxic smoke, and increasing the number of fatalities even though the population may be somewhat shielded from the direct effects of the blast by the infrastructure.

Vulnerability of Remote Communities: Even attacks in "remote" areas can have fatal effects on nearby populations due to the dispersion of highly radioactive nuclear fallout. Areas that seem remote are home to communities of people who live far from city centers and may not have timely access to the medical care required to prevent acute radiation fatalities or to treat radiation-induced leukemia and cancer.

Unintended, Unpredictable, and Uncertain: Due to the variation in population size and density surrounding targets of nuclear detonations, the number of fatalities from a given attack does not necessarily directly relate to the weapon yield or the height-of-burst. As the number of people in an area at any given time is highly variable, for example, as commuters move from offices to home and back, the death toll resulting from a nuclear conflict is highly unpredictable, regardless of the weapon yield that is used, and is unacceptably high even when only low-yield nuclear weapons are used. High-altitude, high-yield nuclear weapon detonations can result in unpredictable and unexpected nuclear fallout patterns under certain weather conditions, and fallout can travel great distances across oceans and international borders and affect large population centers far from ground zero. One of the greatest unintended consequences of nuclear war is the spread of nuclear fallout. Regional nuclear conflict can escalate to global nuclear conflict when significant levels of radioactive fallout cross international borders, resulting in unintended political consequences.

Glossary

Becquerel (Bq)	SI unit of radioactivity, equal to 2.703 x 10^{-11} Curies (Ci).
Cal/cm^2	Calories per square centimeter, a measure of thermal (heat) fluence. One calorie equals 4.184 Joules (J).
Cold War	The Cold War was a conflict in the aftermath of World War II through 1989 between competing blocs led by, respectively, the United States and USSR, in which there were few active military engagements but significant build-up of armaments and global tension regarding potential nuclear conflicts.
CTBT	Comprehensive Nuclear Test Ban Treaty.
Deterrence	"Deterrence [is a], military strategy under which one power uses the threat of reprisal effectively to preclude an attack from an adversary power,"[96] such as using the threat of use of nuclear weapons to deter an attack by another with conventional or nuclear weapons.
DPRK	Democratic People's Republic of Korea.
EMP	Electromagnetic pulse. See also HEMP.
Enrichment	The process of raising the proportion of the uranium-235 isotope in natural (or already enriched) uranium by separating U-235 from U-238, typically by a process of centrifugation of uranium hexafluoride (UF_6) gas.
Fallout	"Fallout is the radioactive particles that fall to earth as a result of a nuclear explosion. It consists of weapon debris, fission products, and, in the case of a ground burst, radiated soil."[97]
Firestorm	Firestorms are mass fires with particular characteristics. In a firestorm, a large enough contiguous area is set aflame, effectively at once, that the fire creates its own wind patterns. As heat from the fire rises, winds arise on all sides traveling toward the fire, sometimes at gale-force velocities of up to 90 miles per hour (about 40 meters/second).

[96] Brittanica.com (probably 2017), "Deterrence, political and military strategy," available as https://www.britannica.com/topic/deterrence-political-and-military-strategy
[97] Atomicarchive.com (2020), "Radioactive Fallout," available as https://www.atomicarchive.com/science/effects/radioactive-fallout.html

Fission	In nuclear fission, an atom splits into two smaller atoms, releasing energy. A nuclear fission bomb relies on fission for its destructive power, using uranium enriched in the isotope U-235 or plutonium as the fissile material.
Fusion	In nuclear fusion, two smaller atoms, typically heavy isotopes of hydrogen, are forced together to form a larger atom, releasing energy. Nuclear fusion bombs use fusion reactions, typically as a second stage in a 2-stage weapon, to provide their destructive power.
Gray (Gy)	Unit of ionizing radiation dose in the International System of Units (SI), defined as the absorption of one joule of radiation per kilogram of matter (for example, human tissue).
H-bomb	A two-stage nuclear weapon (thermonuclear) where a nuclear fission primary stage ignites a secondary nuclear fusion stage.
HEMP	High Altitude Electromagnetic Pulse. A 2008 Report by the United States Congressional Research Service (2008), for example,[98] defines HEMP as "Electromagnetic Pulse (EMP) an instantaneous, intense energy field that can overload or disrupt at a distance numerous electrical systems and high technology microcircuits, which are especially sensitive to power surges."
IAEA	International Atomic Energy Agency.
ICBM	Intercontinental ballistic missile.
INF	Intermediate-Range Nuclear Forces Treaty. "The 1987 Intermediate-Range Nuclear Forces (INF) Treaty required the United States and the Soviet Union to eliminate and permanently forswear all of their nuclear and conventional ground-launched ballistic and cruise missiles with ranges of 500 to 5,500 kilometers."[99] The United States withdrew from the INF treaty in 2019.
Isotopes	Species of an element with different numbers of neutrons in their nuclei and therefore different atomic weights, such as U-235 and U-238.
Joule (J)	Measure of energy in SI units equal to one $kg\text{-}m^2/s^2$, or one N-m (Newton-meter).
Kiloton (kT)	A measure of the explosive power of a nuclear detonation, and nominally denoting the amount of explosive force achieved by detonating 1000 tons of 2,4,6-Trinitrotoluene, or TNT. Typically defined as one teracalorie (10^{12} calories, or 4.184×10^{12} Joules), but definitions do vary by country and even by organization within each country—see attachment on this topic for more detail.

[98] Clay Wilson (2008), *High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments*, US Congressional Research Service, updated March 26, 2008, and available as https://www.wired.com/images_blogs/dangerroom/files/Ebomb.pdf. A more recent publication by the US Air Force Civil Engineer Center (AFCEC, 2020), "High Altitude Electromagnetic Pulse (HEMP) Effects and Protection," updated 08-07-2020, and available as https://www.wbdg.org/resources/high-altitude-emp-effects-protection, provides a description of the effect and of ways to protect equipment from EMPs.

[99] Arms Control Association (2019), ibid.

Kim Jong Un	Chairman and hereditary Supreme Leader of the DPRK. His father, Kim Jong Il, until his death in 2011, served as the DPRK leader following the 1994 death of his own father, Kim Il Sung, who founded the DPRK state in 1948.
Mass Fire	Interactions occurring when large areas are ignited and burning simultaneously.[100]
Megaton (MT)	A measure of the explosive power of a nuclear detonation equal to 1000 kilotons.
NEA	Northeast Asia.
NPT	Treaty on the Non-Proliferation of Nuclear Weapons.[101]
"Nuclear Umbrella"	Extension of nuclear deterrence by a nuclear weapons state that is in effect an implicit or explicit guarantee to defend a non-nuclear allied state.
NUDET	Detonation of a nuclear weapon or other nuclear explosive device that derives its explosive power, at least mostly, from nuclear fission and/or fusion reactions.
NWFZ	Nuclear Weapons-Free Zone.
NWS	Nuclear Weapons States (declared).[102]
PGM	Precision-guided munitions, or precision guided missiles, are guided munition (or missiles) intended to precisely hit a specific target. PGM are also sometimes called smart weapons, smart munitions, or smart bombs.
Plutonium	Element (symbol, Pu) found very seldom in nature, but produced by nuclear fission reactions when Uranium-238 reacts with a neutron to produce (mostly) Pu-239, which can be used to produce nuclear explosives (and in nuclear energy reactors).
PRC	People's Republic of China (China).
Prompt Effects	Impacts of a nuclear detonation occurring within a short time of the explosion, typically within seconds, minutes, or hours, but sometimes including deaths caused by the detonation but with victims not succumbing for days or weeks.
psi	Pounds per square inch (English units) measure of overpressure.
rad	Unit of absorbed ionizing radiation dose, defined as 1 rad = 0.01 Gray or 0.01 J/kg of body mass deposited by X-rays or gamma rays.
rem	"Roentgen equivalent man," defined as the dosage of radiation in rads that is the equivalent of one rad.

[100] Mark A. Finney and Sara S. McAllister (2011), ibid.

[101] See, for example, United Nations Office for Disarmament Affairs (undated, but between 2015 and 2020) "Treaty on the Non-Proliferation of Nuclear Weapons (NPT)," available as https://www.un.org/disarmament/wmd/nuclear/npt/

[102] Wikipedia (2022), "List of States with Nuclear Weapons," last updated January 6, 202, and available as https://en.wikipedia.org/wiki/List_of_states_with_nuclear_weapons, includes the following: "Five [states that have announced having nuclear weapons] are considered to be nuclear-weapon states (NWS) under the terms of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). In order of acquisition of nuclear weapons these are the United States, the Soviet Union (now Russia), the United Kingdom, France, and China."

Reprocessing	The processing of spent nuclear fuel to remove and separate out the plutonium (Pu-239) produced when neutrons from nuclear fission collide with uranium-238. The resulting plutonium can be used in "mixed oxide" fuel for nuclear energy reactors, but it can also be used to make nuclear weapons.
RF	Russian Federation (Russia).
ROE	Rules of engagement: "military directives meant to describe the circumstances under which ground, naval, and air forces will enter into and continue combat with opposing forces.[103]
ROK	Republic of Korea.
Sievert (Sv)	Unit of absorbed ionizing radiation, equal to 100 rem.
Thermonuclear	A device that derives explosive energy from nuclear fusion reactions, sometimes in combination with fission reactions.
TNT	2,4,6-Trinitrotoluene, a high-explosive chemical whose yield of energy when detonated is the basis for the definition of a "kiloton" of nuclear explosive yield.
UN Command	The United Nations Command (UNC or UN Command) is the multinational (conventional) military force that supported and supports the ROK during and after the Korean War.[104]
UNSC	United Nations Security Council.
Uranium	Natural element (U) found fairly widely in the earth's crust. The isotopic composition of natural uranium is about 0.7 percent uranium-235, which is radioactive, with almost all of the rest being U-238, which is stable.
US	United States of America.
USFK	United States Forces Korea—the name of the US military force stationed in the ROK.
Use Case	For the purposes of this report, a description of a case of nuclear weapons use starting with the detonation of one or more nuclear weapons in an attack or counterattack against a military opponent.
Weapons-grade U	Uranium-235 (typically) of a purity sufficient for use in a nuclear weapon, typically 90 percent U-235 or greater.
Yongbyon	Location of the DPRK's main nuclear weapons complex, including (at least) a "5 MW" reactor for producing plutonium, facilities for separating plutonium from spent fuel, a small research reactor, a uranium enrichment facility, and a recently built, but apparently not-yet used, experimental light-water reactor (ELWR) with an estimated capacity of about 25-30 MW (electric).

[103] Britannica, The Editors of Encyclopaedia (2016), "Rules of engagement." *Encyclopedia Britannica*, last edited 2016, available as https://www.britannica.com/topic/rules-of-engagement-military-directives

[104] See, for example, UN Command (undated) "Under One Flag," available as https://www.unc.mil/About/About-Us/

ANNEXES

Annex 1: Nuclear Use Cases Developed During and Subsequent to Project Year 1 from which Evaluated Use Cases Were Selected

Suite of use cases developed during and subsequent to project Year 1, and criteria for selecting use cases for further analysis

<u>Presentation of use cases</u>

Table A1-1 provides an overview of the key elements of the use cases presented in the Year 1 Report, plus the additional Russia as First User cases described above, and how the use cases are related. Details of these use cases are provided in the Year 1 Report (and above).

Use cases shaded in red are those that have been selected for quantitative analyses, as described below, and also appear with yellow check marks in Figure A1-1.

We emphasize that although we have designed these use cases to be plausible, they only provide examples of an essentially infinite set of potential circumstances in which nuclear weapons use could occur in the region. Moreover, each of these use cases could evolve in a multitude of ways, potentially involving different actors and targets. The 30 total use cases that we present below, and the five cases we evaluate quantitatively in this Report, are thus only a few examples of the wide and deep range of possible illustrations of what might happen once a nuclear conflict begins. We definitely do not assess that these use cases are **likely**, rather we posit and evaluate them here only to help learn about and demonstrate the potential range of impacts that a nuclear conflict might have, and ultimately, how policies to avoid nuclear use in the first place might be developed and implemented.

Table A1-1: Summary of Use Cases Considered

Use Case Title	Triggering Events and First Use	How the Conflict Evolves	Use Case Consequences	Uncertainties, Ultimate Outcome, Policy Lessons
"We're Still Here" Variant 1	Frustrated by lack of progress in negotiations, **DPRK** demonstrates a nuclear weapon on a low-value, non-military ROK target.	**US/UN Command** conventional attack on DPRK forces near DMZ, US nuclear attack on nuclear weapons targets in DPRK.	High-level US mission reassures China and Russia, engagement keeps exchange limited, leads to diplomacy, DPRK opening.	Would US/ROK be able to refrain from attacking DPRK leadership? Close call leads to renewed efforts at arms control. Lessons: Need to take stock of DPRK intentions before firing back, be ready to deploy high-level delegations to DPRK and China.
"We're Still Here" Variant 2	As above, but **DPRK** attack not carried out due to malfunction or timely, successful negotiation.	**US/UN Command** develop counterattack plan, but do not implement because of successful diplomacy.	China and Russia support DPRK engagement with international community, diplomacy re-starts.	
"We're Still Here" Variant 3	As in Variant 1, but **DPRK** attacks a US naval battle group offshore of the ROK with a nuclear missile fired from DPRK territory.	**United States** uses nuclear and conventional (with ROK) weapons on DPRK military and nuclear targets, in part at insistence of ROK and Japan.	Scale of US counterattack leads DPRK to begin conventional war on ROK, nuclear attacks on United States and Japan. United States attacks DPRK troops with low-yield weapons.	Would Russia and China be willing to stay out of the war? Would the Europe and others in the international community be able to mediate a crisis of this magnitude?
"The Best Defense is a Good Offense" Variant 1	Changes in United States and ROK behavior leave **DPRK** leadership convinced that an attack is imminent, and it launches what is effectively a preemptive strike on United States and ROK bases.	**US** responds with conventional attacks on military installations, nuclear weapons on ICBMs and other nuclear sites and on Pyongyang command bunker.	Remaining DPRK leadership offers terms for ceasing military conflict with international access to and control over DPRK's nuclear weapons in exchange for "Marshall Plan" for the DPRK. China and Russia stay out of war, but demand say in governing DPRK, maybe through UNSC.	DPRK nuclear mines on DMZ might leave Peninsula divided and badly damaged. Defeated DPRK leadership could inflict pain to ROK civilian populations, leaving Korea uninhabitable. Lessons: Importance of leadership, US attention, understanding between allies.
"The Best Defense is a Good Offense" Variant 2	As above, but with fraying of US/ROK Alliance.	As above, with **US** nuclear attack depending on analysis of DPRK ICBM capability at the time.		

Use Case Title	Triggering Events and First Use	How the Conflict Evolves	Use Case Consequences	Uncertainties, Ultimate Outcome, Policy Lessons
“The Best Defense is a Good Offense” Variant 3	As in Variant 1, but with triggering events including additional DPRK challenges on the domestic front, and with DPRK first use in the form of a covert attack on an ROK nuclear power plant to cause chaos in the ROK.	**United States/ROK leaders** conclude broader DPRK attack is imminent, ROK/US troops needed in ROK, so attack DPRK troops near DMZ, DPRK leadership with air bombardment, then nuclear weapons.	With its remaining arsenal, the DPRK uses conventional artillery and/or nuclear weapons on Seoul area, uses ICBMs on United States if operable Russia and China stay out of war, may respond to overflight of missiles, planes.	Additional to the above, lessons related to reactor security, provision of backup power for reactors, military, civilians that is separable from the main grid.
“Last Option for Survival” Variant 1	United States/ROK responds to social unrest in DPRK with troop incursion, **DPRK responds with nuclear** attack on ROK.	**US/UN Command counterattack** on nuclear weapons and other military sites in DPRK.	China and Russia mass troops at DPRK border, with some incursion by China, but no nuclear response.	May not be probable that USFK/ROK refrain from attacking DPRK leadership. Will China be compelled to protect DPRK? Lessons: Monitor conditions in DPRK, offer humanitarian support (international community).
“Last Option for Survival” Variant 2	Perceived or actual DPRK provocation spurs US/ROK conventional attack on DPRK leadership, induces **DPRK nuclear use on ROK**.	As above, but could include attack on DPRK leadership in Pyongyang if US casualties substantial.	Attack on Pyongyang causes China to at least threaten United States with ICBMs.	
“We’ve Got Them Where We Want Them”	**DPRK** takes advantage of slow-moving talks to invade ROK, **nuclear attack on US bases in ROK, Okinawa.**	**ROK asks United States** to use nuclear weapons on DPRK nuclear facilities, troop concentration, leadership bunkers.	China, Russia go on high alert, Japan comes into conflict, humanitarian crisis at DPRK/China border.	Would DPRK attack while negotiations underway? Would DPRK discount US counterattack possibility? Could US counterattacks be mistaken for attacks on China or Russia?
“Help Not Wanted”	As DPRK leadership loses control of its Northern areas due to bad economy and disasters/crop failures, Chinese forces enter to stabilize, and fearing being overrun, **DPRK**	**China** launches counterattacks aimed at DPRK weapons systems, including with nuclear missiles on deeply buried targets.	US/ROK and Russian troops go on alert, but do not move into DPRK while China is there, United States seeks treaty on northern Korean	Would DPRK fear China enough to attack with nuclear weapons? Would US/ROK troops come to the aid of northern DPRK rebels?

Use Case Title	Triggering Events and First Use	How the Conflict Evolves	Use Case Consequences	Uncertainties, Ultimate Outcome, Policy Lessons
	launches nuclear attack on China.		Peninsula governance with China, Russia.	Would Chinese nuclear strikes be mistaken by United States/Japan?
"The Best Defense is a Good Defense"	A ground war starts across the DMZ, and the **United States**, distracted by conflicts elsewhere, fears losing, mounts conventional (PGM) and nuclear strikes on DPRK weapons systems.	Fearing an attack on its leadership, the **DPRK** launches a nuclear attack on a US base in the ROK and/or Okinawa/Guam.	As in other cases above, China/Russia are eager to see the United States weakened but do not want to enter conflict themselves, accept US assurance that conflict limited to DPRK, future Korea governance deal.	Could US PGM weapons be deployed in time? Would the particular US president in power at the time use nuclear weapons first?
"US Leadership Hubris"	Overconfident **US** president is convinced that DPRK nuclear weapons can be destroyed without counterattack, **so attacks DPRK nuclear weapons systems.**	**DPRK** uses remaining nuclear weapons, counterattacks **ROK/Japan**, possibly by land or sea, to cause major damage and sue for peace. Possible DPRK attack on a Japanese reactor to cause chaos, induce truce.	China attacks with conventional weapons to keep US/ROK south of DMZ. If DPRK leadership attacked, China might attack United States with nuclear weapons.	Lack of communication by US/ROK with China/Russia might cause them to use nuclear weapons, trending toward global conflict. Lessons: Maintain secure procedures for war authorization that include those outside of leader's inner circle; consult with both allies and potential adversaries.
"Response to DPRK Proliferation"	Proliferation of DPRK nuclear technologies leads to NUDET elsewhere, **United States** blames DPRK and attacks **DPRK nuclear infrastructure.**	**DPRK** assumes attack on its leadership imminent, strikes US bases in ROK, other military targets, and possibly US targets if ICBMs advanced enough and survive attack.	If US attack seem as "unprovoked", China might come to DPRK aid, but probably with conventional forces designed to contain US/ROK on peninsula.	Would ROK condone attack on DPRK? Could nuclear forensics lead the United States to conclude that DPRK was responsible for original attack?

Use Case Title	<u>Triggering Events and First Use</u>	<u>How the Conflict Evolves</u>	<u>Use Case Consequences</u>	<u>Uncertainties, Ultimate Outcome, Policy Lessons</u>
"Tripped at the Finish Line"	Engagement and diplomacy with the DPRK going well, but tripped up by change of US leadership or unforeseen event, US miscalculation of DPRK reaction leads United States to attack DPRK nuclear missiles with PGM and nuclear missiles.	**DPRK** conventional bombardment of Seoul, **uses remaining nuclear weapons on US bases in region**, leading to full-scale war on the Peninsula.	China and Russia mass troops at border but stay out of conflict Japan may become involved if DPRK attacks Okinawa.	How would DPRK respond to late-game change in US diplomacy? Would China join if fallout damaged NE China? Would United States correctly identify DPRK brinksmanship and seek to reduce tensions?
"A Promise is a Promise" Variant 1	After worsening relations with Japan, DPRK launches HEMP over Tokyo, Japan demands **United States** respond with nuclear attack targeting DPRK leadership to remove possibility of counterattack.	With initial US attack on its leadership unsuccessful, **DPRK attacks Japan or ROK populations with nuclear weapons** so as to cause pain, possibly also using ICBMs on US territory. US renews attack on leadership with larger, penetrating weapons.	Original DPRK HEMP attack allows China to consider US nuclear attack "provoked." China (and Russia) go on alert, but do not directly intervene.	Could US attack modes (missiles from bombers, submarines, ships) be mistaken by China, Russia, for attacks on them? Major refugee crisis in the region likely (ROK and DPRK). Would Japan or ROK consider HEMP vs. chemical/biological attacks sufficiently different as to change whether they ask for US use of nuclear? Lessons: Build HEMP-resilient infrastructure, discuss with allies what kinds of attacks require nuclear response, work to avoid DPRK conditions triggering attack.
"A Promise is a Promise" Variant 2	As above, but ROK is focus of DPRK HEMP.			
"A Promise is a Promise" Variant 3	As in Variant 1, but DPRK delivers chemical and/or biological weapons to Japan.			
"Not Going Well in Taiwan"	Pro-independence government in Taiwan, trouble at home leads **China** to attack Taiwan, which is aided by US, but war goes poorly, so China launches nuclear attacks on US bases.	**US** attacks Chinese military sites threatening Taiwan with conventional weapons, attacks hardened nuclear sites in China (such as ICBM bases) **with nuclear weapons.**	Russia may stay out of conflict, but China likely counterattacks United States might ask NATO to come to its aid, involving Europe War may go global.	Unclear with the DPRK would do as it would likely be surrounded by fallout, but its survival (as with everyone else) would be in jeopardy

Use Case Title	Triggering Events and First Use	How the Conflict Evolves	Use Case Consequences	Uncertainties, Ultimate Outcome, Policy Lessons
"Threats to Russian SSBN Bastions"	Higher tensions over territorial disputes put Russian submarine corps on maximum alert, increased tempos, leads to a sub mistaking exercise or missile test for an attack, and launches nuclear missiles on US base on Okinawa.	United States, encouraged by Japan, attacks Russian Pacific Fleet headquarters and other Russian bases in the East. Russia attacks US Bases in ROK, elsewhere.	Absent extraordinary and timely communications, nuclear war expands to ICBM launch by both United States and Russia on each other's territory.	What standing orders would Russian Federation (RF) submarine commanders revert to in times of crisis? Lessons: Raise awareness Communications among militaries about interpretation of perceived actions.
"Dead Hand Error"	At a time of high tensions between Russia and the West, communications interruptions caused by a severe solar storm puts some Russian early warning radars offline, automated nuclear launch system mistake ROK space launch for nuclear attack on Russian bases, leading to launches on US bases in ROK.	**United States** nearly counterattacks Russia with nuclear weapons, but is persuaded not to by feverish diplomacy both by parties inside the US and by Russian officials and diplomats, Russian military concessions, and Russian offers of compensation payment to ROK.	Arms control talks are reinvigorated, as are security talks with the DPRK; DPRK economic reform initiated, Russian political and military reform begins.	Could a solar storm really affect Russian systems sufficiently to cause error? Could a US president be convinced to refrain from a counterattack? Lessons: Use extreme caution in using artificial intelligence in nuclear launch systems and improve nuclear-related communications between nuclear weapons states.
"Sending a Message, Eastern Doorstep" Variant 1		Possibly forewarned of the attack, US/NATO leadership set nuclear and conventional forces on high alert, and increase sanctions, but do not launch a nuclear counterattack.	Additional detonations of nuclear weapons just avoided via intense negotiation, which, along with increased Russian economic problems and dissent, force settlement of Ukraine conflict.	Could war really be avoided following a Russian Detonation? Would China take the opportunity to move on Taiwan? What positions would Japan and the ROK take on escalation? Could the Ukraine conflict really come to a resolution as in variant 1?

Use Case Title	Triggering Events and First Use	How the Conflict Evolves	Use Case Consequences	Uncertainties, Ultimate Outcome, Policy Lessons
"Sending a Message, Eastern Doorstep" Variant 2	Reversals of Russian military gains in the Ukraine conflict, plus the results of expanding dissent in Russia due to physical and economic hardships related to sanctions against Russia and the effort needed to sustain the conflict, cause Russian leadership to conclude that only nuclear weapons can reverse Russia's declining military fortunes and allow a face-saving conflict settlement.	United States/NATO/Japan believe the attack is meant as a prelude to an attack on military or civilian targets in the Far East, launch nuclear attack in reprisal on Russian Pacific Fleet targets	US attacks/Russian counterattacks bring on exchanges of ICBMs causing wide devastation in the US, Europe, Russia, and Northeast Asia, cripple world economy	Lessons: Importance of building mechanisms for communications between adversaries aggressive launch is perceived, and to limit second strikes.
"Conflict from Ukraine Spreads East"	To restrain Russia from using nuclear weapons in Northeast Asia, the **United States** bring more nuclear weapons back into the region, causing Russian nuclear forces in the region to go to a higher alert status, and ultimately, to attack US military assets with nuclear weapons.	United States launches a tactical nuclear attack on a Russian submarine base in the region, destroying the base as well as several surface vessels and submarines in port at the time.	US leadership announces targeting of key military and leadership locations in Russia, invoking of Article 5 of the NATO treaty. NATO forces move toward Western Russia but stop when Russia stands down its nuclear forces. Ultimately, domestic changes in Russia end the conflict without further nuclear use.	Would the United States stop at the destruction of Russian Far East bases and submarines? Would Russian nuclear forces hold their fire after the first nuclear exchange? How would Russian leadership respond to the situation? How do China, Japan, and the ROK respond? Lessons: Important roles of military-to-military communications between adversaries, restraint on using nuclear weapons by civilian leaders, communications between nations throughout both government and civil society if there is a major upheaval in leadership.

Use Case Title	<u>Triggering Events and First Use</u>	<u>How the Conflict Evolves</u>	<u>Use Case Consequences</u>	<u>Uncertainties, Ultimate Outcome, Policy Lessons</u>
"Broken Promises Leads to Breakout" Variant 1	New, hawkish leadership and loss of faith in US umbrella leads **Japan** to develop nuclear weapons and use them in response to DPRK provocations **on DPRK missile and nuclear infrastructure.**	**DPRK** replies with nuclear missile attack on **Japanese infrastructure** or with smuggled-in warhead to Japan if the DPRK's missile infrastructure isn't operable.	Attack fractures ROK/Japan relationship, United States caught in middle. China intervenes to slow flow of DPRK refugees with Chinese troops in DPRK. ROK takes lead in rebuilding the Korean peninsula if not too badly damaged.	ROK breakout also possible under similar conditions. Lessons: Unwise to think that entire DPRK nuclear arsenal can be destroyed by a targeted attack. Also, it may be unwise to expect that the DPRK population will embrace the ROK as the victor in a conflict between the Koreas.
"Broken Promises Leads to Breakout" Variant 2	For similar reasons to the above, the **ROK** develops nuclear weapons, uses low-yield warheads to strike at DPRK leadership.	As above, but with attacks focused on **ROK infrastructure.**		
Terrorist Nuclear Weapons use Potential Variant 1	Domestic or international terrorist organization detonates warhead in Tokyo—9/11-type event.	Terrorist group claims responsibility, but evidence points to DPRK proliferation**, United States** attacks DPRK nuclear sites as in "Promise is a Promise," at **Japan's request.**	Renewed attention on nonproliferation and antiterrorist initiatives. If DPRK blamed, series of nuclear exchanges United States to DPRK, DPRK to region and/or to United States.	
Nuclear Weapons use by Terrorists, Potential Variant 2	Domestic terrorist organization detonates warhead in Chinese city.	**China** attacks ethnic enclaves within China, possibly with nuclear weapons, might assume United States was behind attack and launch at a US carrier group sailing in the region.	China could obtain sympathy from international community, depending on whether it decides upon harsh collective punishment.	

Use Case Title	Triggering Events and First Use	How the Conflict Evolves	Use Case Consequences	Uncertainties, Ultimate Outcome, Policy Lessons
Nuclear Weapons use by Terrorists, Potential Variant 3	Cyberwarriors attack nuclear command-control, launches nuclear missile from China, Russia, or United States.	**Varying evolution** depending on when launch is detected, whether hacked nation warns targets, whether targeted nation assumes attack to have been launched on purpose by nation owning missiles.	If attack was assumed deliberate by targeted nation(s), result is probably an escalating series of exchanges. Other paths of evolution yield frantic diplomacy, more attention on safeguards, disarmament.	Would terrorist group be intercepted before detonation of device? If so, more emphasis on non-proliferation efforts, disruption of nuclear black market worldwide. Would domestic terrorists in China have organization, skills, money to carry out such an attack? Would Chinese punishment of ethnic groups spur Western countries to intervene on Chinese soil or pursue economic and political sanctions? Or lead instead to a joint response by the great powers? Policy lessons include: Intensify work on nonproliferation Improve international nuclear materials control Establish or strengthen hotlines to allow immediate reporting of hacked or accidental nuclear launches to targeted states

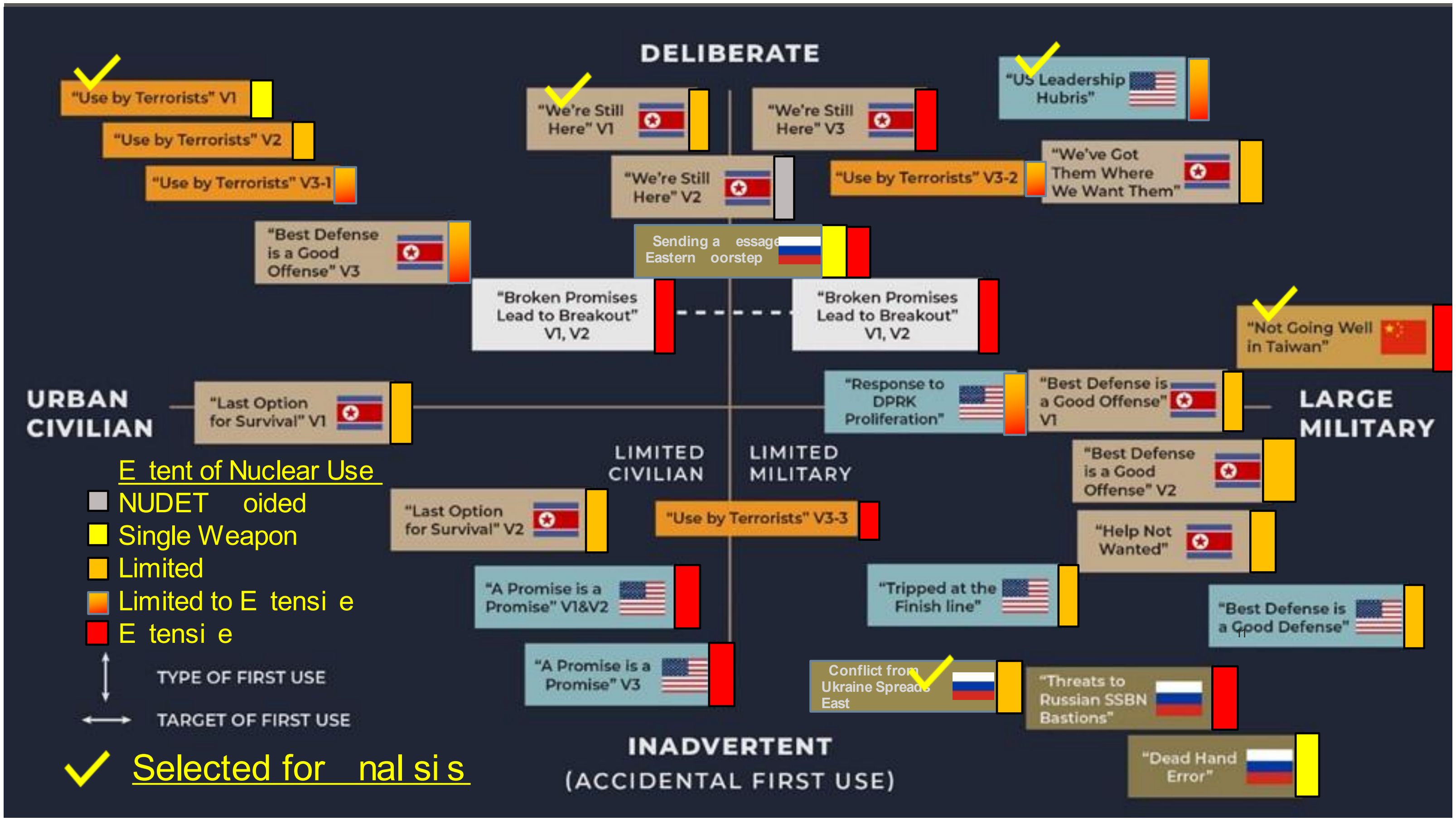


Figure A1-1: Nuclear Use Cases Assembled and Considered, and Use Cases Selected for Analysis

New use cases developed after Project Year 1 incorporating lessons from Ukraine Conflict

The (virtual) ink was barely dry on our Year 1 Report when the Ukraine conflict presented a set of circumstances that had not been fully anticipated among the set of 27 Year 1 Use Cases. These new circumstances suggested that the relatively few plausible use cases with Russia as the first user of nuclear weapons needed to be augmented, given what Russia's actions and statements in the Ukraine conflict might portend for its actions in NEA.

Although the lessons of the war in Ukraine are yet, as of this writing, to be fully learned, both by Russia and by the rest of the world, it is clear that nuclear war involving Russia is getting much more consideration than it was at the beginning of 2022. How might Russia's experience in Ukraine change how it might become a first user of nuclear weapons in NEA? The "Sending a Message, Eastern Doorstep" and "Conflict from Ukraine Spreads East" cases, provided below, develop two possibilities. These cases augment those presented in the Year 1 Report, namely:

- "Threats to Russian SSBN Bastions" case, in which a Russian submarine commander is confused by what is perceived to be a nuclear attack but is actually a weapons test or an exercise, and, unable to corroborate the situation with Pacific Fleet command, follows existing rules of engagement (ROE) and fires nuclear weapons on a US base in the region; and
- "Dead Hand Error," in which the growing capabilities of artificial intelligence (AI) as used in nuclear command and control by Russia, coupled with consideration of the 1980s Soviet "Dead Hand" system for launching nuclear weapons if military leadership were incapacitated, posits an accidental use of nuclear weapons when the AI system relied upon (in part, at least) by Russia to launch a retaliatory nuclear strike becomes convinced that enemy weapons are incoming and launches nuclear weapons in response.

<u>"Sending a Message, Eastern Doorstep"</u>

The combination of attrition and eroding morale in its armed forces, as the war with Ukraine continues, together with growing uncertainty about prevailing in the war and alarm about the NATO expansion that the war has induced, convince Russian leadership that only a nuclear detonation will allow it to negotiate an end to the war from a position of strength. Not wishing to use a nuclear weapon nearer to its own population centers in Eastern Europe (or near to NATO territory), it chooses the waters off the Russian Far East for a demonstration high-altitude nuclear detonation, delivered by a long-range missile (an ICBM) fired from a base in Siberia.[105] This detonation is in form similar to a nuclear test, but would mark the first time in nearly 60 years since the signatories of the Limited Test Ban Treaty of 1962, and over 40 years since any nation,

[105] This use case draws from ideas in Gregg Herken, Avner Cohen, and George M. Moore (2022), "Scenarios for How Putin Could Actually Use Nukes: Here's how to think about the unthinkable," *Politico*, dated May 16, 2022, and available as https://www.politico.com/news/magazine/2022/05/16/scenarios-putin-nukes-00032505. The authors of the Politico piece chose as the first of their scenarios a high-altitude, low-yield explosion over the old Soviet nuclear testing area of Novaya Zemlya, about 2000 km north and east of Moscow, but only about 1000 km from the territory of new-NATO-members-to-be Sweden and Finland (and of NATO member Norway).

has detonated a nuclear weapon in the atmosphere.[106] This nuclear first use would be categorized at the "deliberate" or "intentional" end of the spectrum.[107]

Triggering Events and First Use

As 2022 passes, the Russian invasion of Ukraine continues to make little headway. By the fall of 2022 Ukrainian forces, bolstered by weapons and supplies from the West, begin little by little to take back territory from Russian forces that are not receiving supplies and reinforcements as inspected, in part because of economic difficulties at home caused by sanctions on the Russian economy by Western nations. In early 2023, Russian forces are pushed back out of the destroyed port city of Mariupol, reversing a hard-won victory from May of 2022,[108] and once again cutting off land routes to the annexed Crimean Peninsula. Two more major warships of the Russian Black Sea Fleet are destroyed by Ukrainian forces.

These reversals, plus expanding dissent in Russia as winter arrives and economic hardships related to sanctions and the effort needed to sustain the conflict in Ukraine take their toll on the Russian population, cause an increasingly reclusive Vladimir Putin, the Russian leader, to conclude that only nuclear weapons can reverse Russia's declining military fortunes and put Russia in position for a face-saving settlement of the conflict. Calculating that a nuclear detonation in Europe, even if in a remote Arctic location such as the Soviet era test site in Novaya Zemlya, would result in sufficient outcry internationally—and perhaps more crucially, at home—that a settlement, and regime survival, would be out of reach,[109] Putin orders a high-altitude (but atmospheric) detonation of a low-yield nuclear weapon (from Russia's large arsenal of tactical nuclear weapons) in the waters off of the Russian Far East.[110] The site chosen, far from both NATO and almost all of the Russian population, is in the North Pacific, about 1000 km east (outside of) the Sea of Okhotsk, about 500 km south of Kamchatka, and therefore only slightly closer to Russian territory than to the easternmost US Aleutian island, Attu. The weapon is delivered by a "Sarmat" ICBM launched from a base in the Krasnoyarsk area, to which these

[106] See, for example, United Nations (undated, but after 2017), "International Day against Nuclear Tests: 29 August", available as https://www.un.org/en/observances/end-nuclear-tests-day/history

[107] Note that for the purposes of this case we are considering this high-altitude detonation as a "first use," although this designation is different than was used in the NU-NEA project Year 1 Report (*Possible Nuclear Use Cases in Northeast Asia: Implications for Reducing Nuclear Risk*) for a similarly-provocative high-altitude nuclear detonation by the DPRK. In the Variant 1 version of the "A Promise is a Promise" case in the Year 1 Report, for which the United States is called the first user, the US response is to a high-altitude electromagnetic pulse (HEMP) from a DPRK nuclear weapon detonated over Japan. We make a change in nomenclature for this Russian first use case in part due to a reconsideration, informed by input from other researchers, of what types of nuclear detonations ought to be defined as first use.

[108] See, for example, Reis Thebault, Paulina Firozi, Paulina Villegas, Amy Cheng, Jennifer Hassan, Ellen Francis, Andrew Jeong, and Julian Mark, "Ukraine abandons defense of besieged steel plant," *Washington Post*, dated May 17, 2022, and available as https://www.washingtonpost.com/world/2022/05/17/russia-ukraine-war-news-live-updates/

[109] Another possible trigger for Putin to order such a detonation might be his fear of an impending coup within the Kremlin, and/or pressure from Kremlin insiders to demonstrate Russian capabilities and resolve.

[110] Although such a detonation has not been carried out in 60 years by the United States or Russia, it is not unprecedented. See, for example, Rod Lyon (2017), "Nuclear tests involving ballistic missiles with live warheads," Australian Strategic Policy Institute, *The Strategist*, dated 7 December 2017, and available as https://www.aspistrategist.org.au/nuclear-tests-involving-ballistic-missiles-with-live-warheads/

missiles were to have been deployed in 2022.[111] The commander of the missile base at first refuses the order to fire, but is overruled, and perhaps even relieved of duty, by a Federal Security Service officer who has been recently posted at the base in case of such an eventuality, placed there based on his loyalty to Putin. The detonation is designed to both serve as a demonstration of the newly-deployed weapon and as a warning to the United States and its allies.

The remoteness of the blast site, the size of the weapon, and the altitude of detonation result in little damage to human infrastructure on the ground, and the resulting radiation, although dispersed worldwide, results in low enough concentrations so as not to cause significant human health concerns. A number of aircraft transiting in the area are affected by the EMP from the weapon, with two Japanese fighter jets on patrol and a trans-Pacific airliner, the daily Korean Air flight KE 24, heading for Inchon from San Francisco, each passing close enough to the blast to compromise their control systems, ultimately crashing into the sea with pilots and passengers killed.

How the Conflict Evolves

Following the launch of the ICBM, Putin orders submarines based in the Sea of Okhotsk to go to the open ocean, both to signal Russian resolve and to better protect the submarines from potential counterattack, enhancing their survivability and preserving them for a potential follow-on strike should the United States and its allies retaliate to the atmospheric detonation. From that point there are many possible variants as to how the conflict might evolve, of which two are described below.

Variant 1: Restraint

Perhaps tipped off in advance by trusted Russian sources that a nuclear detonation is imminent and is intended as a demonstration, not an attack, US and NATO leadership do not immediately assume that the missile launch is an attack, and set nuclear and conventional forces on high alert but do not launch a nuclear counterattack. Rather, and following the conclusions offered from the authors of the May 2022 *Politico* article,[112] US leadership, in consultation with other Western leaders (NATO) and those of Japan and the ROK, consider a nuclear response, but ultimately choose to "rally the nations of the world in a universal condemnation of Putin for breaking the nuclear taboo and taking the most dangerous first step toward a nuclear war." This would include doubling down on economic sanctions on Russia, doing everything short of physical attack on Russian assets to disable key military and economic infrastructure, and increasing military aid to Ukraine.

It is likely that the United States and its allies would only exercise this kind of restraint if leaders were in possession of reports that persuasively confirm that Russian intentions in ordering the nuclear detonation are in fact well-understood, which may require that the intelligence is in fact sourced from an individual who is known (by intelligence sources) to be fully briefed on Russian nuclear strike decision-making.[113]

[111] The flight from Siberia to the target site, at around 4500 km (ground distance), would be well within the 35,000 km (22,000 mile) range of the Sarmat ICBM. See, for example, *Al Jazeera* (2022), "Russia to deploy new intercontinental nuclear missiles by autumn", dated 23 April 2022, and available as https://www.aljazeera.com/news/2022/4/23/russia-to-deploy-sarmat-missiles-in-major-nuclear-upgrade

[112] Gregg Herken, Avner Cohen and George M. Moore (2022), ibid.

[113] In this variant of this use case, intelligence assurances at a sufficient level to keep Western leadership from responding militarily likely implies that someone in the Russian leadership inner circle would be passing

Faced with increased success by the Ukraine military, Russian troops start to leave their posts. At home, facing crippling sanctions and with economic difficulties very much in evidence in everyday life, pressure mounts for Russian leadership to step down, and after Putin disappears from public view, more moderate elements within the existing Russian leadership signal a willingness to begin to negotiate a cessation of hostilities, which is accepted by the United States, Ukraine, NATO, and their allies, ultimately fending off calls for military reprisals from factions in Japan and the ROK. Another possibility is that there is a coup against Putin, resulting in either his disappearance or his delivery to the International Criminal Court (ICC) to stand trial for war crimes committed in Ukraine. Presumably, in the latter case, the new Russian leadership's cooperation with the ICC would be part of a deal to spare other members of the Russian leadership prosecution for similar crimes.[114]

Variant 2: Reaction

In this variant, either the United States/NATO/Japan do not receive any warning of the launch or do receive warning but do not believe that the detonation is meant to be mostly a demonstration. Rather, when the launch is detected, first by Japanese early-warning systems on Hokkaido, command and control systems automatically ready US nuclear-tipped missiles in Alaska, and alert nuclear submarines in the area. With sufficient apparent evidence at hand to conclude, rightly or wrongly,[115] that the Russian launch is meant as the prelude to an attack on military or civilian targets in the Far East, the US leadership feels obliged, perhaps encouraged by Japan (as in the "Threats to Russian SSBN Bastions" use case, above), to launch a nuclear attack in reprisal on the Russian Pacific Fleet headquarters (and nearby airfields) in and near Vladivostok, and on the Kamchatka Peninsula. These attacks destroy the airfields there and much of the land-based fleet infrastructure, but most of the submarines and ships normally based there are at sea, and thus survive the attack. In response, and again as in the earlier use case, Russian submarines and ships fire conventional and nuclear missiles on other US bases in the region, including navy bases and airfields in the ROK.

The evidence that might lead the United States and its allies to conclude that the Russian launch is a prelude to a broader nuclear attack by Russian forces might include, for example, intercepted Russian nuclear alert orders, submarine fleet dispersion orders, identified warhead movement (from satellite images or other intelligence), and/or apparent strike orders intercepted to specific nuclear forces, which intelligence analysts with the ear of the US president cite (again, rightly or wrongly) as evidence of further preparation by Putin of next steps in nuclear escalation if the

information to the United States or NATO. It must be understood that the authors of this use case are merely positing this as a condition for restraint by the United States and its allies and have no knowledge of such information conduits one way or another, although such conduits have historical precedents.

[114] Note that if a coup resulted in a split in the Russian military, it could precipitate a very dangerous period in which the United States and NATO do not know who controls the Russian nuclear launch codes. Such a situation occurred during the period when a coup was mounted against Soviet President Mikael Gorbachev in 1991. See, for example, Sara Fritz and John M. Broder (1991), "COLUMN ONE: Nuclear Russian Roulette: The coup plotters briefly got their hands on Gorbachev's satchel that controls atomic weapons. And that's just the start of security worries in the crumbling Soviet Union," *Los Angeles Times*, dated August 31, 1991, and available as https://www.latimes.com/archives/la-xpm-1991-08-31-mn-1279-story.html

[115] The evidence that might lead the United States and its allies to conclude that the Russian launch as the prelude to a broader nuclear attack by Russian forces might include, for example, intercepted Russian nuclear alert orders, submarine fleet dispersion orders, identified warhead movement, and/or apparent strike orders intercepted to specific nuclear forces.

atmospheric nuclear detonation did not have the desired effect of forcing NATO to back off in Ukraine and/or the western front. Other desired effects of the nuclear detonation, from Putin's point of view, might include solidifying the support of Putin's inner circle of Russian leadership and flushing out generals who did not agree with Putin and/or other potential traitors who might mount a coup against his leadership. If the detonation does not (or does not sufficiently) strengthen Putin's position at home, Western analysts might conclude that Putin may be readying further nuclear escalation.

Use Case Consequences

In the "**Restraint**" variant (1) of this use case, additional detonations of nuclear weapons are avoided, if only just barely. A period of intense negotiation between Russia and the United States/NATO/Japan/the ROK ensues, during which Russian economic problems mount, and Russian troops first withdraw to territory held prior to February 2022, and then begin returning home. While negotiations are going on, opposition groups in Russia grow stronger and become political forces. As a result, Russian positions in negotiation change as Russian leadership changes. Ultimately, agreement is reached that resets Ukraine's borders back to pre-2014 conditions, specifies the governance of regions of Ukraine previously held by Russia, and sets a schedule for reparations to Ukraine from Russia for the damage caused by the war, paid for in part by seized and frozen Russian assets (state and private), and in part by funds deducted from European payments for resumed deliveries of Russian oil and gas, although those deliveries are at a much lower, and decreasing, level than was the case before the conflict in Ukraine. Russia also agrees to reduce its deployed forces in the NEA region, and to pay reparations to damages done in the region by the nuclear detonation. In return, a militarily and (likely) economically diminished Russia is allowed, in phases and over a probationary period of many years—during which democratic reforms are monitored by the international community—to rejoin international institutions. With new leadership in Russia, and with continued support in the United States, new nuclear arms control discussions begin and make progress. With its European oil and gas sales less lucrative, Russia is drawn back into discussions of trade in forms of renewable energy, including in NEA.

China, still battling COVID and (in part as a result) showing lower economic growth and starting to hear more domestic voices critical of the regime, focuses inward, refrains from escalating military confrontations in East Asia, and largely watches the negotiations between the United States/NATO and others and Russia play out. Although it does not join the new nuclear arms control discussions, at least in the short term, it does throttle back on building new nuclear weapons facilities, in part to avoid further international attention and in part to save money for domestic infrastructure investments.

The DPRK, facing a COVID crisis of its own, also substantially stays out of the conflict. With its supporters in Russia no longer willing or able to provide backing for a belligerent DPRK, and with DPRK leadership not relishing the thought of increased dependence on China, the DPRK uses the opportunity to request and receive a "reset" in its relations with the West, and embraces a slow, phased path toward engagement and threat reduction, including collaboration with the United States and with the DPRK's neighbors in the region on a range of energy and other initiatives.

The "**Reaction**" variant (2) of this use case results in a decidedly different outcome. US attacks on Russian bases, and resulting Russian counterattacks, bring on exchanges of ICBMs that leave major areas of the United States, Europe, Russia, and NEA in ruins and the world economy in tatters and effectively no longer functioning.

Use Case Uncertainties, Ultimate Outcome, and Policy Lessons

Uncertainties in this use case include:

- Would the United States and its allies be able to avoid escalating a nuclear conflict following the "demonstration" Russian nuclear detonation, as in Variant 1?
- Is it really possible that the type of first use described above will have relatively limited direct impacts?
- Would China refrain from taking advantage of US engagement with Russia and not, for example, increase pressure on Taiwan?
- Would Japan and/or the ROK encourage or discourage the United States from responding to a Russian "demonstration" with nuclear weapons?
- Is it possible that the end-game of a Ukraine conflict could really unfold as in Variant 1? That is, could Russian governance and international outlook change sufficiently to allow Russia to become once again an acceptable partner in the international community?
- Are there ways in which Variant 2 could be stopped short of nearly global nuclear war?

The ultimate outcomes of the two variants, following the threads above, could be as follows:

In Variant 1, Russian leadership becomes less erratic and provocative. Russia accepts a more collaborative, less aggressive role in the world order, and gradually is accepted as a more reliable partner in world affairs. China becomes less assertive with its neighbors and around the world after seeing what has happened in Russia (and to the Russian economy), and undergoes a gradual changing of its leadership, with a younger, more West-friendly group of leaders taking over, and gradually working toward offering more in the way of personal liberties for Chinese citizens. The DPRK is mindful of what has happened in Russia, but also notes that the United States and its partners did exercise restraint in Russia's case. Facing increasing difficulties with COVID and the economy at home, the DPRK's leadership comes back to negotiations, freezes its nuclear program, and over time, in exchange for economic and security guarantees, takes steps to reduce the threat posed by its nuclear weapons program.

In Variant 2, absent some restraint on United States/NATO and Russian second strikes, or a rapid breakthrough in negotiations that seems incompatible with recent leadership trends in Russia (at least), much of Europe, North America, and NEA would likely be devastated, as well as possibly Asian locations in Russia where ICBMs are located. Australia, as a US ally, might not be spared, and whether China could somehow stay out of the conflict is uncertain, and may depend on whether US warheads land near Chinese territory.

Initial policy lessons from this case include, as in the "Dead Hand Error" case, the importance of working to build in opportunities and mechanisms for communications between adversaries when an aggressive launch is perceived, and, if second strikes are initiated, to limit second strikes so that nuclear war does not go global.

“Conflict from Ukraine Spreads East”

Recognizing that Russia is a nuclear power on both the West and East ends of Eurasia, the United States and its Western allies seek to restrain Russia from using nuclear weapons in Northeast Asia. Even though they have not deployed troops to Ukrainian (or Russian or Belarusian) territory, the United States and NATO continue to retain and reinforce substantial deployments on the Eastern edge of NATO and continue to send arms into Ukraine in sufficient quantities that NATO’s supplies of weapons, and supply lines, are stretched. This leaves the United States with little additional manpower or conventional weapons inventory to deploy to counter rising threats from China, the DPRK, and Russia in Northeast Asia. As a result, and at the urging of a less DPRK-conciliatory government in the ROK and similar sentiments in Japan, the US bring more nuclear weapons back into the region, on submarines and ships, and places more nuclear-capable bombers in the region. This causes Russian nuclear forces in the region to go to a higher alert status, and ultimately, to attack US military assets with nuclear weapons. This first use is considered to be toward the “unintentional” end of the spectrum, because it is based on a miscalculation about the intent of the US and its allies in moving nuclear weapons to the region.

Triggering Events and First Use

With Russian nuclear forces in the region on high alert, and the Russian military and leadership feeling the strain of the impact of sanctions on the Russian economy building up within the Russian people, Russian leadership begins to see an excuse to escalate tensions to what it believes will be a survivable limited nuclear exchange. Russian leadership's intent is to use nuclear weapons in order to bolster support at home, but it wants to do so away from the population centers of western Russia. The excuse comes in the form of the participation of one or more US warships recently arrived in Northeast Asian waters in large joint US/ROK/Japan exercises, to be held in the late spring. The US warships are believed (or possible even announced) to be carrying nuclear weapons and to be outfitted for advanced anti-submarine warfare. Russia first states that it believes the exercise to be a prelude (or cover) for an attack on its nuclear submarine fleet and threatens the use of nuclear weapons if the exercise is not discontinued and the participating US warships withdrawn. When the US ships are not withdrawn, Russia uses nuclear weapons from a patrolling nuclear submarine on a naval base in the region hosting the ships, likely in Japan,[116] and on a flotilla of US and allied vessels at sea.

How the Conflict Evolves

The incoming missile targeting the flotilla of US and allied vessels is detected on launch, and the flotilla begins to scatter before the warhead on the missile is detonated. Although many of the vessels in the flotilla are disabled or sunk, several key vessels with antisubmarine capabilities survive, and, along with US and allied submarines and aircraft, immediately begin searching for Russian submarines in the region. In addition, the United States launches a tactical nuclear attack on a Russian submarine base in the region, destroying the base as well as several surface vessels and submarines in port at the time.

At this point, US leadership announces to Russia that is targeting key military and leadership locations in Russia, and also announces that it is invoking Article 5 of the NATO treaty,

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[116] But probably not in Okinawa, where the US doesn’t have a large naval presence—rather, for example, in Sasebo, near the southern end of the Japanese archipelago on Kyushu.

following the attack on its ships.[117] As a result, NATO forces begin to move toward Russia's western borders. At that point, however, heeding the pleas of ROK and Japanese leaders to try and engage in diplomacy before additional nuclear shots are fired, and mindful of China's movement to high alert status, the United States and NATO offers Russia an opportunity to avoid further exchanges of nuclear weapons if it stands its nuclear forces down. Although faced with war on two fronts and suffering from military attrition caused by the Ukraine war, Russian leadership initially resists the call to cease hostilities, but, perhaps with the intervention of commanders or other personnel directly responsible for using nuclear weapons, does not immediately fire additional nuclear weapons.

Use Case Consequences

Within days it becomes clear that Russian leadership has erred in assuming that its use of nuclear weapons would galvanize public support behind it, as massive public rallies in Moscow and other cities in Russia overwhelm security personnel, and Russian leadership goes into hiding as chaos reigns for several days. The United States and its allies watch the situation warily, and work to directly contact Russian military units in charge of Russia's nuclear weapons, indicating that although nuclear weapons locations in Russia are being targeted by US weapons, the United States does not intend to fire on those locations absent further provocation from Russia. An uneasy cessation of hostilities ensues, in which both sides pursue rescue and recovery operations in the areas that have been attacked.

China closely monitors the situation but makes no military moves. China nervously watches the movement of fallout from the attack on Okinawa to see if its coastal cities, including Wenzhou and Taizhou (each about 700 km from Okinawa, and with about 16 million residents between them) will need to be evacuated, although it is unlikely that fallout from that distance will pose a radiological hazard.

Within weeks, it becomes clear that, although there have been no official pronouncements, Russia's leadership has essentially abdicated, and as popular protests continue, formerly jailed or marginalized opposition leaders begin to take power in a process of reorganization of Russian governance that will ultimately take many months before the overall direction is clear, and longer before government systems are once again fully stable.

Use Case Uncertainties, Ultimate Outcome, and Policy Lessons

Uncertainties in this use case include:

- Would the United States stop at the destruction of Russian Far East bases and submarines?
- Would Russian nuclear forces hold their fire after the first nuclear exchange?
- Could a situation such as that outlined above become severe enough to induce Russian leadership to abdicate? Would key leaders need to be provided with personal security guarantees in order for an abdication to happen, and if so, would such guarantees be

[117] NATO (2022), "Collective defence - Article 5," last updated: 24 Mar. 2022, and available as https://www.nato.int/cps/en/natohq/topics_110496.htm

palatable to either the Russian people or the international community, particularly with the alleged war crimes during the Ukraine conflict in mind?

- As in other cases, would China refrain from taking advantage of US engagement with Russia and not, for example, increase pressure on Taiwan?
- Would Japan and/or the ROK encourage or discourage the United States from launching a broader attack on Russia?

The ultimate outcomes of this use case, following the processes set in motion as above, could be similar to the first variant of the "Sending a message…" case above, with Russian leadership, in this instance, having changed completely, becoming much more West-friendly, and gradually accepted again as a partner in world affairs, although likely not at the same level of importance as before. Russia and the United States restart nuclear disarmament talks in earnest and make significant progress on threat reduction. China also begins to experience turnover in its leadership, and as in the previous use case, could become more West-friendly. The DPRK, with Russia no longer likely to be a supporter at the same level as before (including much-reduced access to military hardware), invites a return to negotiations on its nuclear program, and those talks also ultimately result in nuclear threat reduction and the DPRK's economic opening to the international community.

Initial policy lessons from this case include, as in the other cases, the importance of working to build in opportunities, channels, and mechanisms for communications at a military-to-military level between adversaries so as to allow the nuclear conflict to be limited. For civilian leaders, remaining open to non-nuclear solutions to a conflict even in moments of crisis are crucial to enabling the avoidance of global nuclear war. And communications throughout both government and civil society between nations—in this case, critically, between Russia, the United States, and China—will be needed to follow and understand what will be an extremely fluid situation if there is a major upheaval in leadership in Russia or any other nation with a major military.

Annex 2: Use Case Elaborations

Augmenting the tables of parameters and summary descriptions provided in section 3 of this report, more detailed narrative elaborations of the evolution of each of the five use cases evaluated are provided below.

"We're Still Here" Variant 1 (Evaluated Use Case 1):

Notes and References, First Use:

The DPRK first use target is the village of Daejin, but the detonation is centered about 500 m offshore, meaning significant damage but not over an extensive area. The HOB of the detonation is designed to limit damage and fallout. The yield (single-stage fission) is at the lower end of assumptions by H. Kristensen/M. Korda regarding the yield range of most DPRK weapons as of 2021.[118] The missile used is assumed to be a short-range type that the United States has designated as KN-23, similar to the Russian Iskander-M missile,[119] with an accuracy of 100-200 m.[120] The time of attack (early afternoon) is designed to create a spectacle.

Notes and References, First Response Detonations:

The United States response targets for nuclear weapons in this use case are the suspected ballistic missiles facilities in the Sino-ri area and at Sangnam-ni.[121] Yield for US responses is assumed to be at the upper end of "low yield" in weapons of adjustable yield such as the submarine ballistic missile warhead W76-2 apparently deployed during the Trump administration.[122] Different sources list various yields for the warheads, including "5 kT," "5-7 kT," and "8 kT." We provisionally use the upper end of this range. Time of attack is in the middle of the night to reduce potential for detection and for movement of missiles from sites by DPRK forces.

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[118] Hans M. Kristensen, Matt Korda (2021), North Korean nuclear weapons, *Bulletin of the Atomic Scientists,* Volume 77, 2021 - Issue 4, pages 222-236, published online: 21 Jul 2021, and available as https://www.tandfonline.com/doi/full/10.1080/00963402.2021.1940803

[119] Missile Defense Advocacy Alliance (2022), "Missile Threat and Proliferation: KN-23," available as https://missiledefenseadvocacy.org/missile-threat-and-proliferation/todays-missile-threat/north-korea/kn-23/

[120] Michael Elleman (2019), *North Korea's New Short-Range Missiles: A Technical Evaluation*, 38 North, dated October 9, 2019, and available as https://www.38north.org/2019/10/melleman100919/

[121] NIKKEI Asia (undated, but probably 2019), "A satellite view of North Korea's nuclear sites", available as https://asia.nikkei.com/static/vdata/north-korea-nuclear/newsgraphics/north-korea-nuclear/, quoting CSIS/Beyond Parallel/Digital Globe 2019.

[122] See, for example, Alex Wellerstein (2022), "Low-Yield Nukes Are Still Dangerously Destructive," Outrider, dated May 25, 2022, and available as https://outrider.org/nuclear-weapons/articles/low-yield-nukes-are-still-dangerously-destructive; Joseph S. Bermudez Jr., Victor Cha and Lisa Collins (2019), "Undeclared North Korea: The Sangnam-ni Missile Operating Base", *Beyond Parallel*, CSIS, dated February 15, 2019, and available as https://beyondparallel.csis.org/undeclared-north-korea-sangnam-ni-missile-operating-base/, and William M. Arkin and Hans M. Kristensen (2020), *US Deploys New Low-Yield Nuclear Submarine Warhead*, Federation of American Scientists, dated January 29, 2020, and available as https://fas.org/blogs/security/2020/01/w76-2deployed/

<u>"US Leadership Hubris" (Evaluated Use Case 2):</u>

Notes and References, First Use:

The United States targets nuclear weapons and related facilities are the suspected ballistic missiles facilities in the Sino-ri area and at Sangnam-ni, a suspected enrichment facility at Kangson, south and west of Pyongyang, and the known enrichment and plutonium production facilities at Yongbyon.[123] In addition, the United States targets a suspected military bunker on the other (Northeast) side of Pyongyang, east of Mt. Taesong, a site described as "[t]his hill has been turned into the fortress with underground bunkers, AAA and SAM batteries, artillery positions and even ballistic missile launch site."[124] Yield for initial US weapons is assumed to be at the upper end of "low yield," such as the submarine ballistic missile warhead W76-2 apparently deployed during the Trump administration.[125] These targets close to (but not in) Pyongyang are selected by US military planners in part to cause "shock and awe" among DPRK citizens.

Notes and References, First Response Detonations:

Following the US attack, the DPRK is able to get several of its hidden ballistic missiles launched and points them toward US military targets. Only one gets through (others are shot down by ROK missile defense systems or fail to function properly), at Camp Humphries in the ROK. At the same time, infiltration missions are set in motion to launch sea-based clandestine attacks in small ships using DPRK special forces to attack mixed military-industrial targets in the ROK and Japan. Two of these are successful, one in the Incheon area of the ROK and one in Yokohama, Japan.

Notes and References, Additional Detonations:

Following the DPRK attacks on their territories, the ROK and Japan insist that the US launch a nuclear attack against the DPRK leadership. Intelligence credible to the US administration places DPRK leadership either at the Changsuwon Palace near Pyongyang or near Wonsan. Because leadership has thought to have retreated to a deeply-buried bunker in one of those locations, both are bombed with B61-12 nuclear bombs with earth-penetrating capability, with yields set at 50 kT.[126] Sources suggest the accuracy of this weapon is 30 meters. This attack would presumably take place by an airstrike, possibly using a B-2 or other type of bomber from Alaska or the US mainland, once DPRK air power and air defenses were largely neutralized by US/ROK conventional weapons. The attacks are assumed to be carried out before dawn to reduce risk to aircraft and enhance the probability of targets being in residence.

The attack on Pyongyang, and specifically, on DPRK leadership targets, brings China into the war, with two successful attacks on Air Force and Marine bases on Okinawa (Kadema AFB and Camp Schwab), and possibly some additional attempted attacks intercepted. China uses 200 kT

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[123] NIKKEI Asia, ibid.

[124] Wikimapia (2017), "Fortress (Pyongyang)," available as http://wikimapia.org/73770/Fortress.

[125] Wellerstein (2022), ibid, and Bermudez et al (2019), ibid.

[126] Hans Kristensen, "Video Shows Earth-Penetrating Capability of B61-12 Nuclear Bomb," Federation of American Scientists, dated, January 14, 2016, and available as https://fas.org/blogs/security/2016/01/b61-12_earth-penetration/; Airforce Technology (2020), "B61-12 Nuclear Bomb," dated November 6 2020, and available as https://www.airforce-technology.com/projects/b61-12-nuclear-bomb/; and Hans M. Kristensen and Robert S. Norris (2014), "The B61 family of nuclear bombs," *Bulletin of the Atomic Scientists*, 70:3, pages 79-84, available as https://www.tandfonline.com/doi/pdf/10.1177/0096340214531546

warheads launched from submarines or using land-based missiles.[127] China also uses ICBMs to attack Joint base Elmendorf Richardson in Alaska,[128] which it claims is the origin of the US nuclear weapons used in the DPRK, and Ellsworth Air Force Base in South Dakota, hoping to reduce US ability to attack Chinese targets with nuclear bombers, and to try and avoid an exchange of weapons that might target national leadership. China also attacks the Norfolk Naval Base in Virginia, however, catching two aircraft carriers in port. China uses ground-based missiles to hit those targets, with an assumed size of 300 kT. Weapons are launched in the early morning hours; those targeting the United States arrive around the middle of the day.

One day after the Chinese attacks on US territory, the United States responds with ICBM attacks on several sites. Those that succeed are as follows. The first is on the Datong-409 Brigade and Datong Airbase (Lanzhou Airport),[129] which is a major missile site and apparently a military (as well as clearly civilian) airport. There is a major, fairly new uranium enrichment facility at Lanzhou, but it is 40 km away and probably would not be affected by a strike at the Datong Airbase unless it were directly targeted. The second is on a reported long-range missile site at Xuanhua, outside of Beijing.[130] The third is near the Southern Theater Command Navy headquarters in Zhanjiang, Guangdong Province. We assume these attacks use W87 warheads with yields of 300 kT.[131] These warheads are assumed to be launched on ICBMS and arrive at night.

<u>"Use by Terrorists" Variant 1 (Evaluated Use Case 3):</u>

Notes and References, First Use:

A terrorist group obtains a bomb, possibly from the DPRK, but possibly from Russia or another source, and brings it in overland and/or by ship/boat to an area near the Tokyo waterfront. In this example, a location near the Shinbashi train is the target, and rush-hour timing on a weekday is chosen for maximum effect. The weapon is brought in by small boat at night to an area a few hundred meters from the target, then moved on a cart or in a small truck to the target area, where it is concealed for remote detonation. Nuclear forensic analysis of residual plutonium from the bomb, although not completed for months after the detonation, points to the DPRK, but it is not strong enough to be unequivocal. The DPRK denies any role in the attack or in providing weapons for the attack. Responsibility for the attack is claimed by a stateless terrorist group.

The combination of the DPRK's denials, the lack of clear evidence identifying DPRK proliferation as the source of bomb materials, and the DPRK's offers to assist Japan in recovering

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[127] See Wikipedia (2023), "China and weapons of mass destruction," available as https://en.wikipedia.org/wiki/China_and_weapons_of_mass_destruction, quoting a 2006 report by Hans M. Kristensen, Robert S. Norris, and Matthew G. McKinzie.

[128] Wikipedia (2023), "Joint Base Elmendorf–Richardson," available as https://en.wikipedia.org/wiki/Joint_Base_Elmendorf%E2%80%93Richardson

[129] Cryptome.org (2008), "People's Republic of China Nuclear Weapons Facilities, Eyeball: Vertical Shaft Testing Facilities, Near Hsin-ko-erh," reference and photo, dated 28 May 2008, available as https://cryptome.org/eyeball/prc-nukes/prc-nukes.htm

[130] Atomic Archive (2023), "PRC's Nuclear Facilities", available as https://www.atomicarchive.com/almanac/facilities/prc-facilities.html

[131] See, for example, Minutemanmissile,com (undated, but possibly 2011), "Minuteman Missile Nuclear Warheads: W59 Warhead," available as https://minutemanmissile.com/nuclearwarheads.html; and Center for Arms Control and Non-Proliferation (2021, updated January 2023), "Fact Sheet: U.S. Intercontinental Ballistic Missiles," available as https://armscontrolcenter.org/fact-sheet-u-s-intercontinental-ballistic-missiles/

from the detonation and general pro-engagement attitude following the detonation convince the United States not to attempt to punish the DPRK using nuclear weapons.

<u>"Conflict from Ukraine Spreads East" (Evaluated Use Case 4)</u>:

Notes and References, First Use:

Deciding that an attack on their bases was imminent, due to changes in US deployment of nuclear weapons in the region, Russia attacks the US naval base at Sasebo with an RSM-56 "Bulava" multiple (in this case, 3)-warhead submarine-launched ballistic missile.[132] This particular missile has been the result of an expensive program of recent development, so as a minor consideration in the use case, the use of the RSM-56 may be helpful in domestic politics for Russia. Russia also attacks a flotilla of US and Japanese ships gathered in the Sea of Japan (as they did in April of 2022[133]) with a pair of RK-55 Granat (SS-N-21) cruise missiles, also launched from submarines.[134]

Notes and References, First Response Detonations:

The United States uses submarine-launched tactical nuclear weapons to attack the Russian submarine base at Petropavlovsk-Kamchatskiy and two naval bases in Vladivostok.[135] Assurances prior to firing keep the Chinese from retaliating, although they are not happy to have nuclear detonations so close to their territory, nor are the DPRK, although the latter also do not respond militarily.[136]

"Not Going Well in Taiwan" (Evaluated Use Case 5):

Notes and References, First Use:

Before the 2024 election in Taiwan, China attacks the island in September of 2023.[137] China attacks Taiwan's perimeter defenses, but suffers significant setbacks, including the loss of airfields in Fujian Province and the loss of significant naval ships, when the United States and its allies, including forces from the ROK and Japan, come to the aid of Taiwan. Considering the US attacks an attack on China, China decides to use nuclear weapons on US military targets in the

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[132] Also called SS-N-32, see Wikipedia (2023), https://en.wikipedia.org/wiki/RSM-56_Bulava, and https://sgp.fas.org/crs/nuke/R45861.pdf

[133] See Mari Yamaguchi (2022), "Japan, US Hold Navy Drills Off Koreas Amid Nuke Test Worry," *The Diplomat*, dated
April 13, 2022, and available as https://thediplomat.com/2022/04/japan-us-hold-navy-drills-off-koreas-amid-nuke-test-worry/

[134] CSIS Missile Threat Project (2021), "RK-55 Granat (SS-N-21)," MissileThreat, dated August 2, 2021, and available as https://missilethreat.csis.org/missile/ss-n-21/

[135] Federation of American Scientists (2000), "Pacific Fleet," updated September 07, 2000, and available as https://nuke.fas.org/guide/russia/agency/mf-pacific.htm

[136] See also Wesley Culp (2022), "Russia's Submarine Fleet In the Pacific Should Make the Navy Sweat", *1945*, dated May 23, 2022, and available as https://www.19fortyfive.com/2022/05/submarines-russia-pacific-expansion/, and David Scott (2022), "Russian Naval Strategy for the Indo-Pacific", dated April 14, 2022, and available as https://cimsec.org/russian-naval-strategy-for-the-indo-pacific/

[137] See, for example Keoni Everington (2022), "US Navy head says China could attack Taiwan before 2024," *Taiwan News*, dated October 21, 20223, and available as https://www.taiwannews.com.tw/en/news/4693479

region, including the naval base at Sasebo, a base on Okinawa, and bases on Guam, in large part to deter US reinforcements for the conflict around Taiwan.[138]

Notes and References, First Response Detonations:

The United States determines that some of the weapons used to attack its bases were fired from a site south of Qingzhou,[139] and uses submarine-launched nuclear weapons with relatively low yields to destroy that site and another missile base in Xinyang.[140] It uses larger "bunker busting" weapons on the new ICBM sites in western China in an attempt to limit the degree to which China can retaliate on the US with ICBMs.[141] The US also attacks a known nuclear missile base in Tianshui.[142]

Notes and References, Additional Detonations:

In reprisal for US attacks on its missile facilities, and to reduce US air power in the region, China attacks the Kunsan and Osan Air Force Bases in the ROK, the latter on the outskirts of Seoul.[143]

"The US responds, somewhat as in ""US Leadership Hubris"", with ICBM attacks on several sites. Those that succeed in this case are as follows. The first is on the Datong-409 Brigade and Datong Airbase (Lanzhou Airport--reference and photo, which is a major missile site and apparently a military (as well as clearly civilian) airport.[144] The second is on a reported (as of 2010, anyway[145]) major nuclear weapons storage site near Taibai, in Shaanxi Province, although as it is unclear if the exact location of this reportedly deeply buried site is known, the attack is on the Taibai county town thought to be near the site in the hopes of damaging local infrastructure sufficiently to make moving weapons out of storage difficult. The third is near the Southern Theater Command Navy headquarters in Zhanjiang, Guangdong Province. We assume these

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[138] References for Missiles and targets: Hans M. Kristensen and Matt Korda, "Nuclear Notebook: Chinese nuclear forces, 2021", *Bulletin of the Atomic Scientists*, dated November 15, 2021, and available as https://thebulletin.org/premium/2021-11/nuclear-notebook-chinese-nuclear-forces-2021/; Brad Lendon (2020), "US Air Force pulls bombers from Guam," *CNN*, dated April 24, 2020, and available as https://www.cnn.com/2020/04/24/asia/guam-us-air-force-bombers-pull-out-intl-hnk/index.html; and US Government Accountability Office (2017), "The Evolving U.S. Military Presence on Guam," dated June 15, 2017, and available as https://www.gao.gov/blog/2017/06/15/the-evolving-u-s-military-presence-on-guam]

[139] Hans Kristensen (2020), "China's New DF-26 Missile Shows Up At Base In Eastern China," Federation of American Scientists, dated January 21, 2020, and available as https://fas.org/blogs/security/2020/01/df-26deployment/

[140] GlobalSecurity.org (undated, but probably 2018), "666 Brigade - DF-26, Xinyang City, Henan Province, 32.168633, 114.125817," available as https://www.globalsecurity.org/wmd/world/china/xinyang.htm

[141] Matt Korda and Hans Kristensen (2021), "China Is Building A Second Nuclear Missile Silo Field," Federation of American Scientists, dated July 26, 2021, and available as https://fas.org/blogs/security/2021/07/china-is-building-a-second-nuclear-missile-silo-field/; and Shannon Bugos and Julia Masterson (2021), "New Chinese Missile Silo Fields Discovered", *Arms Control Today,* dated September 2021, and available as https://www.armscontrol.org/act/2021-09/news/new-chinese-missile-silo-fields-discovered

[142] Jeffrey Lewis, David Joël La Boon, and Decker Eveleth (2020), "China's Growing Missile Arsenal and the Risk of a 'Taiwan Missile Crisis'", NTI, dated Nov 18, 2020, and available as https://www.nti.org/analysis/articles/chinas-growing-missile-arsenal-and-the-risk-of-a-taiwan-missile-crisis/

[143] East USA.com (undated, but probably 2014), "US military bases in South Korea," available as https://east-usa.com/us-military-bases-in-south-korea-on-map.html

[144] cryptome.org (2008), ibid.

[145] Mark A. Stokes (2010), *China's Nuclear Warhead Storage and Handling System*, Project 2049, dated March 12, 2010, and available as https://project2049.net/wp-content/uploads/2018/05/chinas_nuclear_warhead_storage_and_handling_system.pdf

attacks use W87 warheads with yields of 300 kT.[146]. As in Evaluated Use Case 2, these warheads are assumed to be launched on ICBMs, and arrive at night.

China's response to the US counterattacks, somewhat as in the "US Leadership Hubris" case, uses ICBMs to attack Joint base Elmendorf Richardson in Alaska,[147] which it claims is the origin of the US nuclear weapons used in the DPRK, and Ellsworth Air Force Base in South Dakota, hoping to reduce US ability to attack Chinese targets with nuclear bombers, and to try and avoid an exchange of weapons that might target national leadership. China also attacks the Norfolk Naval base in Virginia, however, catching two aircraft carriers in port. China uses ground-based missiles to hit those targets, with an assumed size of 300 kT. Weapons are launched in the early morning hours; those targeting the United States arrive around the middle of the day. China also attacks the Yokosuka Naval base, south of Tokyo, with a 200 kT weapon. Note that although we are not choosing to model more attacks, these are unlikely to be the last detonations in this conflict by the US, China, and possibly, ultimately, other participants.

[146] Minutemanmissile,com, ibid, and Center for Arms Control and Non-Proliferation (2021, updated January 2023), ibid.

[147] Wikipedia (2023), "Joint Base Elmendorf–Richardson," available as https://en.wikipedia.org/wiki/Joint_Base_Elmendorf%E2%80%93Richardson)

Annex 3: Additional Results of Use Cases Evaluation

The following presents tables and maps providing detail on results for each of the detonations included in the use cases described above.

"We're Still Here" Variant 1 (Use Case 1):

Maps of impact contours for prompt radiation, thermal fluence, overpressure, and firestorm, Use Case 1.

Figure A3-1: Use Case 1, FUD-1, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: (firestorm not possible due to overwater detonation)

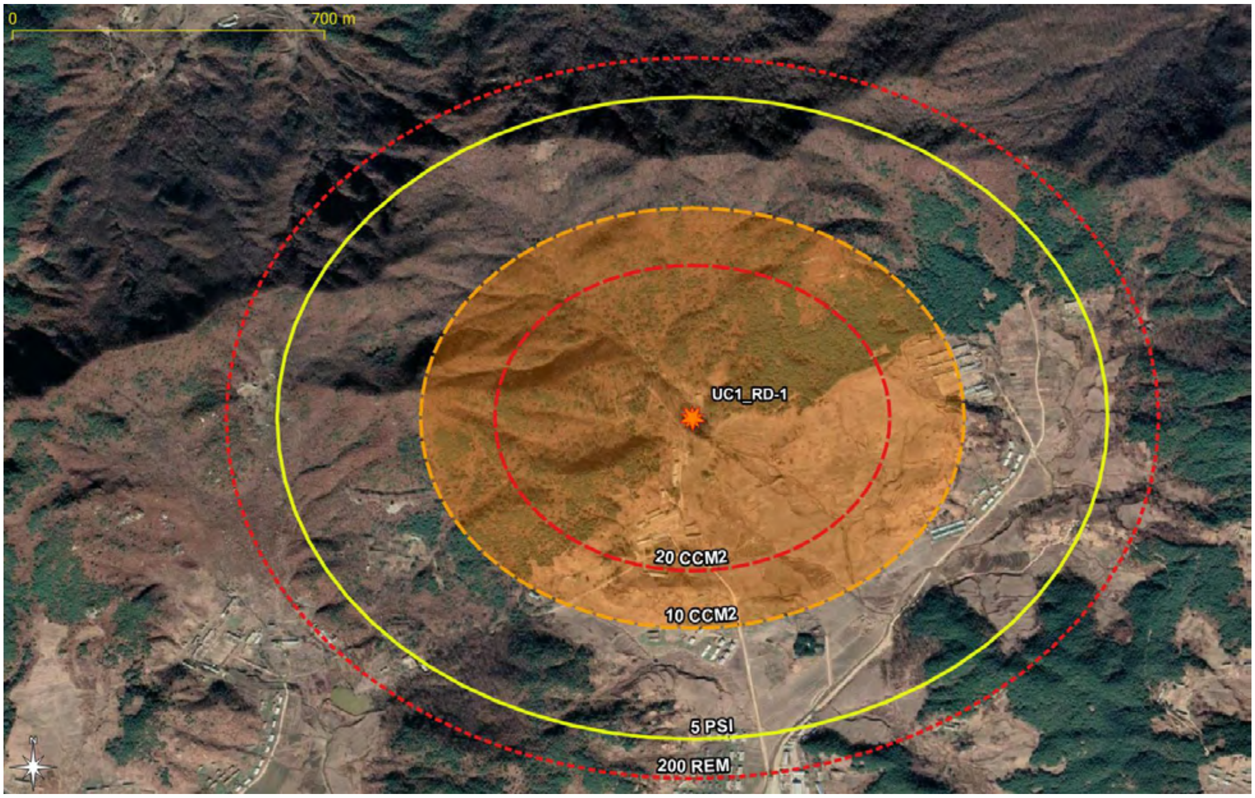


Figure A3-2: Use Case 1, RD-1, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Contour over combination of low-density forests and fields, in rugged terrain, fuels not sufficient for firestorm, rugged (but forest/fields fires probable).

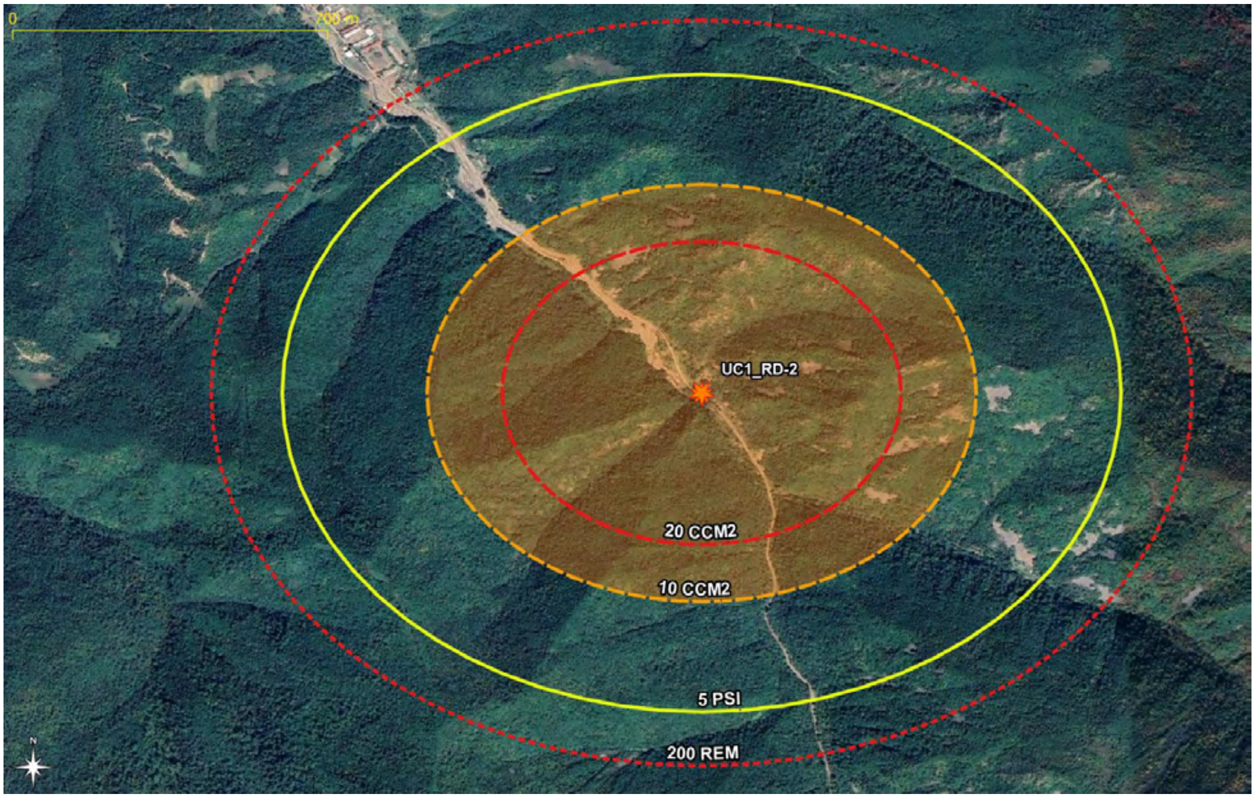


Figure A3-3: Use Case 1, RD-2, Potential Ranges of Potential Firestorm and Other Likely Lethal Impacts.

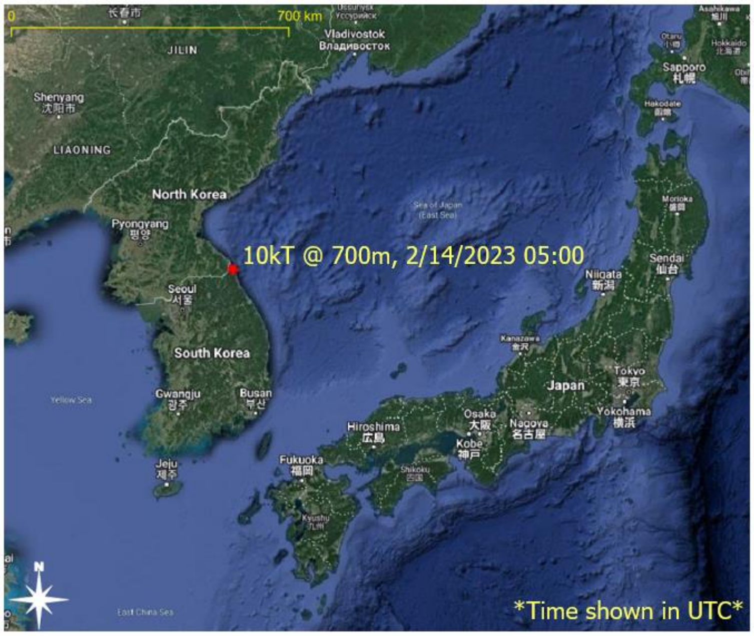
Firestorm potential assessment: Contour over medium density forest with rugged terrain probably not sufficient fuel for firestorm (but forest fires probable).

Summary of Estimated Overall Likely Deaths and Eventual Cancer Deaths in Use Case 1 from Different Impacts All Detonations:

Table A3-1: Estimated Likely Deaths, Use Case 1

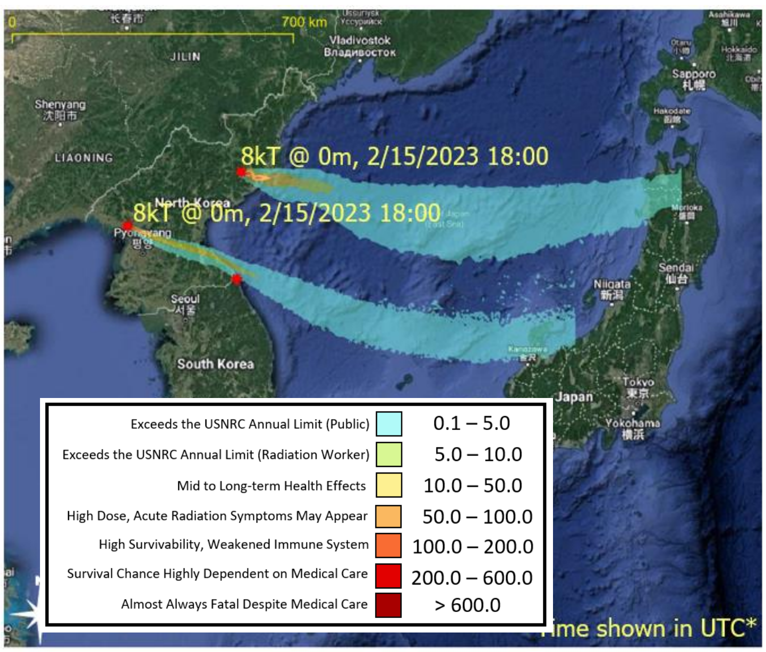
Estimated Likely Deaths: Use Case 1 (8-10 kT)	
Prompt (days to weeks)	5,500
Short-Term (weeks to months)	5,600
Additional Impact: Firestorms	Firestorm Unlikely
Total (0.5 psi Zone) (Total Pop., % Lethality)	**11,000** (41,000, 27%)
High Radiation Fallout Dose (short-term)	Low Fallout
Radiation-Induced Cancer Deaths (long-term)	**16,000 - 36,000**

Nuclear Fallout Simulation Results: Use Case 1



"We're Still Here" Variant 1 First Use Detonations : Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	0
10-50	0
50-100	0
100-200	0
200-600	0
> 600	0

Figure A3-4: Use Case 1, First Use Detonations, Fallout Modelling Results.



"We're Still Here" Variant 1 First Use Detonations : Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	370,000
10-50	850,000
50-100	290,000
100-200	23,000
200-600	0
> 600	0

Figure A3-5: Use Case 1, All Detonations, Fallout Modelling Results.

“US Leadership Hubris,” Use Case 2:

Maps of impact contours for prompt radiation, thermal fluence, overpressure, and firestorm, Use Case 2.

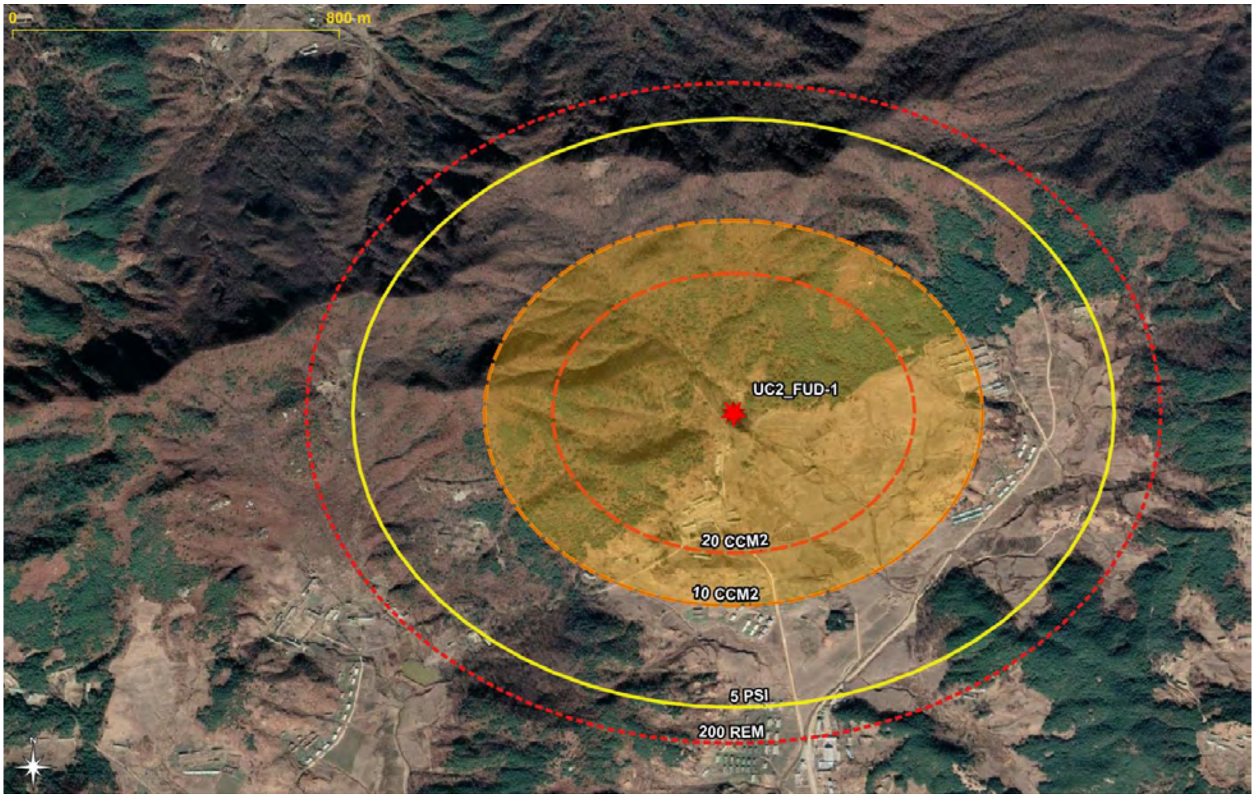


Figure A3-6: Use Case 2, FUD-1, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: The >10 cal/cm^2 contour is largely over fields and sparse forest with few buildings, thus the overall density of fuel probably is too low to form a firestorm, although individual fires will destroy forests and residential areas.

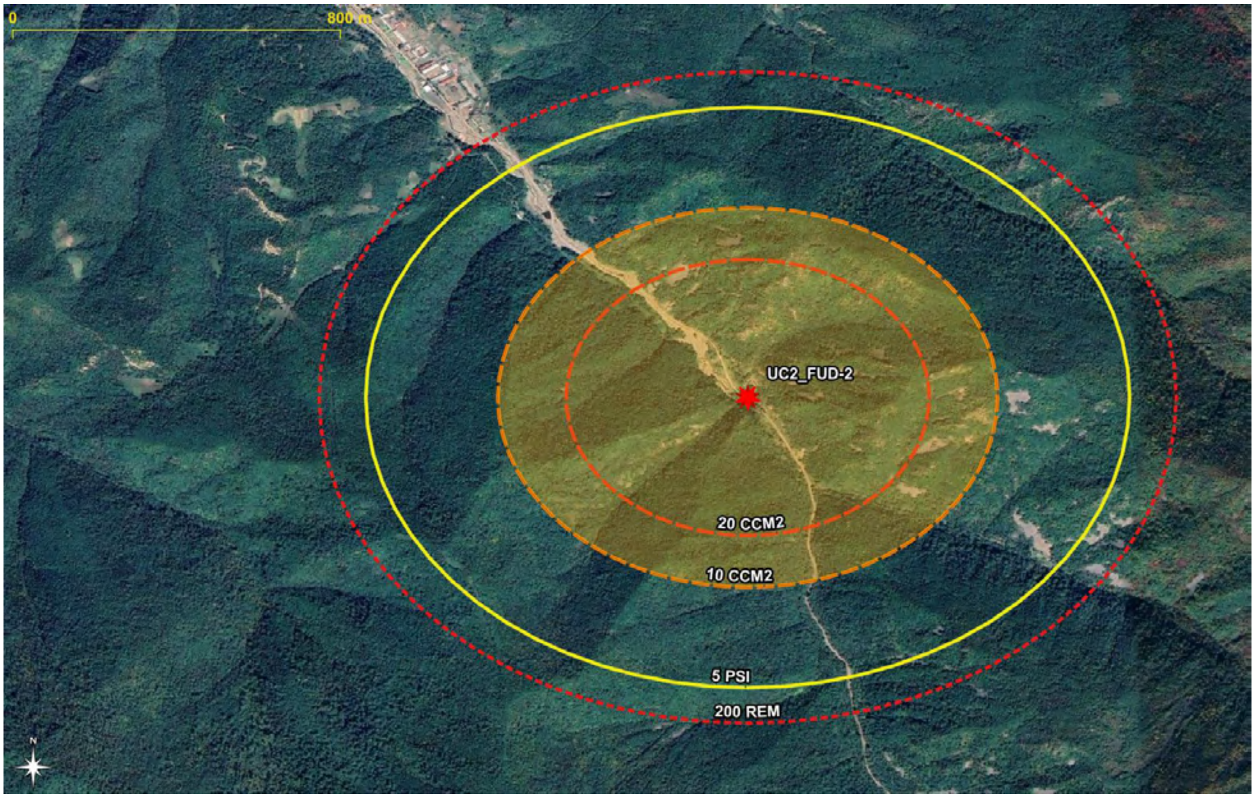


Figure A3-7: Use Case 2, FUD-2, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: The >10 cal/cm^2 contour is over medium density forest with rugged terrain and probably does not provide sufficient fuel for firestorm (but forest fires are probable).

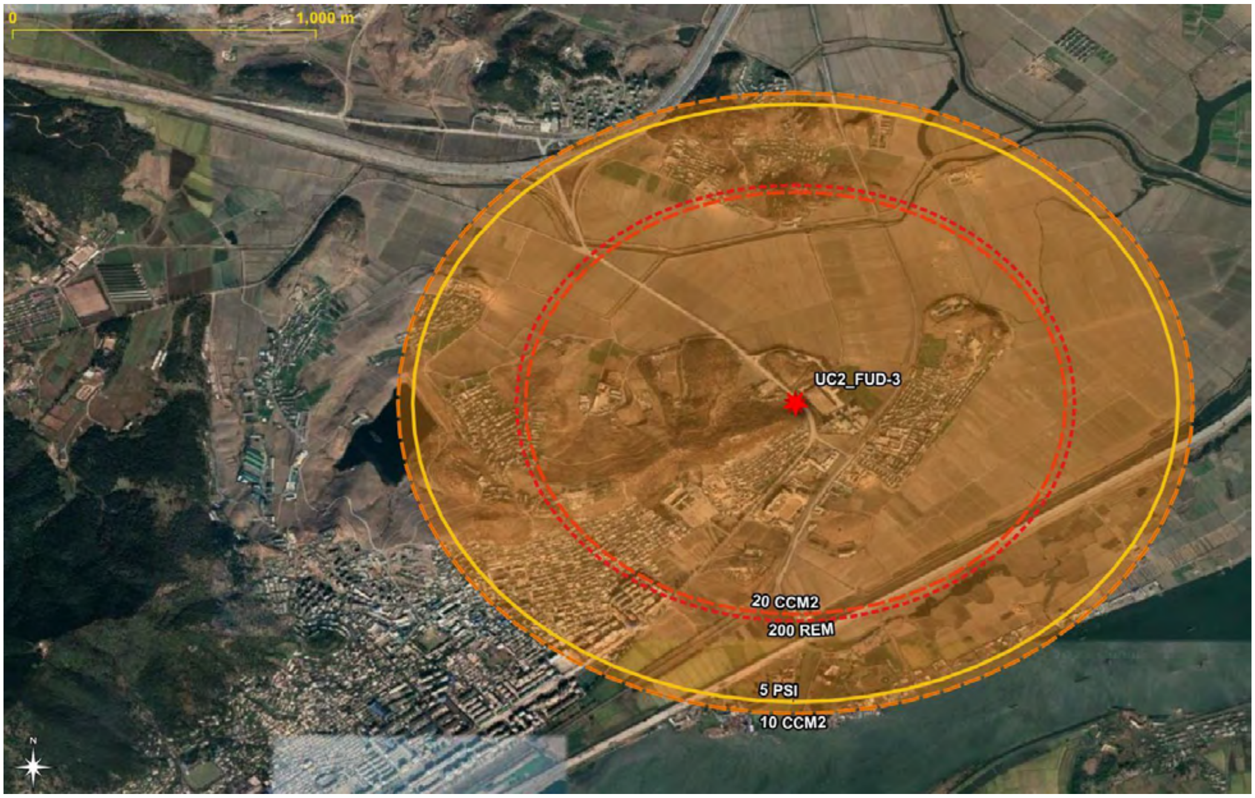


Figure A3-8: Use Case 2, FUD-3, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: The >10 cal/cm^2 contour is largely over fields, with buildings in only part of the contour, thus the overall density of fuel probably is too low to form a firestorm, although fires in residential areas will likely be significant.

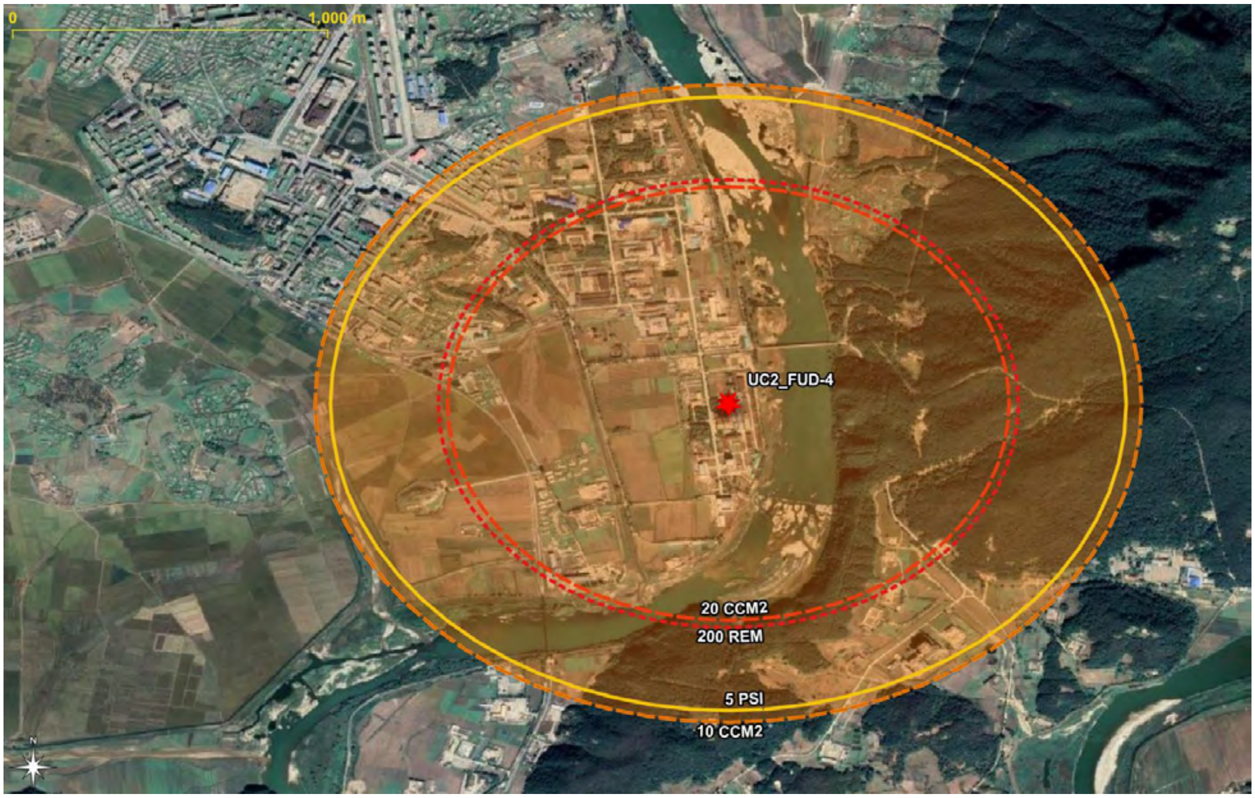


Figure A3-9: Use Case 2, FUD-4, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: The >10 cal/cm^2 contour is mostly over fields, medium density forest, river, with some structures. Probably not enough to sustain firestorms, but special considerations in terms of emissions from spot fires is required due to nuclear fuel cycle activities at Yongbyon site.

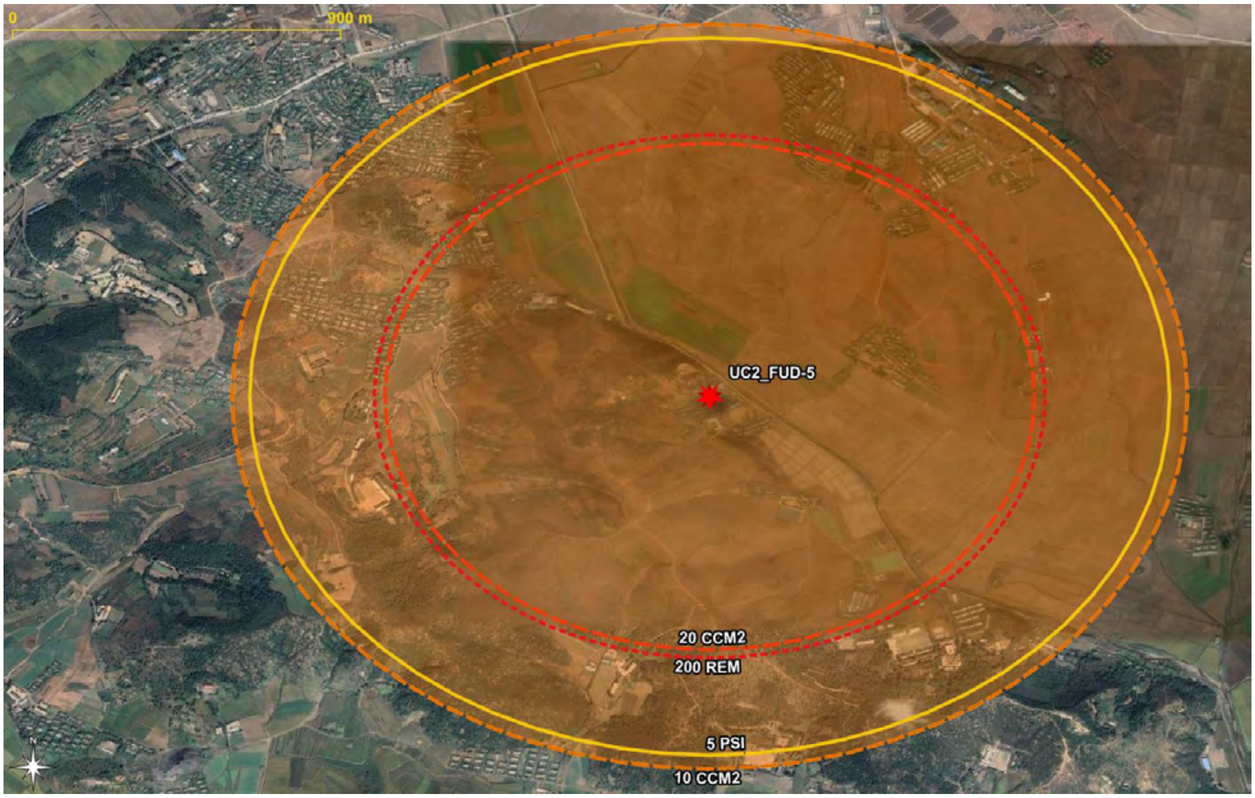


Figure A3-10: Use Case 2, FUD-5, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: The >10 cal/cm^2 contour is mostly over fields, with relatively few buildings, thus the overall density of fuel probably is too low to form a firestorm, although fires in residential areas will likely be significant.

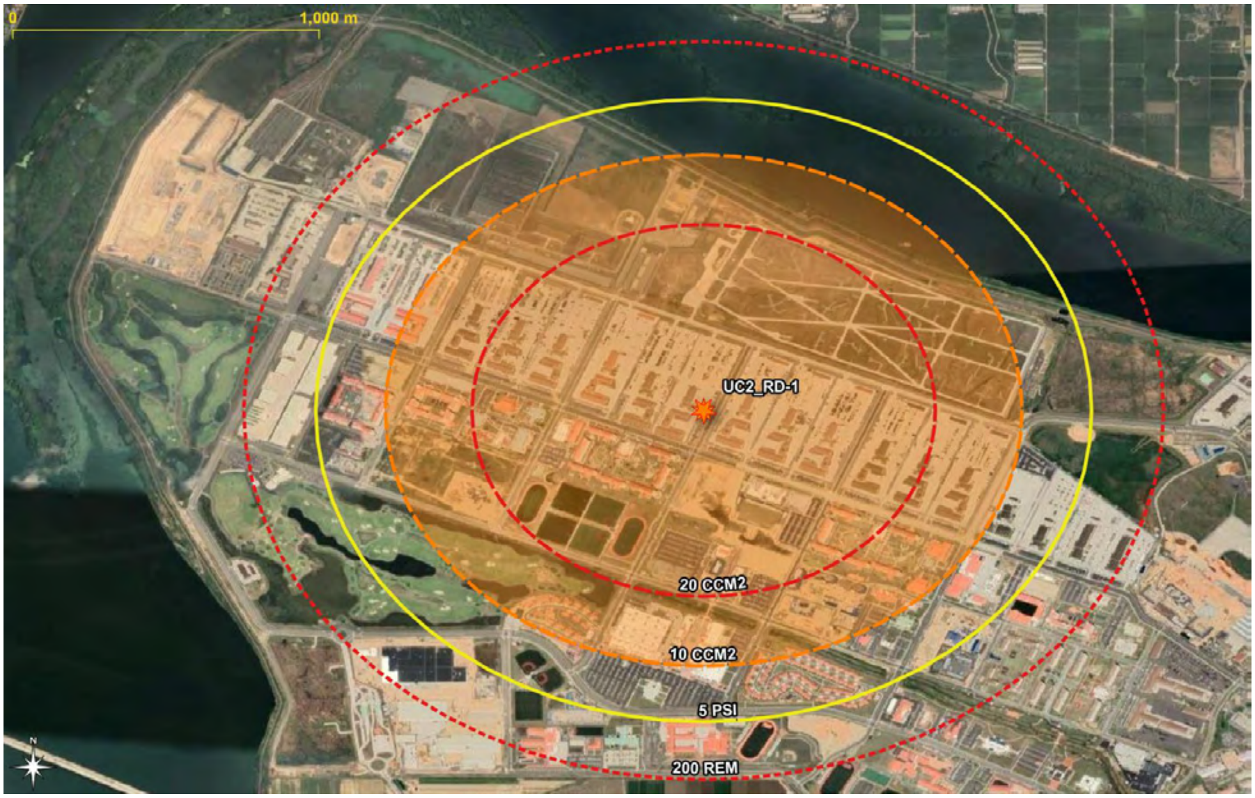


Figure A3-11: Use Case 2, RD-1, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Mix of buildings and open space, but the overall density of fuel is probably too low to form firestorm, although fires in some large buildings (warehouses and other buildings) will be significant.

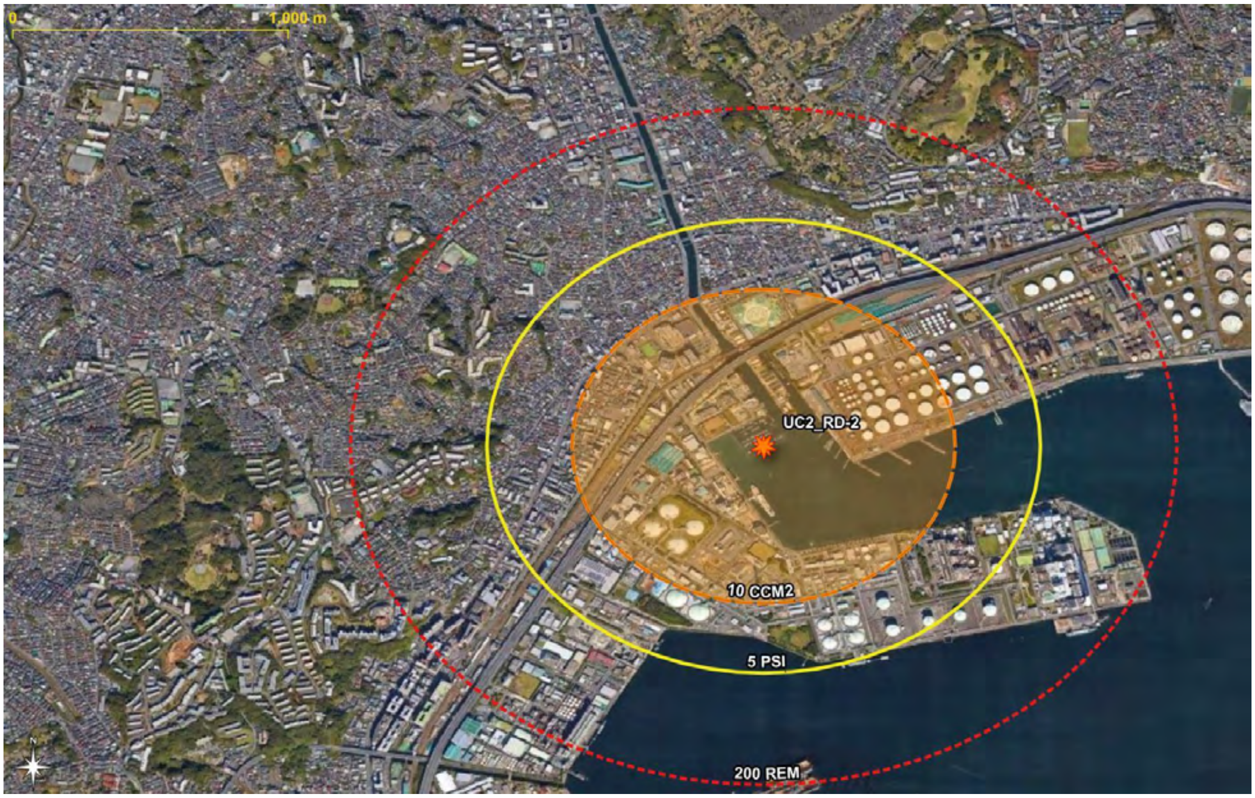


Figure A3-12: Use Case 2, RD-2, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm considered possible. Although some of the area within the >10 cal/cm2 contour is over water, the presence of large fuel tanks, as well as some dense housing, within the contour would seem to make a firestorm quite possible. In addition, extensive residential areas within the 5-psi zone but outside the firestorm zone would make the possibility of secondary fires significant.

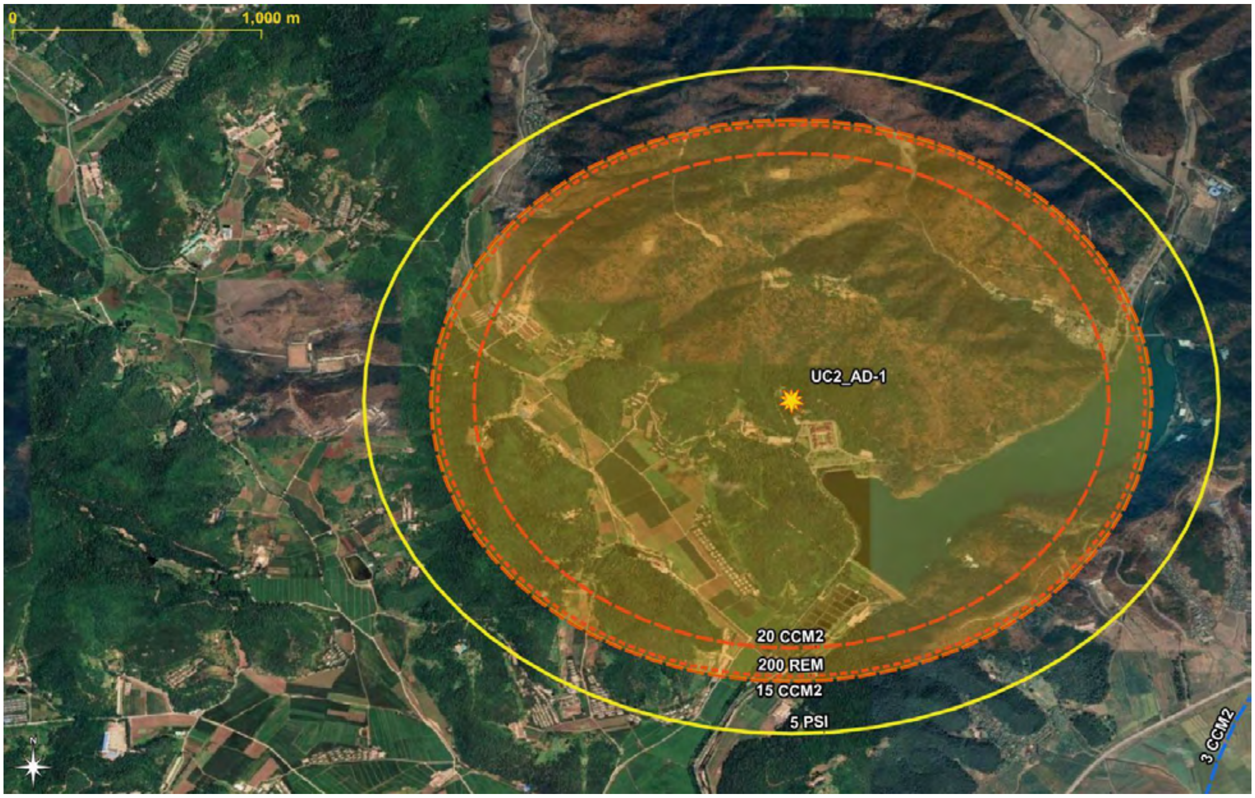


Figure A3-13: Use Case 2, AD-1, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm considered unlikely due to low-density forests, little built-up areas in ranges of >15 cal/cm^2 fluence.

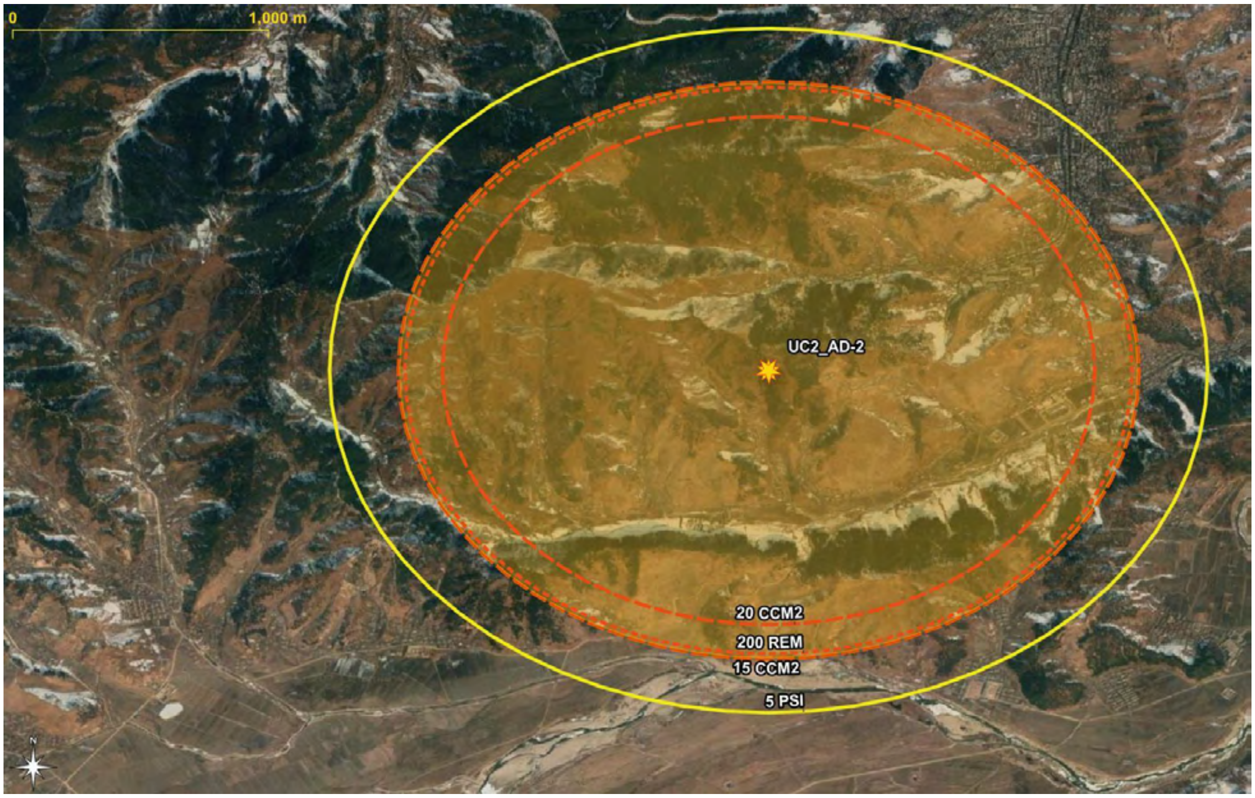


Figure A3-14: Use Case 2, AD-2, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Low vegetation in the zone of fluence >15 cal/cm^2, few built-up areas, and rugged terrain suggest a firestorm from this detonation is unlikely.

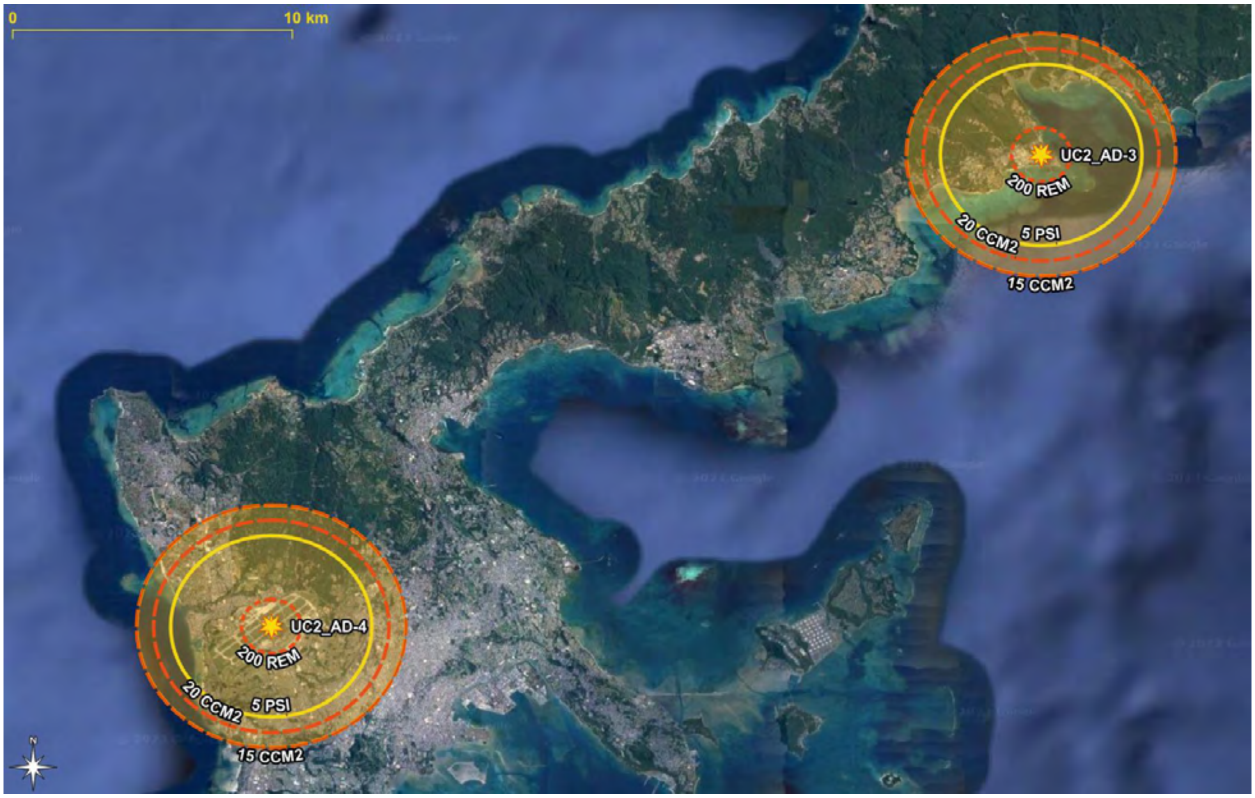


Figure A3-15: Use Case 2, AD-3 and AD-4, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm considered possible for AD-4 due to inclusion of built-up areas within much of the contour. In In addition, extensive residential areas nearby may would make the possibility of secondary fires significant. For AD-3, as much of the area within the >15 cal/cm^2 contour is over water. A firestorm seems unlikely, but many of the separated built-up areas and forest areas will likely burn.

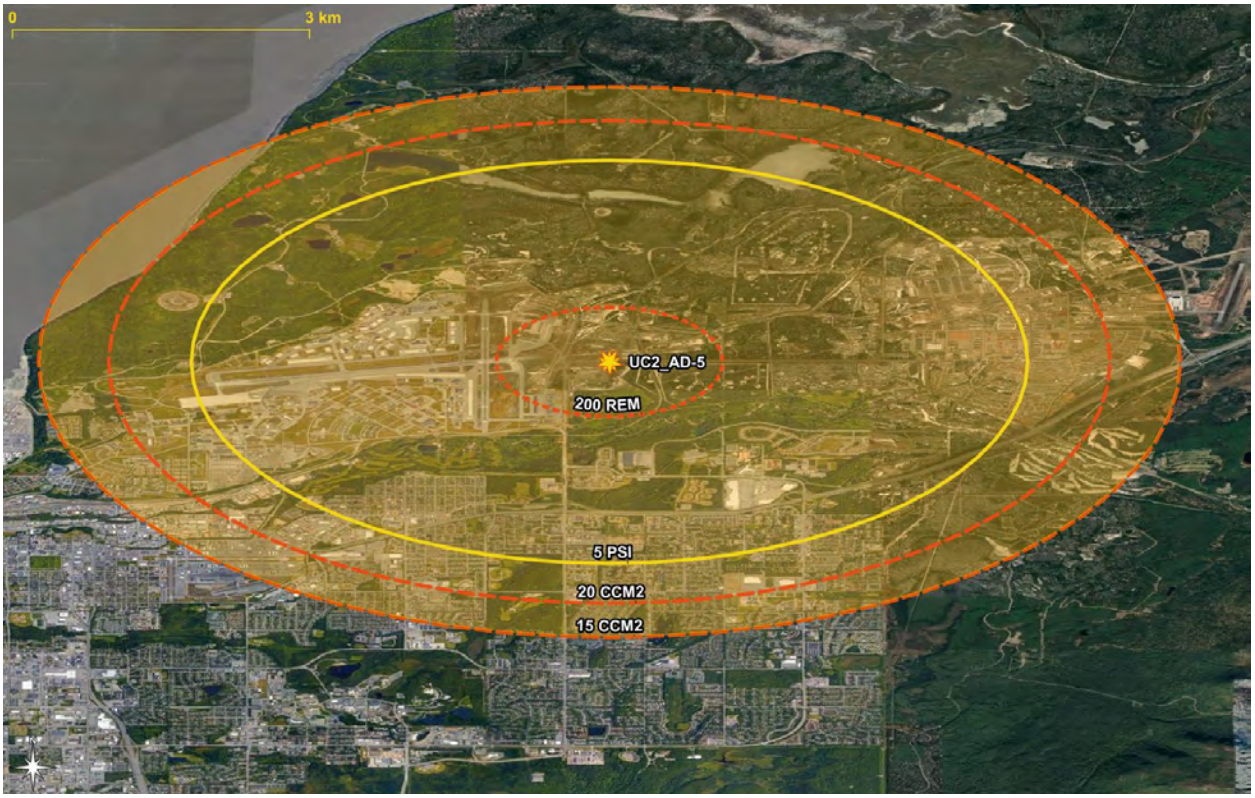


Figure A3-16: Use Case 2, AD-5, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm considered possible due to inclusion of built-up areas within much of the contour, although about half of the area is mostly forest or wetlands. In addition, extensive residential areas nearby may would make the possibility of secondary fires significant.

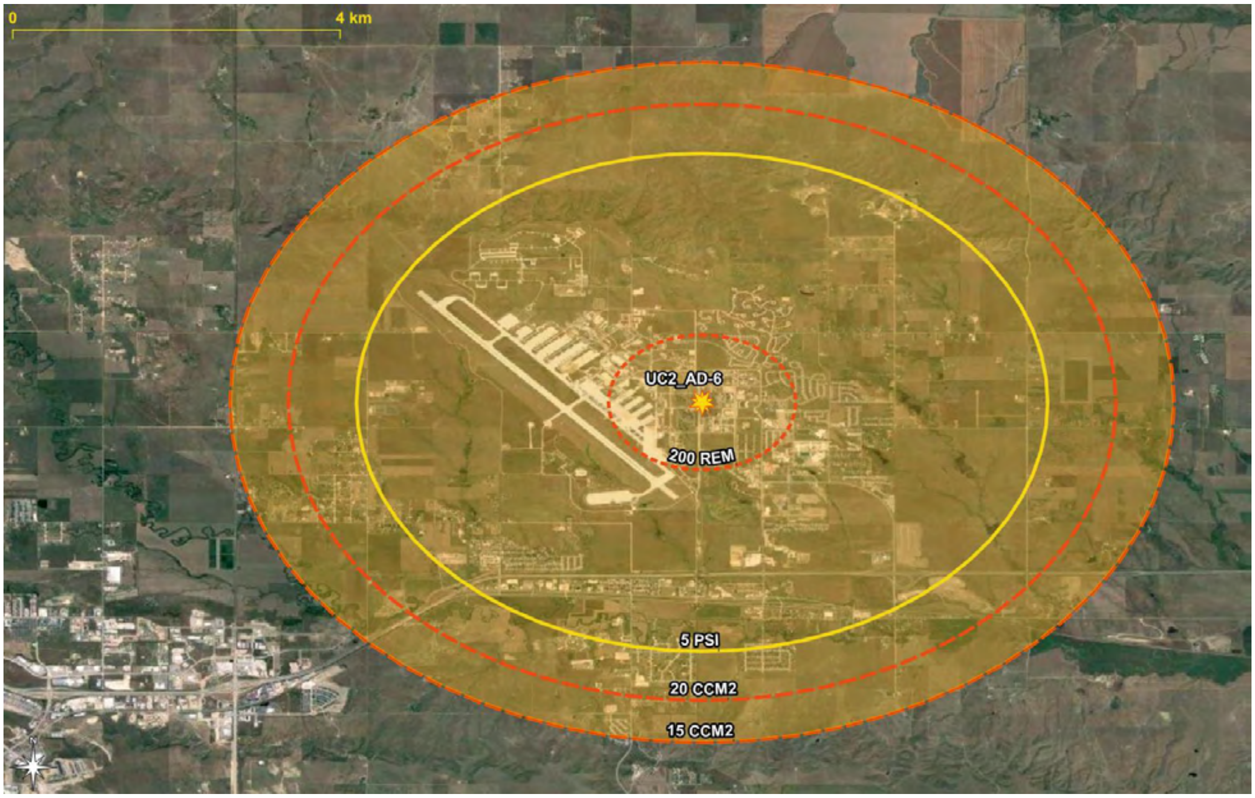


Figure A3-17: Use Case 2, AD-6, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Low vegetation, much concrete, and relatively few structures in the zone of fluence >15 cal/cm^2 suggest a firestorm from this detonation is unlikely.

Figure A3-18: Use Case 2, AD-7, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Although much of the zone of fluence >15 cal/cm^2 is over water, enough contiguous built-up areas are within the contour that a firestorm from this detonation appears possible.

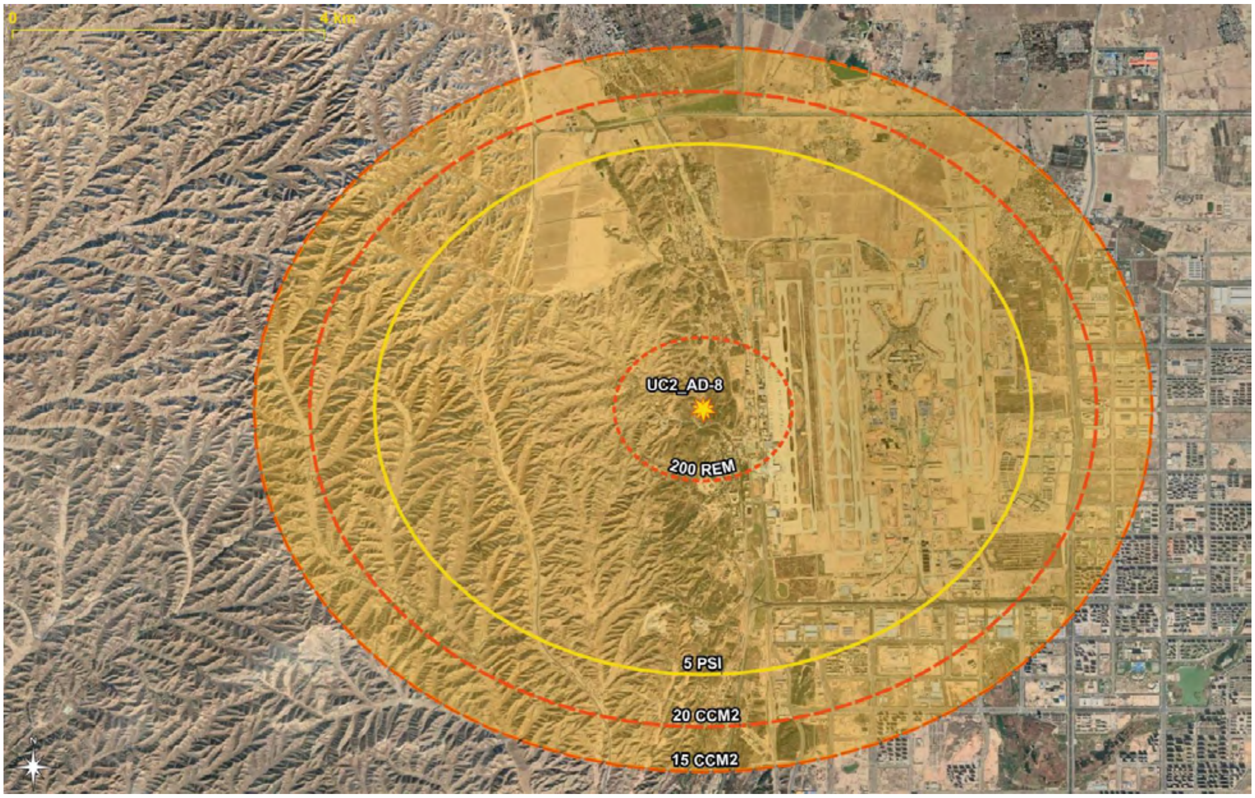


Figure A3-19: Use Case 2, AD-8, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Low vegetation in the zone of fluence >15 cal/cm^2, and relatively little built-up areas, suggest a firestorm from this detonation is unlikely.

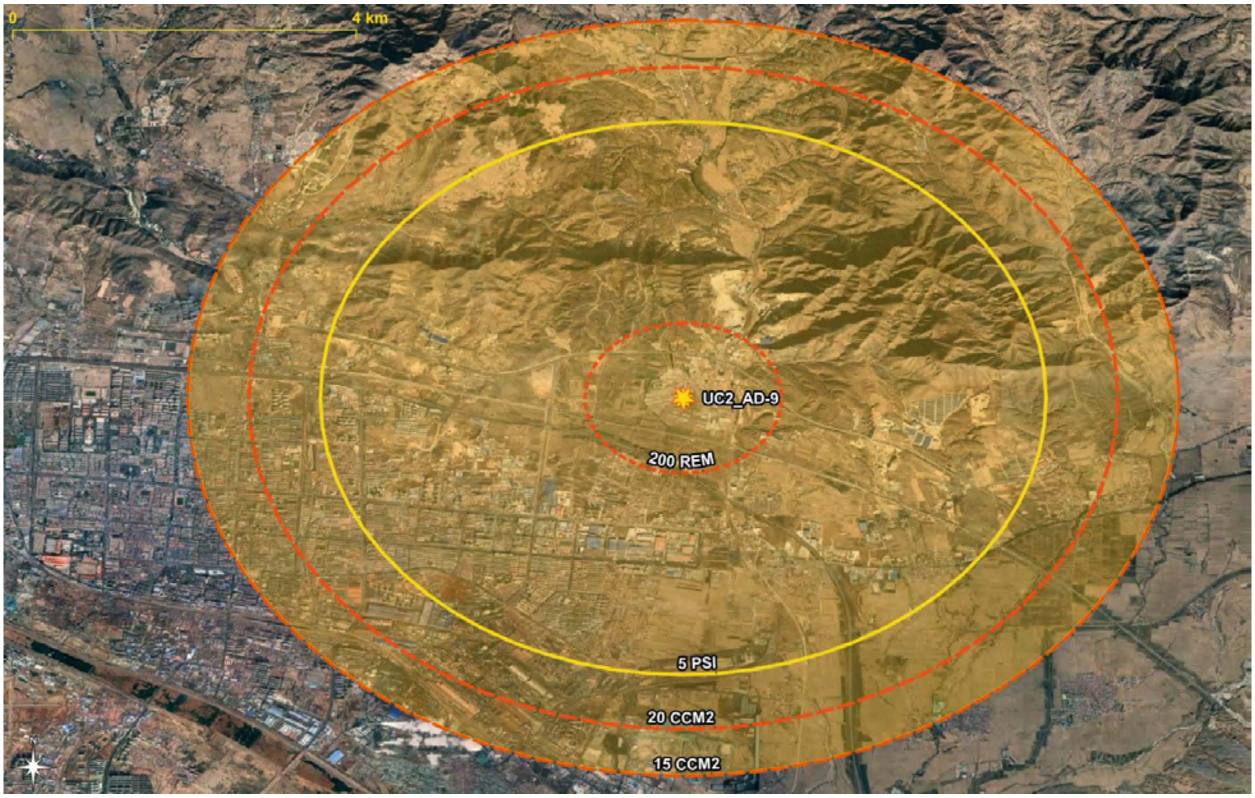


Figure A3-20: Use Case 2, AD-9, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Although some of the area within the zone of fluence >15 cal/cm^2 is over areas of limited vegetation, about one-third of the area is covered relatively densely with buildings, making a firestorm in that area possible.

Figure A3-21: Use Case 2, AD-10, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm possible due to high density of housing and other buildings.

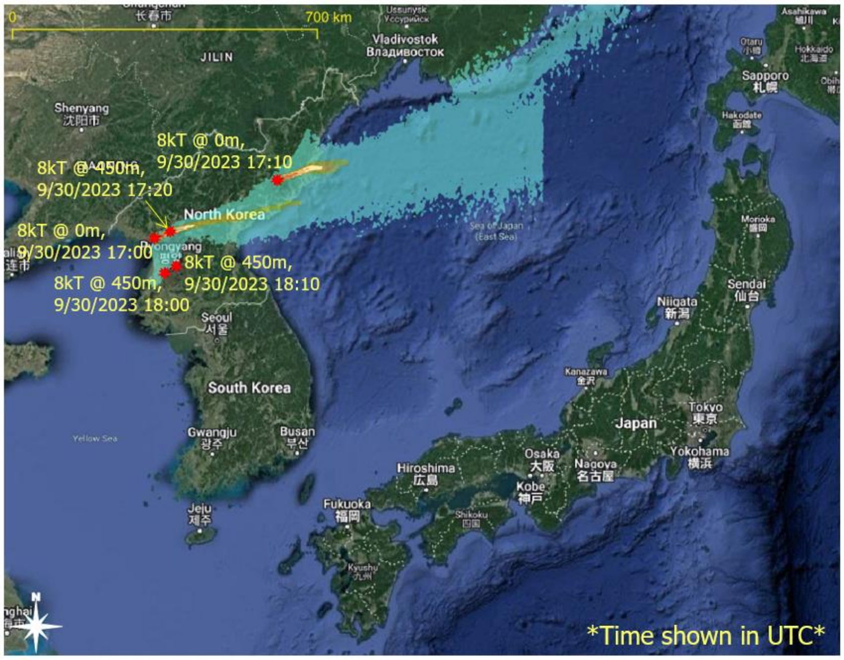
Summary of Estimated Overall Likely Deaths and Eventual Cancer Deaths in Use Case 2 from Different Impacts All Detonations:

Table A3-2: Estimated Likely Deaths, Evaluated Use Case 2

Estimated Likely Deaths: Use Case 2 Additional Detonations* (50-300 kT)	
Prompt (days to weeks)	1,100,000
Short-Term (weeks to months)	810,000
Additional Impact: Firestorms	170,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**2,100,000** (6,200,000, 33%)
High Radiation Fallout Dose (short-term)	11,000 - 1,200,000
Radiation-Induced Cancer Deaths (long-term)	480,000 - 920,000

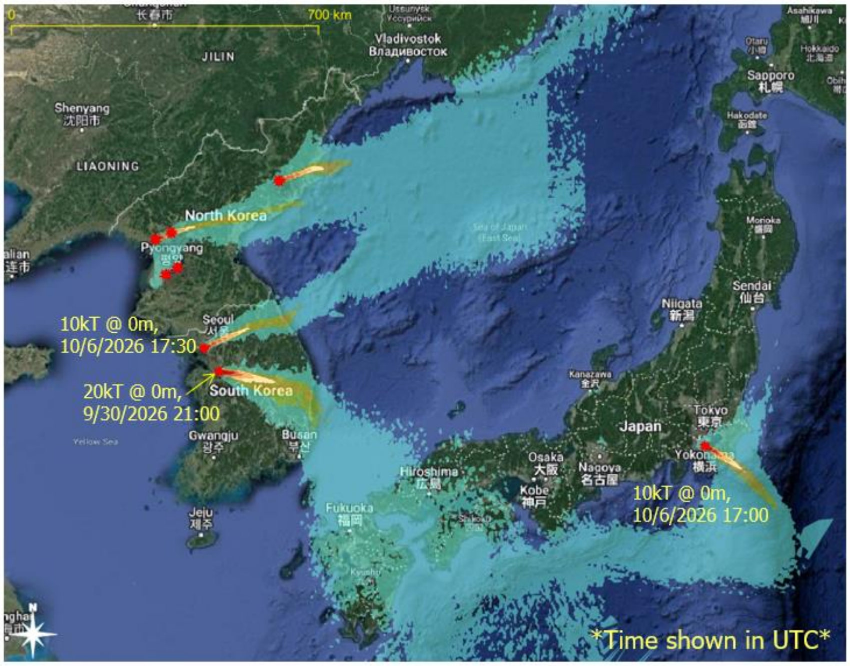
*Cumulative with First-Use and Response Detonations

Nuclear Fallout Simulation Results: Use Case 2: "US Leadership Hubris"



"US Leadership Hubris" First Use Detonations : Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	450,000
10-50	560,000
50-100	160,000
100-200	110,000
200-600	12,000
> 600	0

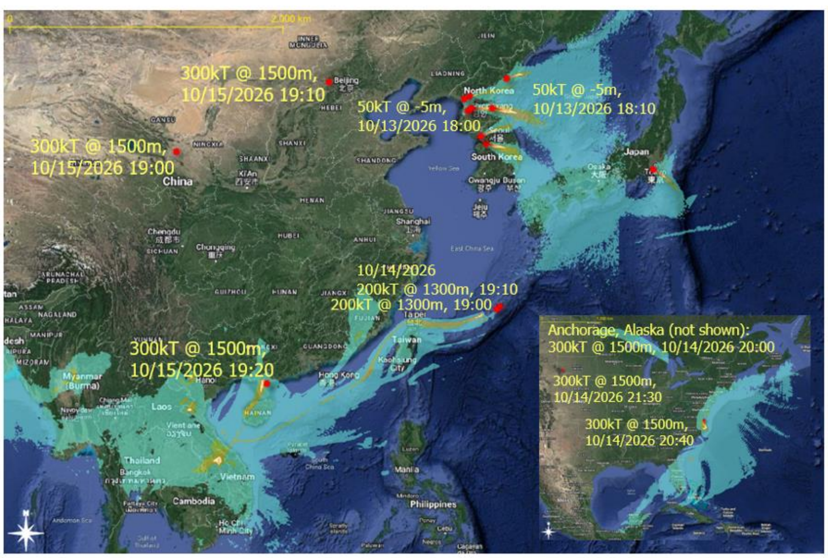
Figure A3-22: Use Case 2, First Use Detonations, Fallout Modelling Results.



“US Leadership Hubris” First Response Detonations : Cumulative* Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	1,400,000
10-50	4,700,000
50-100	3,200,000
100-200	3,200,000
200-600	990,000
> 600	11,000

*Includes Results from First Use Detonations

Figure A3-23: Use Case 2, First Use and Response Detonations, Fallout Modelling Results.



“US Leadership Hubris” Additional Detonations : Cumulative* Population Affected by Fallout Radiation Dose			
Dose (rem)	**Population**		
	Korean Peninsula	**Asia**	**Americas**
5-10	1,800,000	6,300,000	2,600,000
10-50	5,400,000	4,700,000	220,000
50-100	3,400,000	82,000	62,000
100-200	3,500,000	0	54,000
200-600	1,200,000	0	11,000
> 600	11,000	0	0

*Includes Results from First Use and Response Detonations

Figure A3-24: Use Case 2, All Detonations, Fallout Modelling Results.

“Use by Terrorist” V1, Use Case 3:

Maps of impact contours for prompt radiation, thermal fluence, overpressure, and firestorm, Use Case 3.

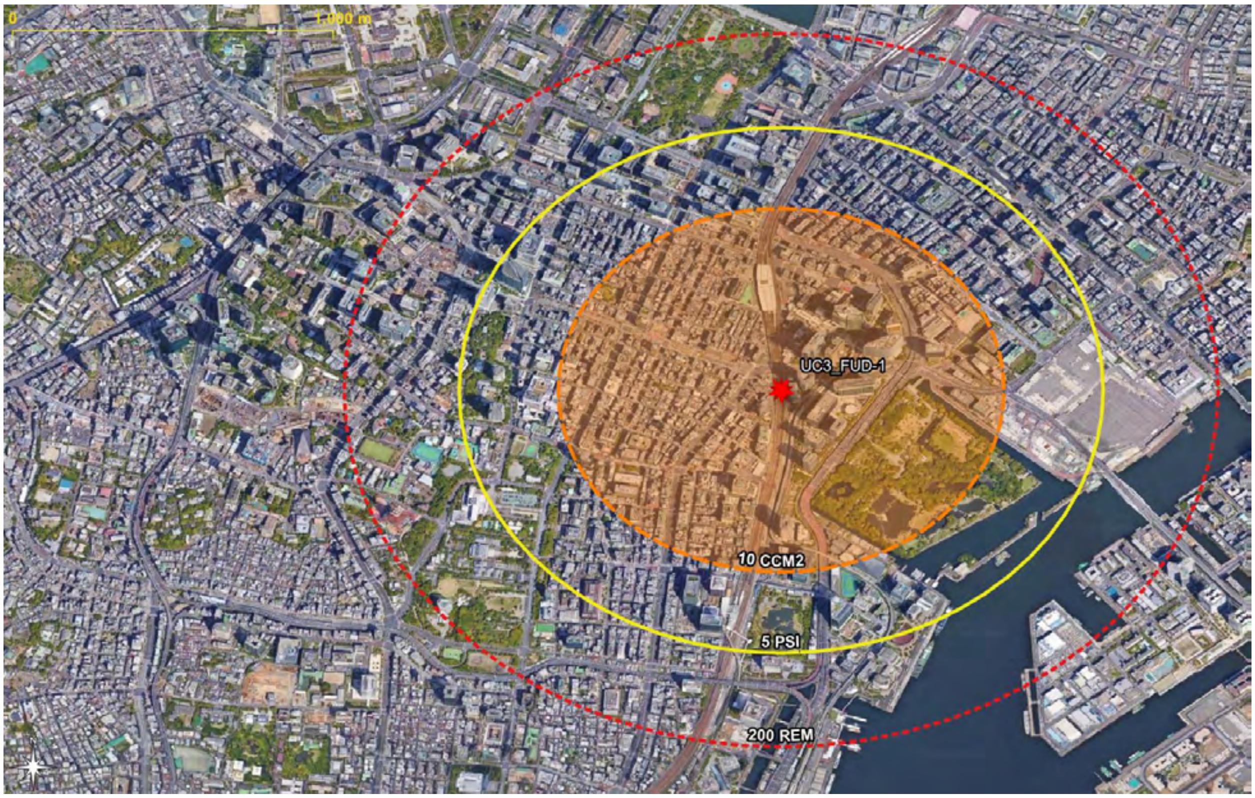


Figure A3-25: Use Case 3, FUD-1, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm possible due to high density of housing and other buildings, although presence of some tall buildings may have an unknown effect.

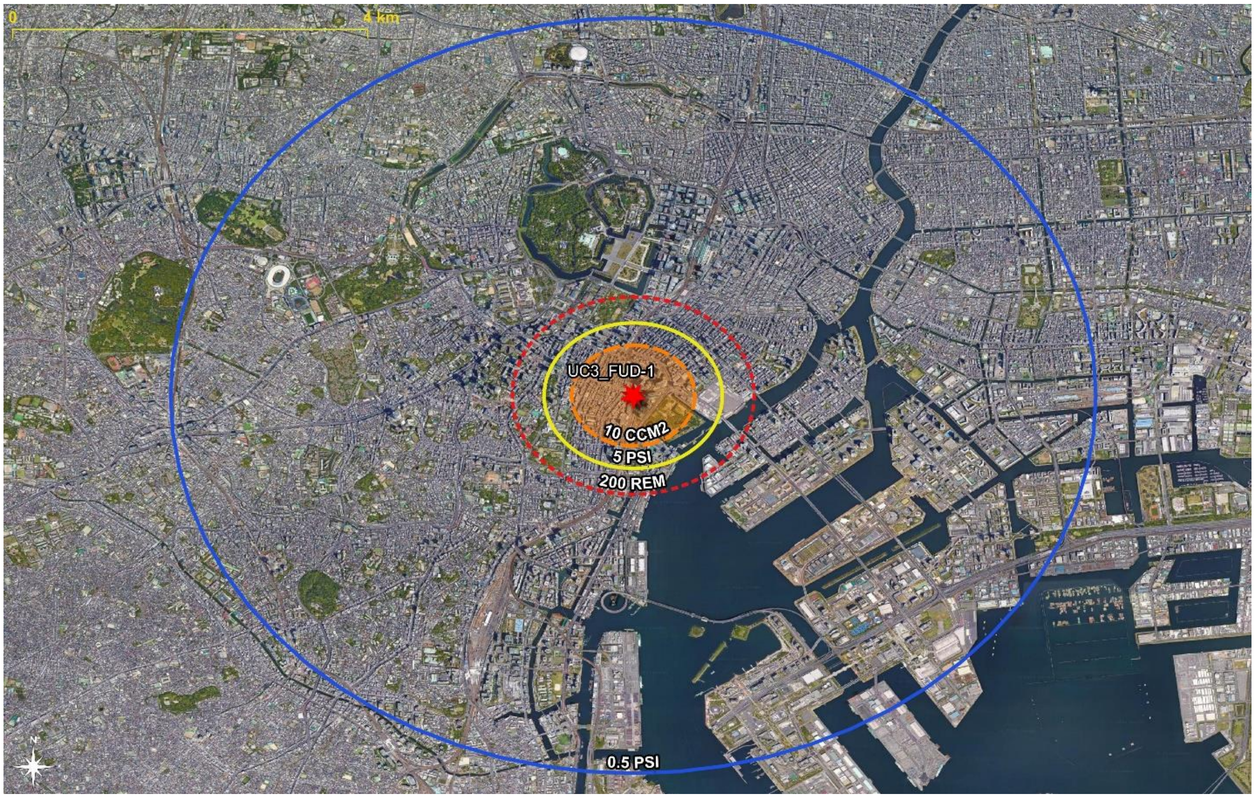


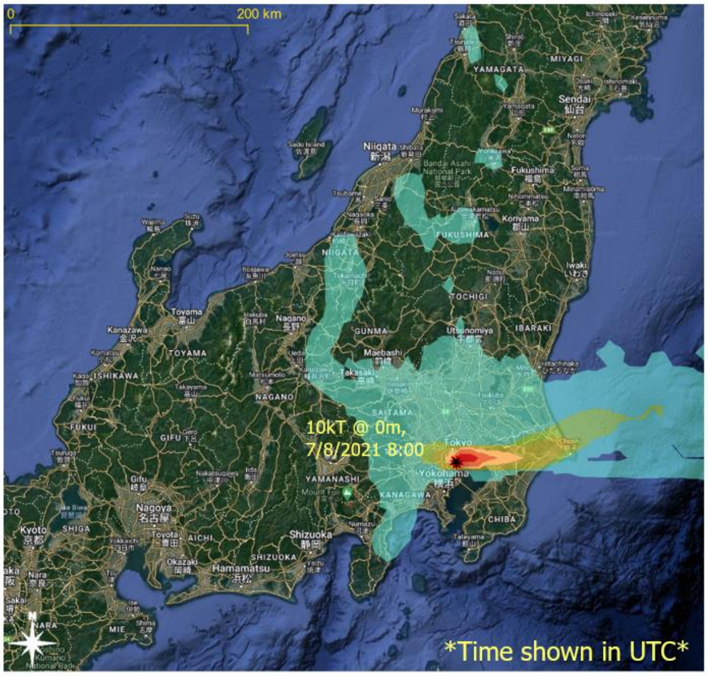
Figure A3-26: Use Case 3, FUD-1, Ranges of Potential Firestorm and Other Likely Lethal Impacts including 0.5 psi impact range (blue circle).

Summary of Estimated Overall Likely Deaths and Eventual Cancer Deaths in Use Case 3 from Different Impacts.

Table A3-3: Estimated Likely Deaths, Use Case 3

Estimated Likely Deaths: Use Case 3 (10 kT Surface-burst)	
Prompt (days to weeks)	82,000
Short-Term (weeks to months)	140,000
Additional Impact: Firestorms	Small Centralized Firestorm
Total (0.5 psi Zone) (Total Pop., % Lethality)	**220,000** (890,000, 25%)
High Radiation Fallout Dose (short-term)	**0 - 1,600,000**
Radiation-Induced Cancer Deaths (long-term)	**410,000 - 560,000**

Nuclear Fallout Simulation Results: Use Case 3: Nuclear Weapon Use by Terrorists Variant 1.



"Terrorist Attack" First Use Detonation : Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	2,700,000
10-50	5,300,000
50-100	2,500,000
100-200	2,400,000
200-600	1,600,000
> 600	0

Figure A3-27: Use Case 3, Fallout Modelling Results.

“Conflict from Ukraine Spreads East”, Use Case 4:

Maps of impact contours for prompt radiation, thermal fluence, overpressure, and firestorm, Use Case 4.

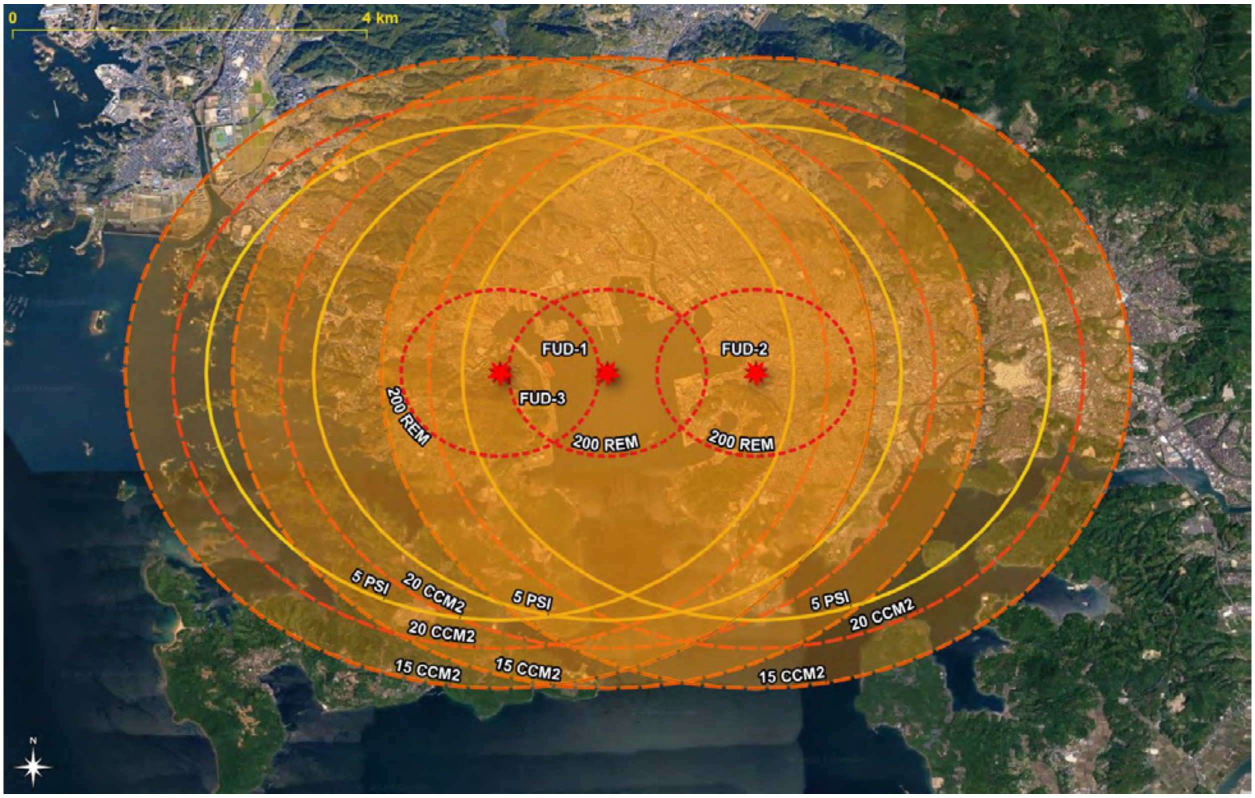


Figure A3-28: Use Case 4, FUD-1 through FUD-3, Ranges of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm possible due to high density of housing and other buildings, although parts within the zones of fluence >15 cal/cm^2 are over areas of forests and water.

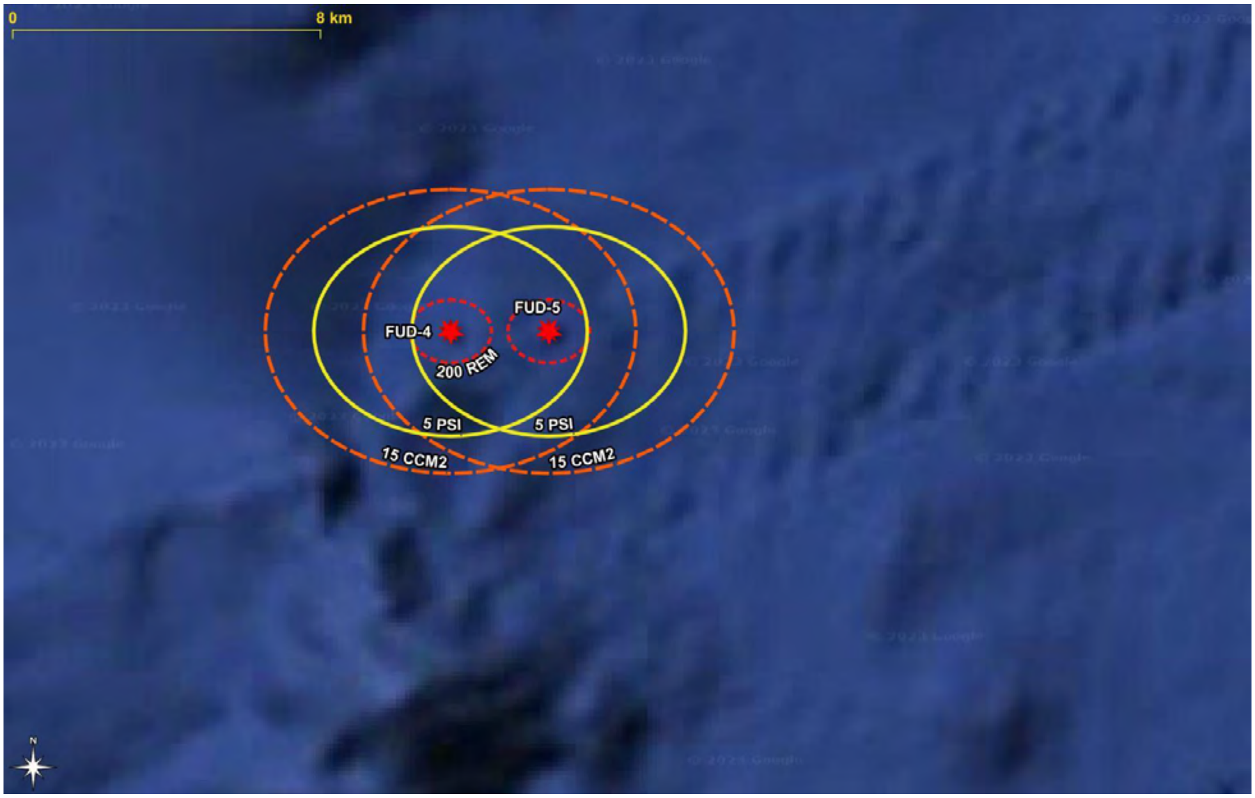


Figure A3-29: Use Case 4, FUD-4 and FUD-5, Attack on Ships at Sea, Ranges of Likely Lethal Impacts.

Firestorm potential assessment: No firestorm is possible as attack is over water, but individual ships will likely be set ablaze.

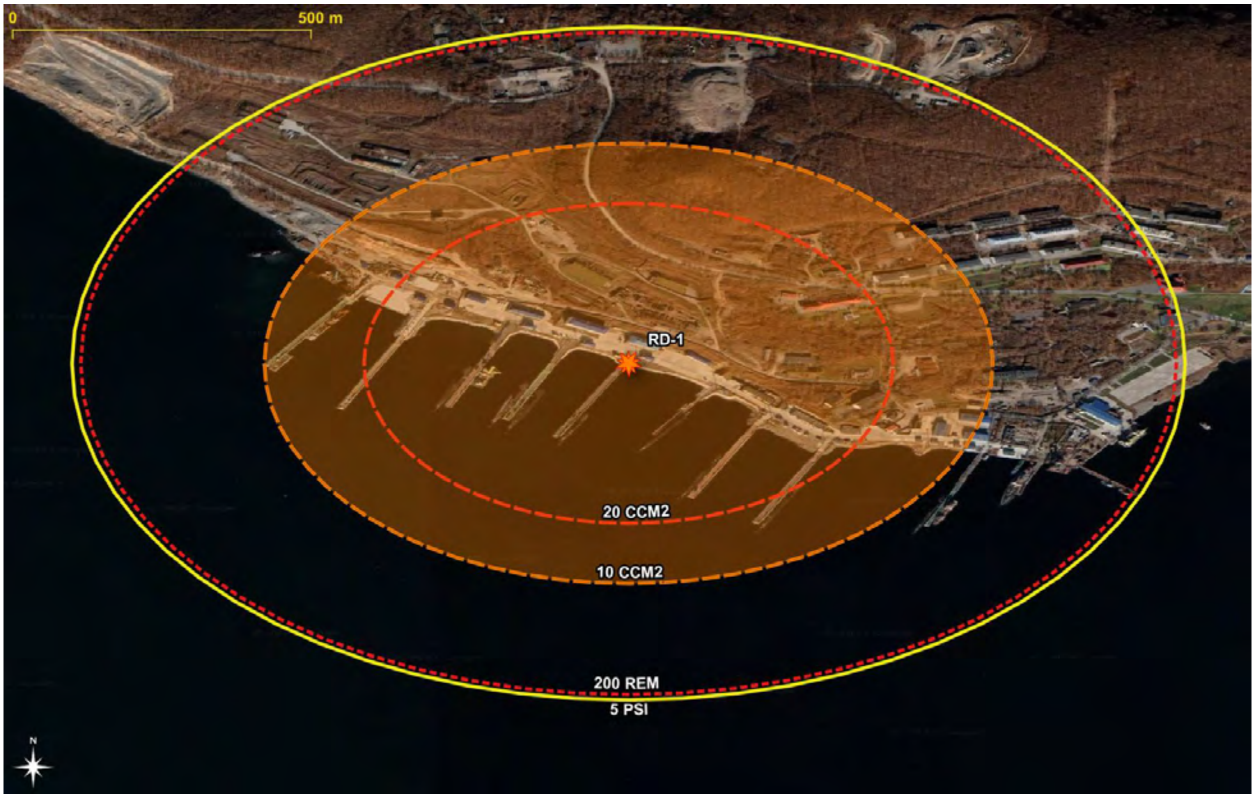


Figure A3-30: Use Case 4, RD-1, Attack on Submarine Base, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm unlikely due to attack being partially over water, limited vegetation and structures, but buildings within area will likely be set ablaze.

Figure A3-31: Use Case 4, RD-2 and RD-3, Attack on Naval Bases, Range of Potential Firestorm and Other Likely Lethal Impacts.

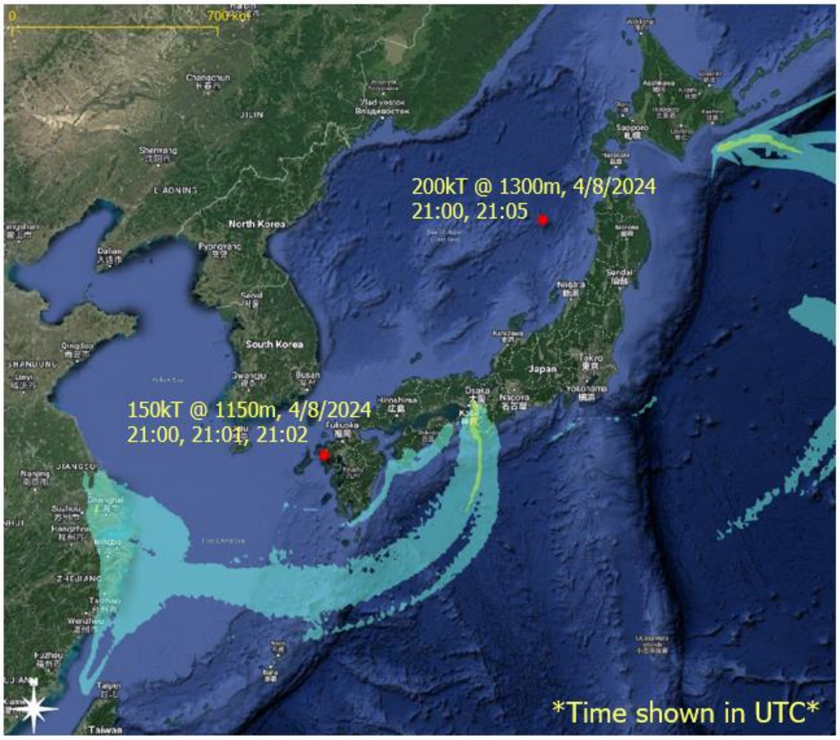
Firestorm potential assessment: Firestorms unlikely because the areas within the zones of fluence >10 cal/cm^2 are areas with limited buildings and limited vegetation, and much of each of the potential firestorm zones are over water.

Summary of Estimated Overall Likely Deaths and Eventual Cancer Deaths in Use Case 4 from Different Impacts, All Detonations.

Table A3-4: Estimated Likely Deaths, Use Case 4

Estimated Likely Deaths: Use Case 4 First-Use + Response Detonations (8 kT Airbursts)	
Prompt (days to weeks)	170,000
Short-Term (weeks to months)	98,000
Additional Impact: Firestorms	15,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**290,000** (800,000, 36%)
High Radiation Fallout Dose (short-term)	Low Fallout
Radiation-Induced Cancer Deaths (long-term)	**14,000 - 85,000**

Nuclear Fallout Simulation Results: Use Case 4: “Conflict from Ukraine Spreads East.”



“Conflict form Ukraine Spreads East” First Use Detonations : Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	2,700,000
10-50	2,500,000
50-100	0
100-200	0
200-600	0
> 600	0

Figure A3-32: Use Case 4, Fallout Modelling Results.

“Not Going Well in Taiwan”, Use Case 5:

Maps of impact contours for prompt radiation, thermal fluence, overpressure, and firestorm, Use Case 5.

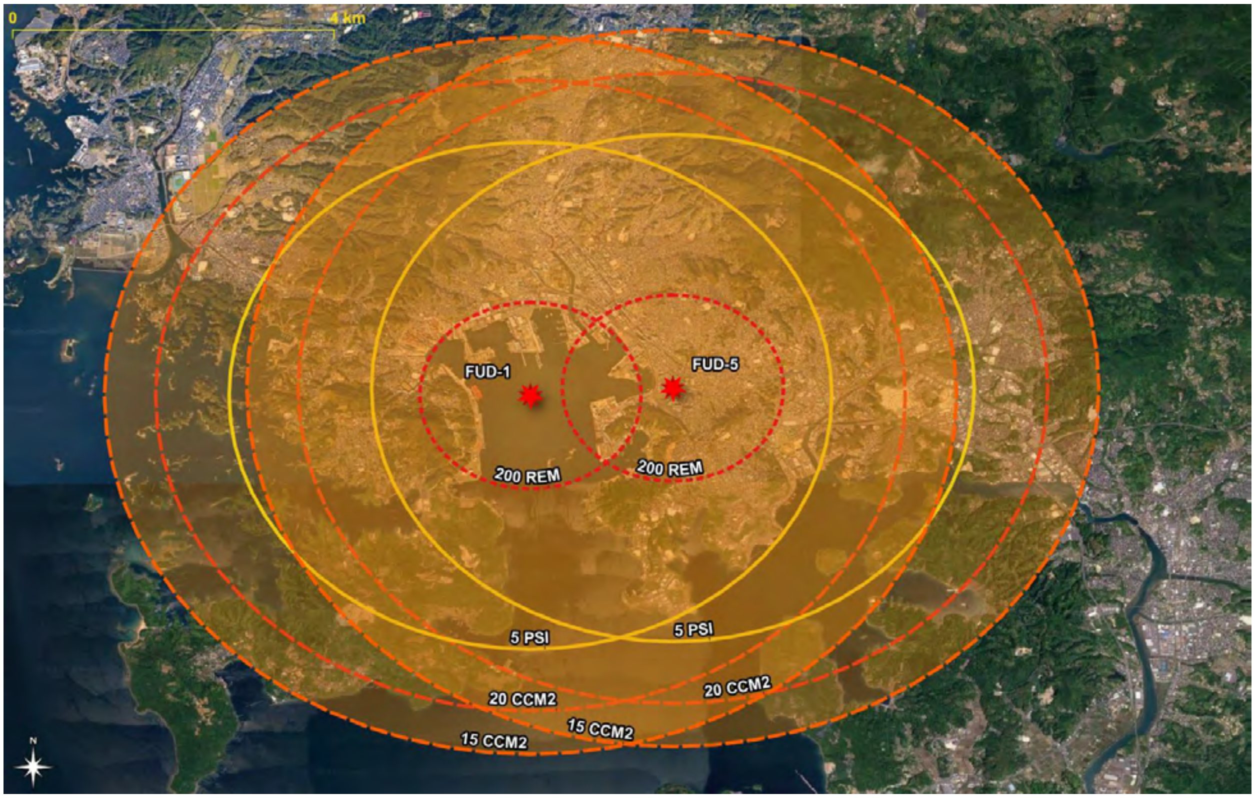


Figure A3-33: Use Case 5, FUD-1 and FUD-5, Attack on Naval Bases, Japan, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm possible due to high density of housing and other buildings, although parts within the zones of fluence >15 cal/cm^2 are over areas of forests and water.

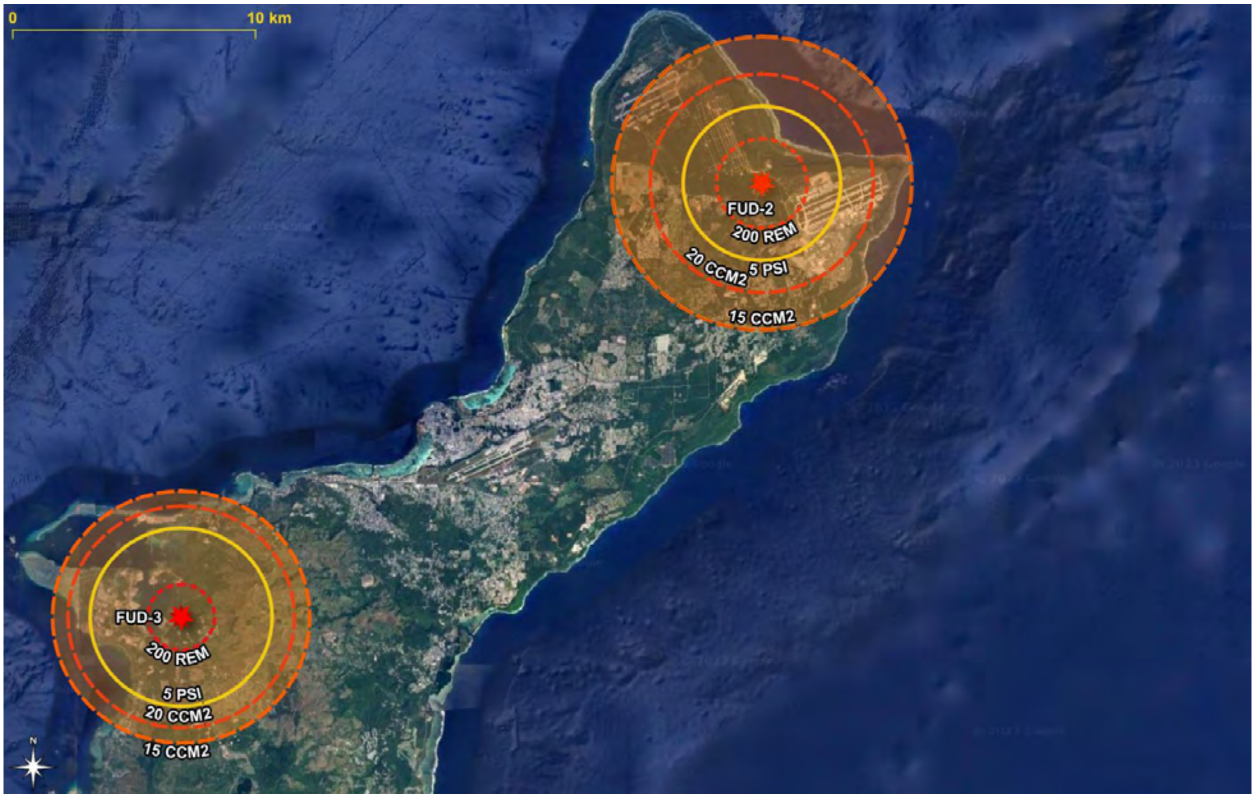


Figure A3-34: Use Case 5, FUD-2 and FUD-3, Attack on Naval Bases, Guam, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm unlikely due to housing and other structures on only a portion of the zones of fluence >15 cal/cm^2, with some of the rest being water and low forest, though local fires and forest fires will likely occur.

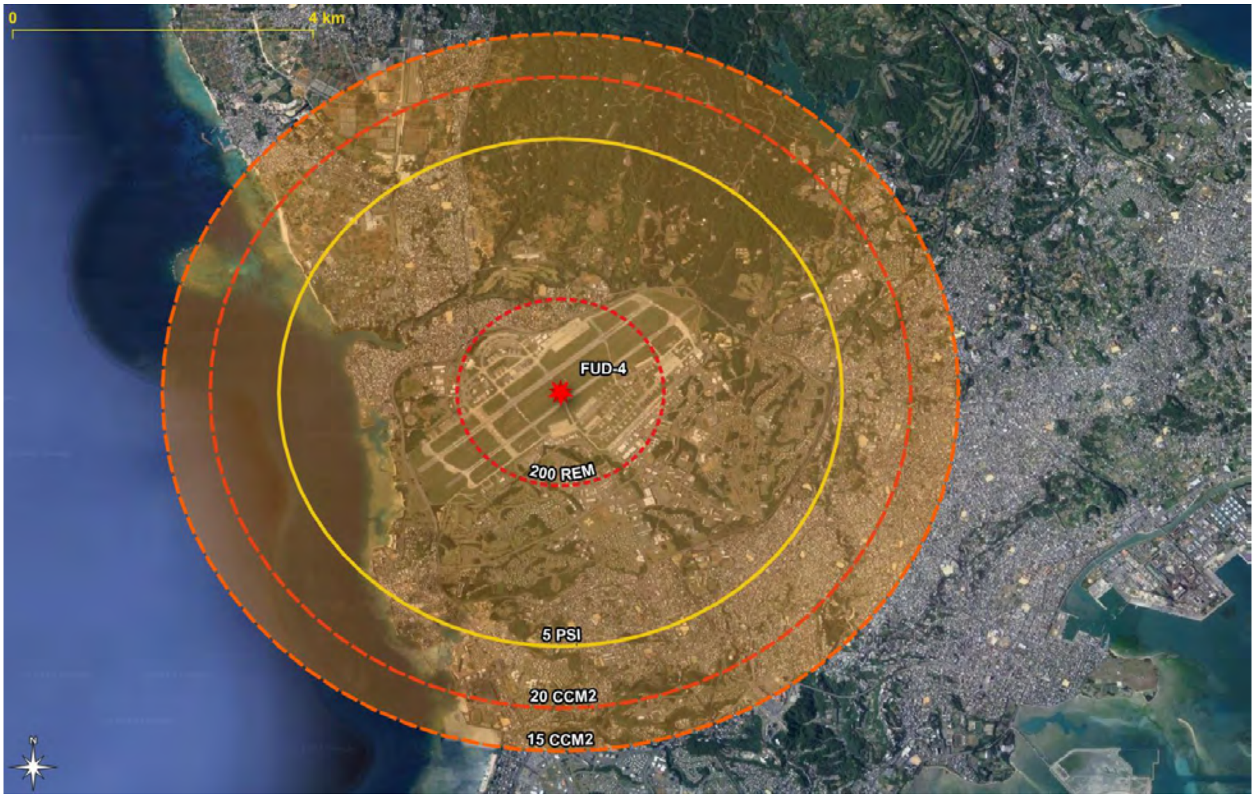


Figure A3-35: Use Case 5, FUD-4, Attack on Military Base, Okinawa, Japan, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm possible due to high density of housing and other buildings, although parts within the zones of fluence >15 cal/cm^2 are over areas of forests, tarmac, and water.

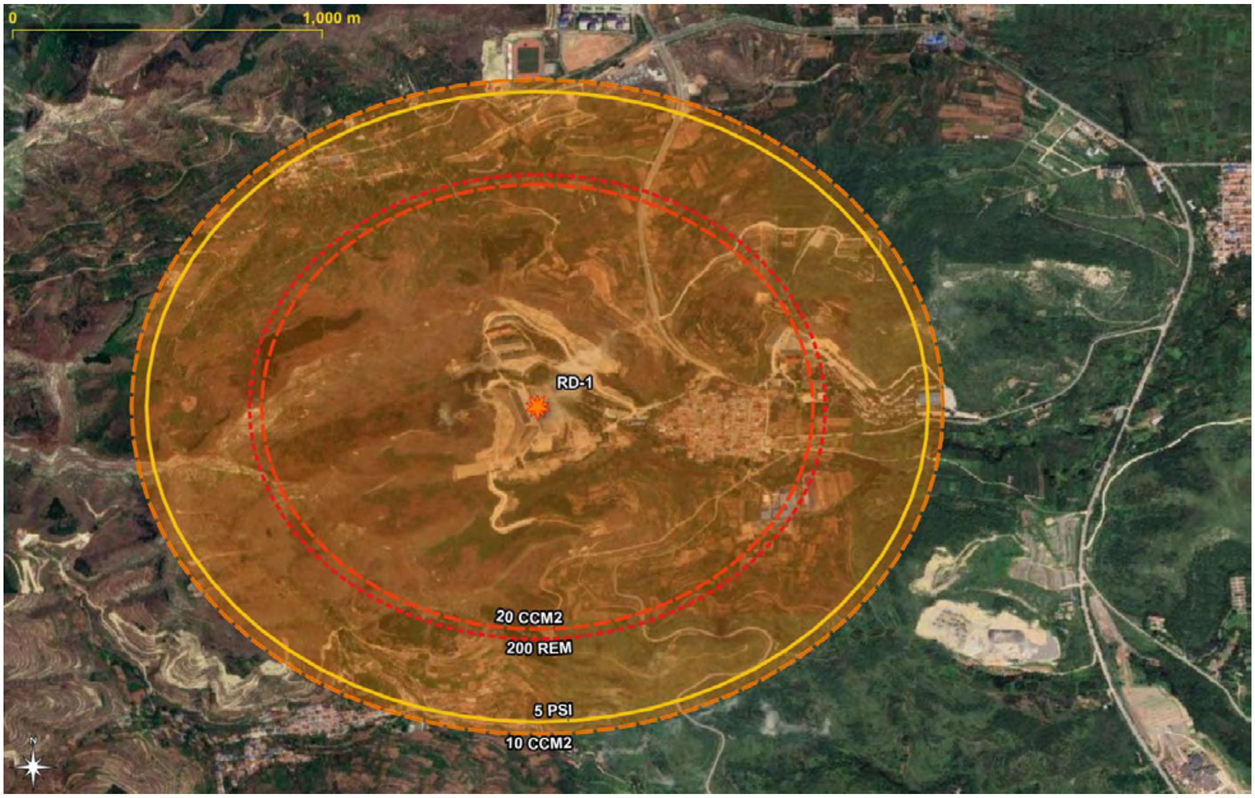


Figure A3-36: Use Case 5, RD-1, Attack on Missile Site, China, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm unlikely due to housing and other structures on only a small portion of the zones of fluence >10 cal/cm^2, with much of the rest being sparse vegetation.

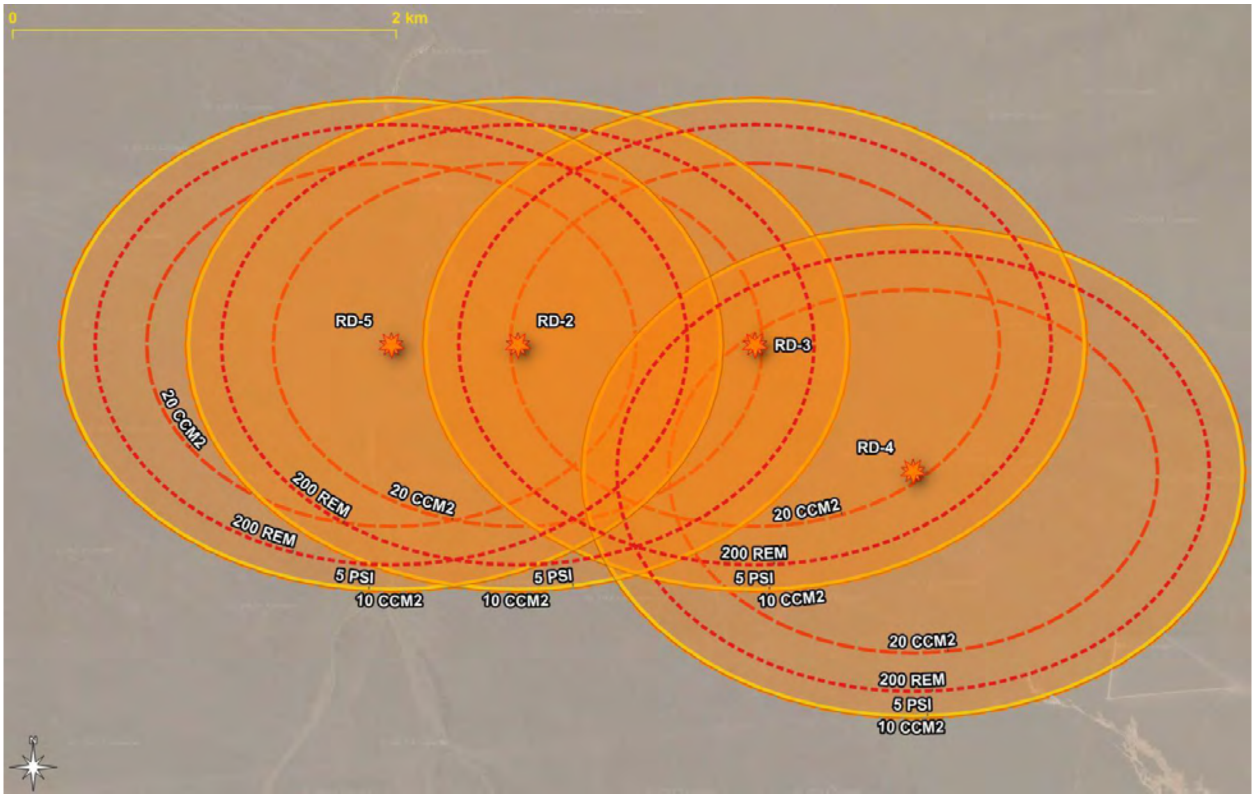


Figure A3-37: Use Case 5, RD-2 through RD-5, Attack on Missile Sites, China, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorms unlikely for these sites due to lack of buildings and vegetation.

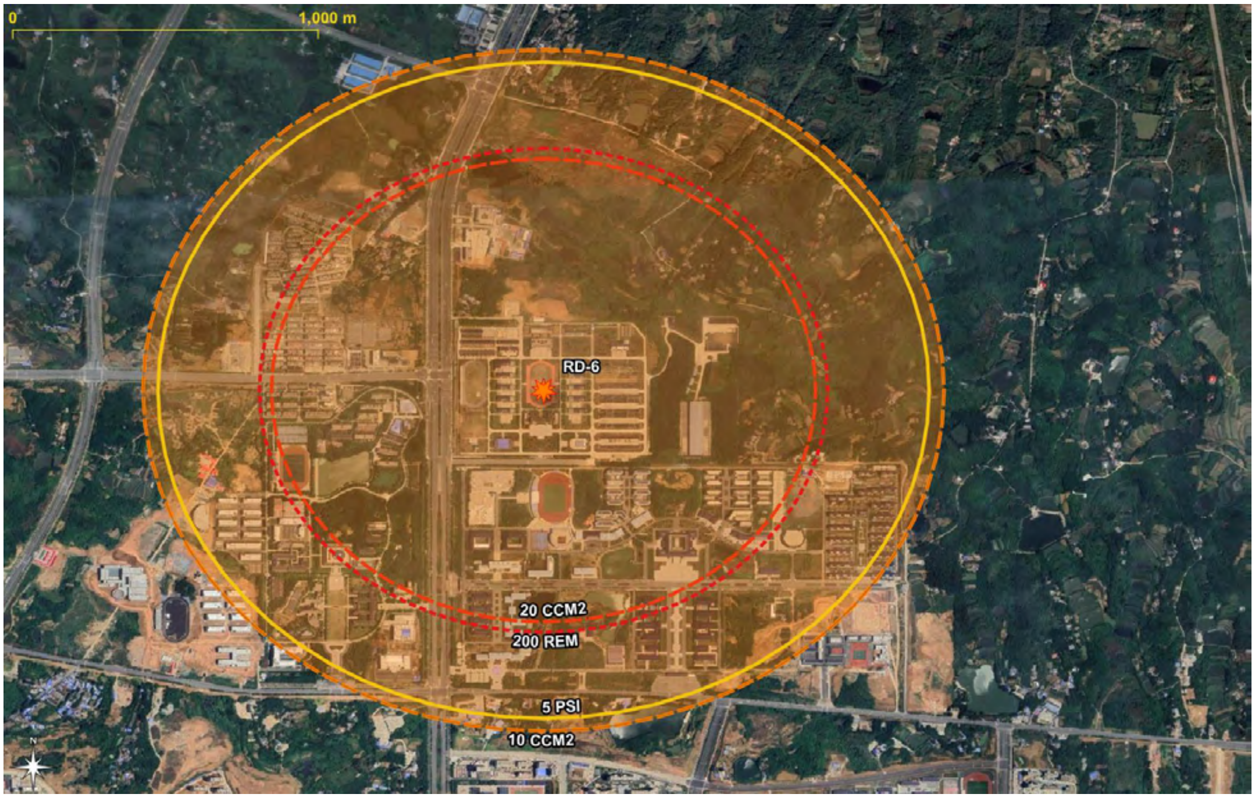


Figure A3-38: Use Case 5, RD-6, Attack on Missile Site, China, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm possible for this site, although site has some open areas of vegetation that may not provide much fuel.

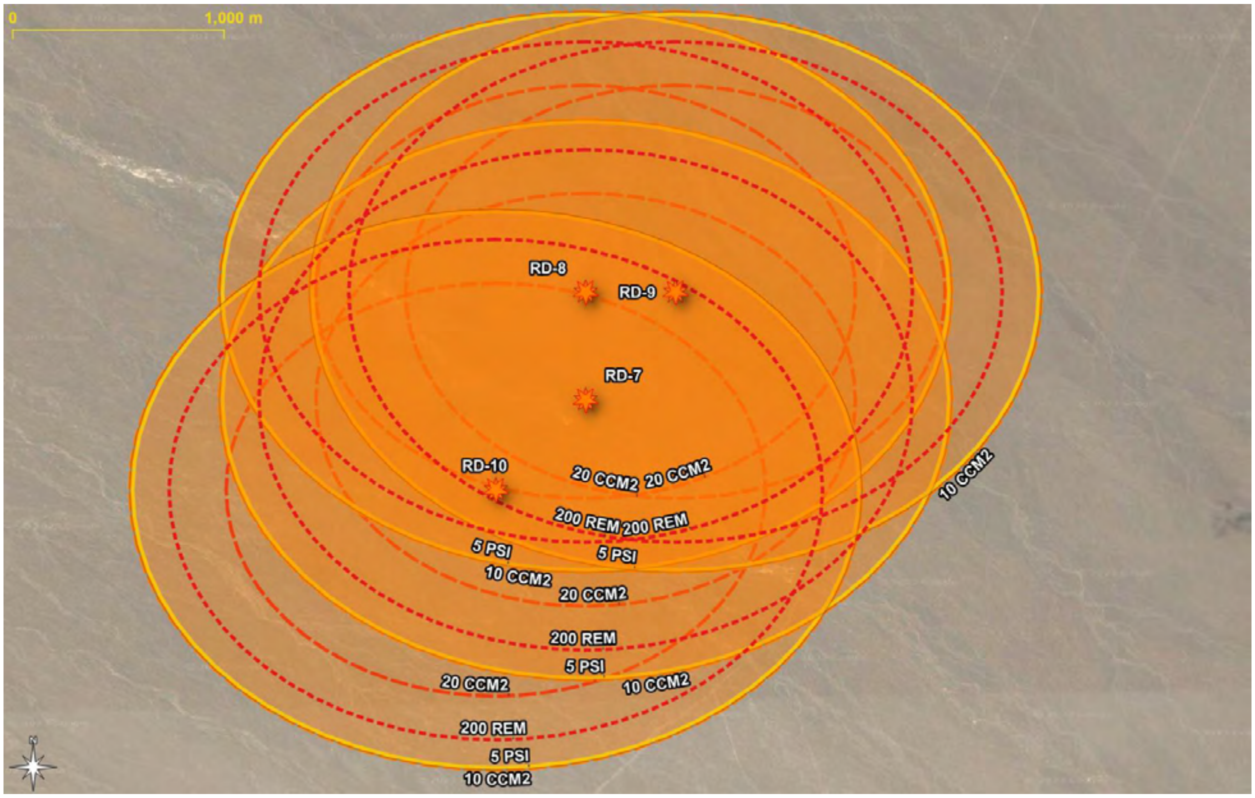


Figure A3-39: Use Case 5, RD-7 through RD-10, Attack on Missile Sites, China, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorms unlikely for these sites due to lack of buildings and vegetation.

Figure A3-40: Use Case 5, AD-1, Attack on Military Base, ROK, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorms probably not likely for this site due to most of the area of 15 cal/cm^2 fluence being agricultural fields, tarmac, solar panels, and golf courses.

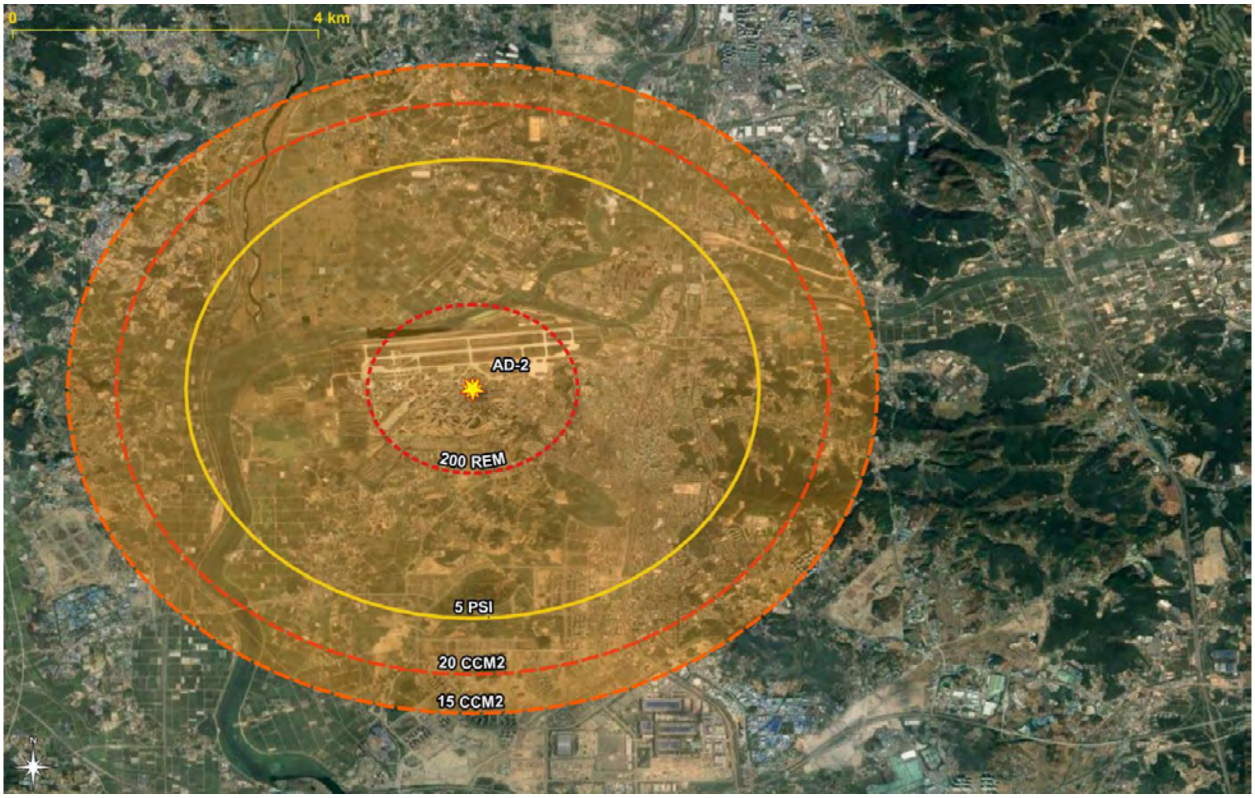


Figure A3-41: Use Case 5, AD-2, Attack on Military Base, ROK, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm is possible for this site due to large built-up areas and dense housing in the southern and eastern part of the contour.

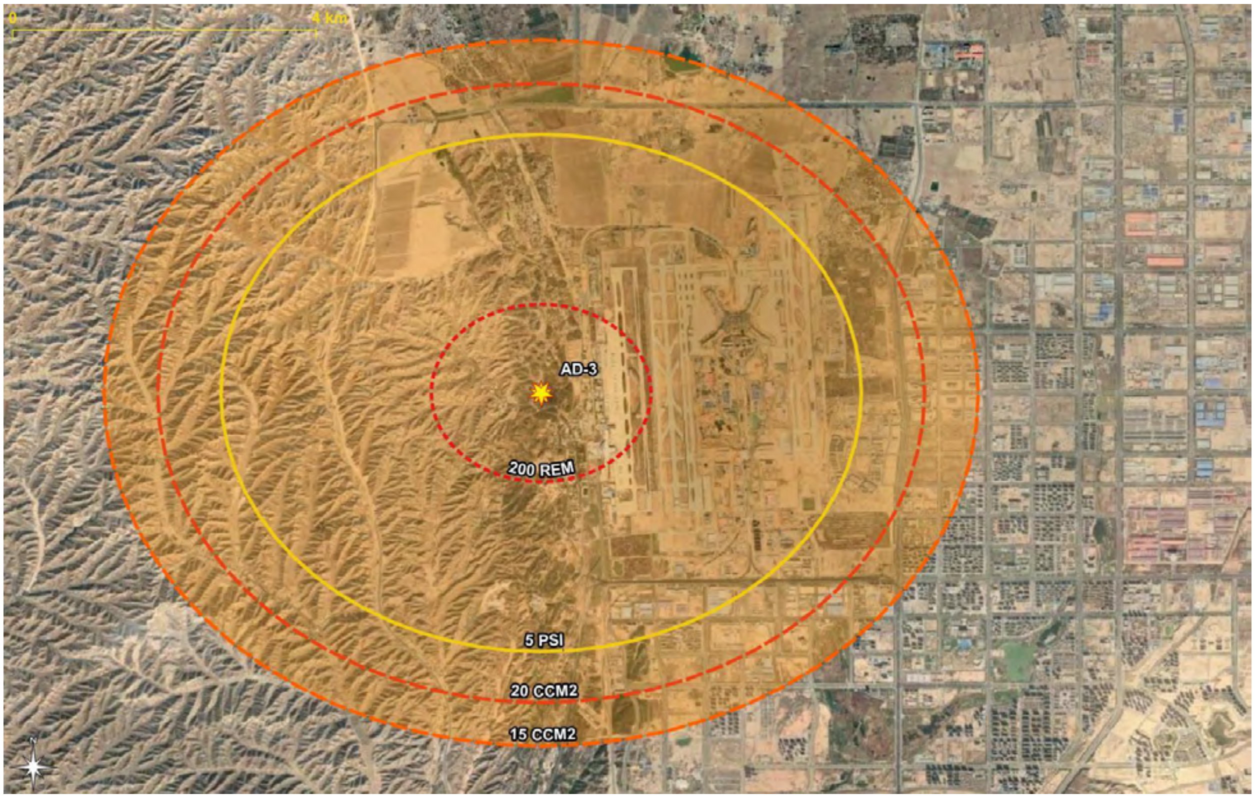


Figure A3-42: Use Case 5, AD-3, Attack on Missile Base, China, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm is unlikely for this site due to lack of vegetation over much of the site, large areas of tarmac, and limited built-up areas within the 15 cal/cm^2 fluence contour.

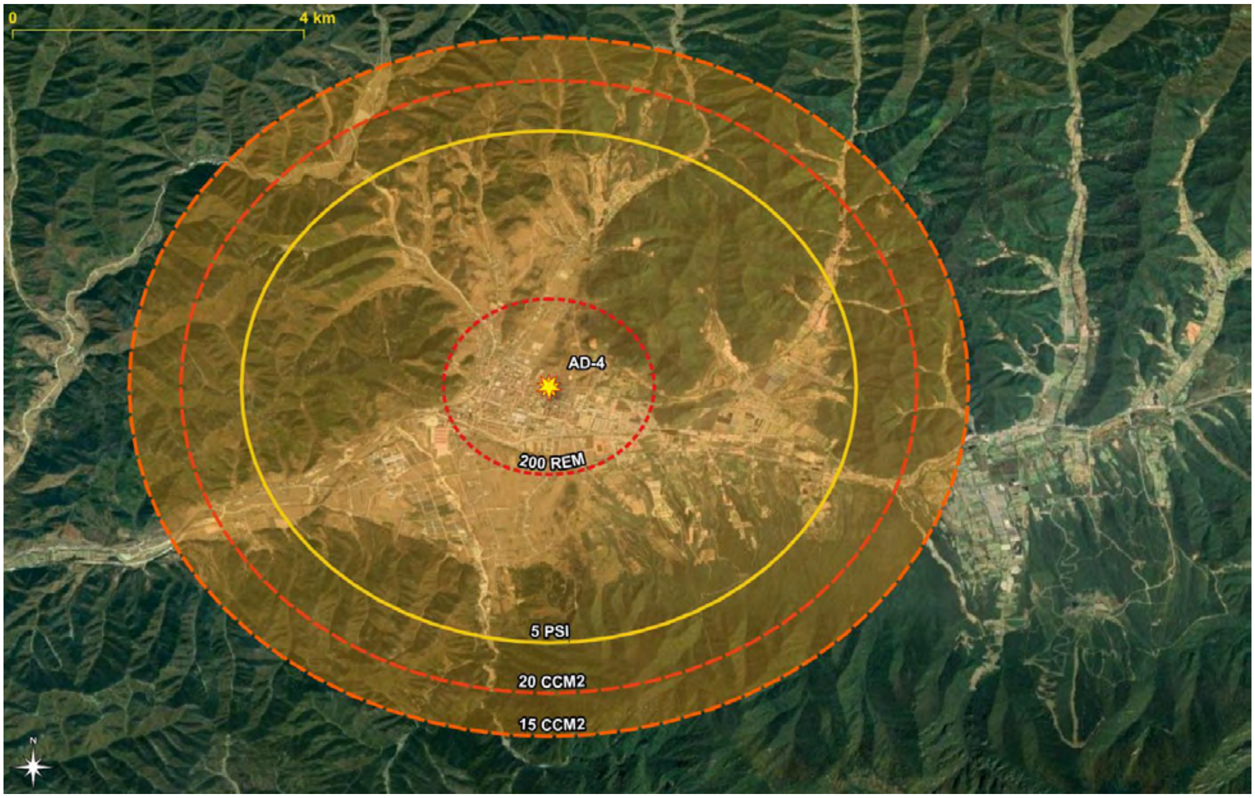


Figure A3-43: Use Case 5, AD-4, Attack on Missile Base, China, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm is unlikely for this site due to relatively sparse forest vegetation over much of the area within the 15 cal/cm^2 fluence contour and the rugged topography of the region, but serious fires likely over the built-up areas near ground zero and in the forests in the surrounding area.

Figure A3-44: Use Case 5, AD-5, Attack on Naval Base, China, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm likely over at least part of this site (western built-up area within the 15 cal/cm^2 fluence contour. Other built-up areas, separated from this built-up area by water, would also likely burn in separate fires.

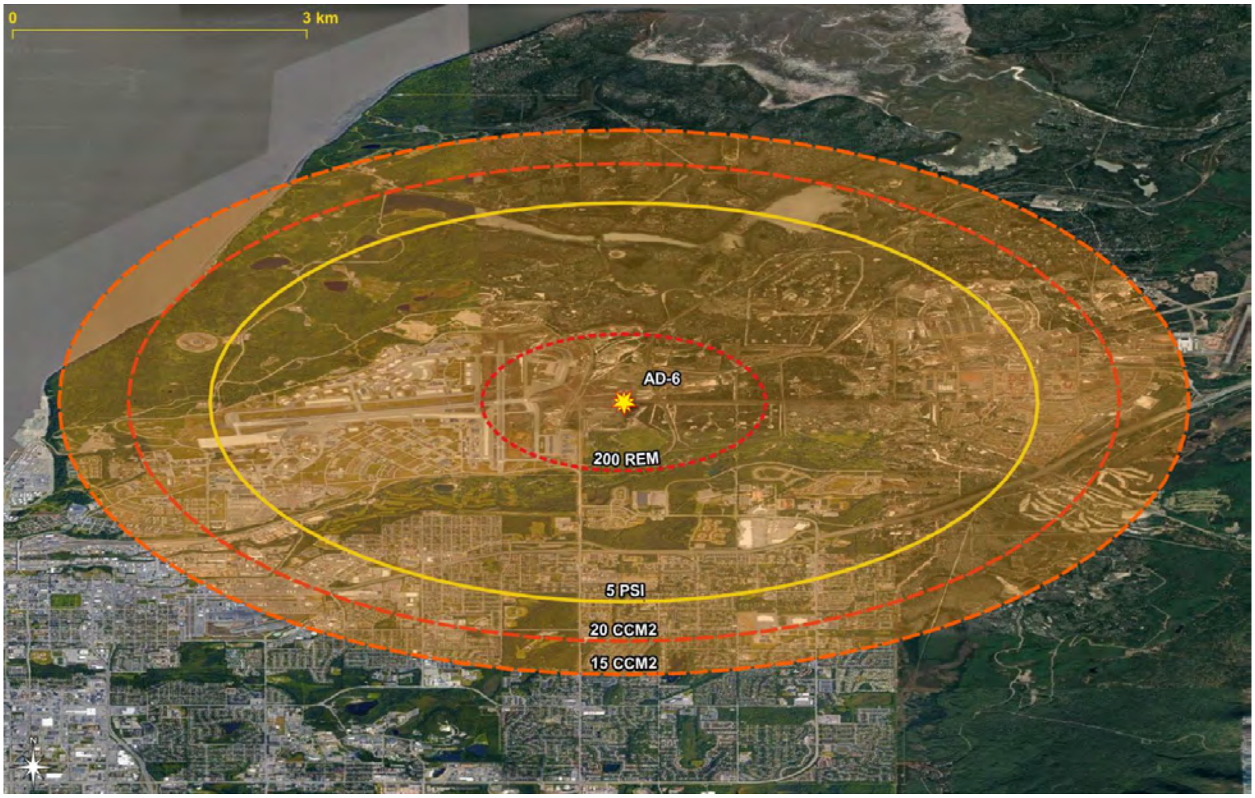


Figure A3-45: Use Case 5, AD-6, Attack on Military Base, United States (Alaska), Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm likely over at least a large part of this site within the 15 cal/cm^2 fluence contour. The northern part of the area likely has insufficient fuel to support a firestorm.

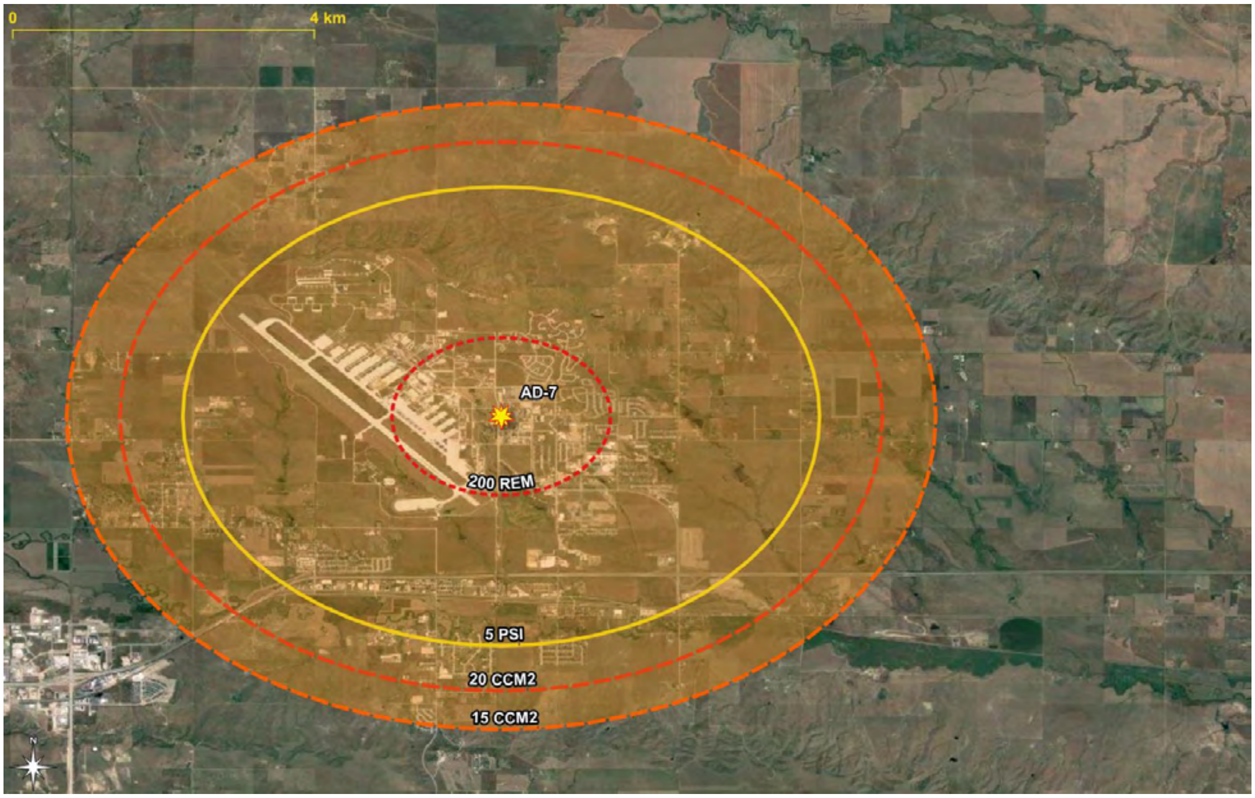


Figure A3-46: Use Case 5, AD-7, Attack on Military Base, United States, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm unlikely due to low vegetation (agricultural fields) and few structures over the 15 cal/cm^2 fluence contour.

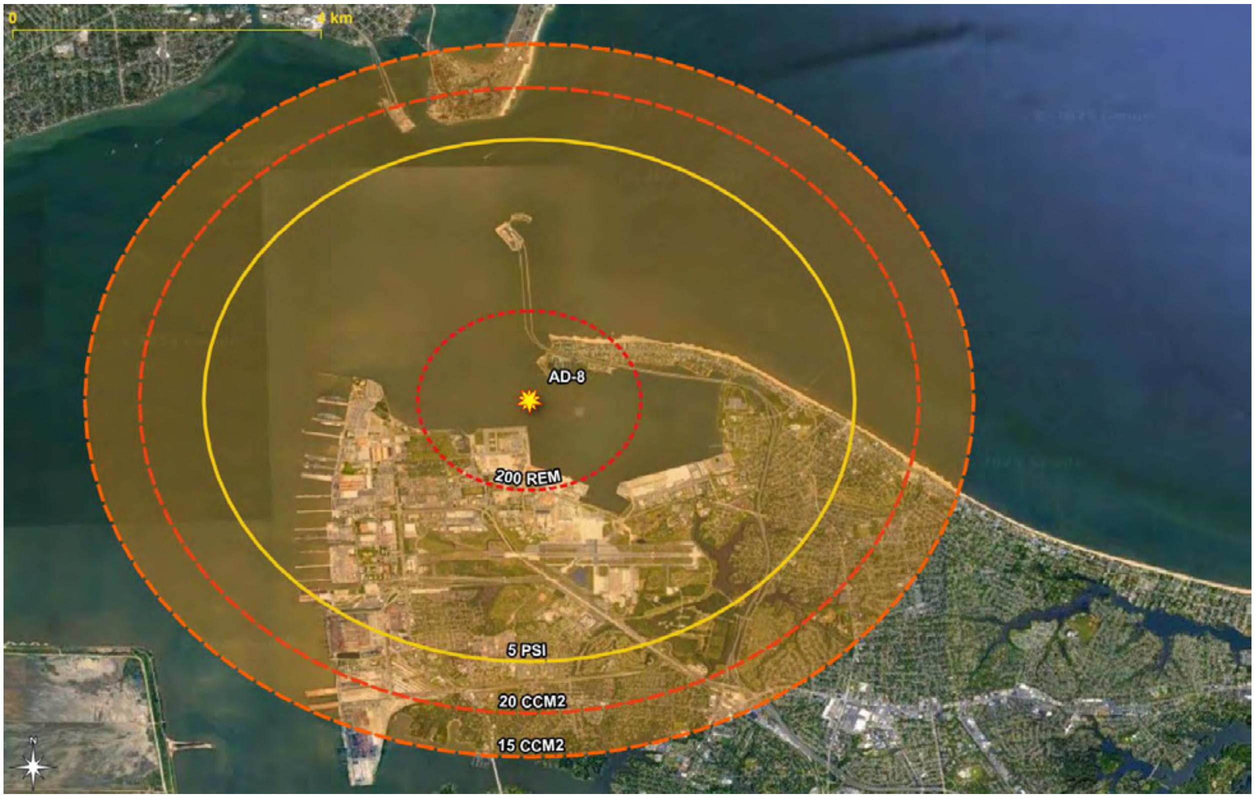


Figure A3-47: Use Case 5, AD-8, Attack on Military Base, United States, Range of Potential Firestorm and Other Likely Lethal Impacts.

Firestorm potential assessment: Firestorm likely in built-up area in the southern part of the 15 cal/cm^2 fluence contour, although much of the fluence contour is over water.

Figure A3-48: Use Case 5, AD-9, Attack on Military Base, Japan, Range of Potential Firestorm and Other Likely Lethal Impacts.

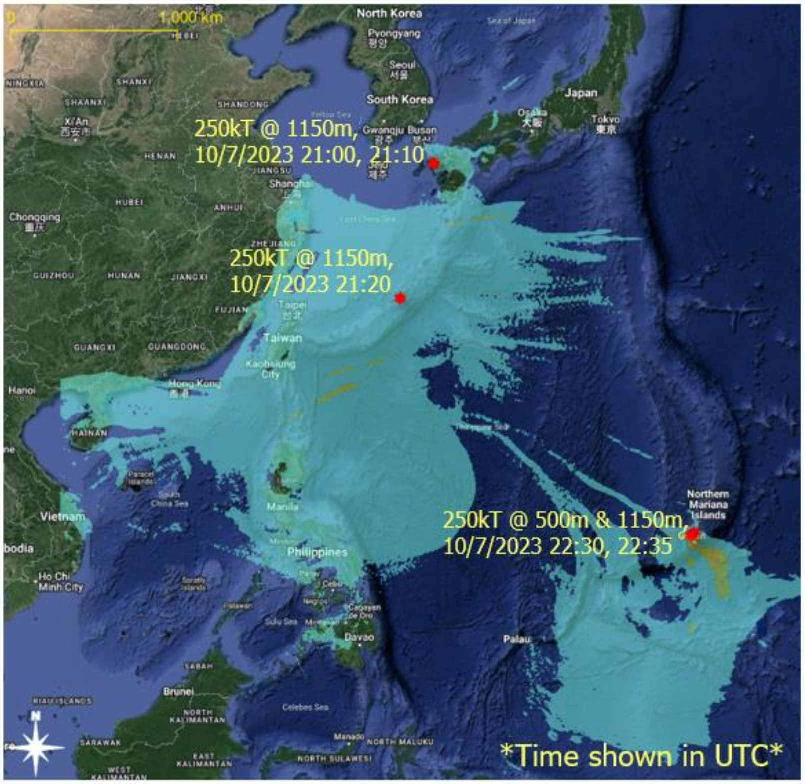
Firestorm potential assessment: Firestorm likely in built-up area over most of the 15 cal/cm^2 fluence contour, although the eastern portion of the fluence contour is mostly over water.

Summary of Estimated Overall Likely Deaths and Eventual Cancer Deaths in Evaluated Use Case 5 from Different Impacts, All Detonations.

Table A3-5: Estimated Likely Deaths, Use Case 5

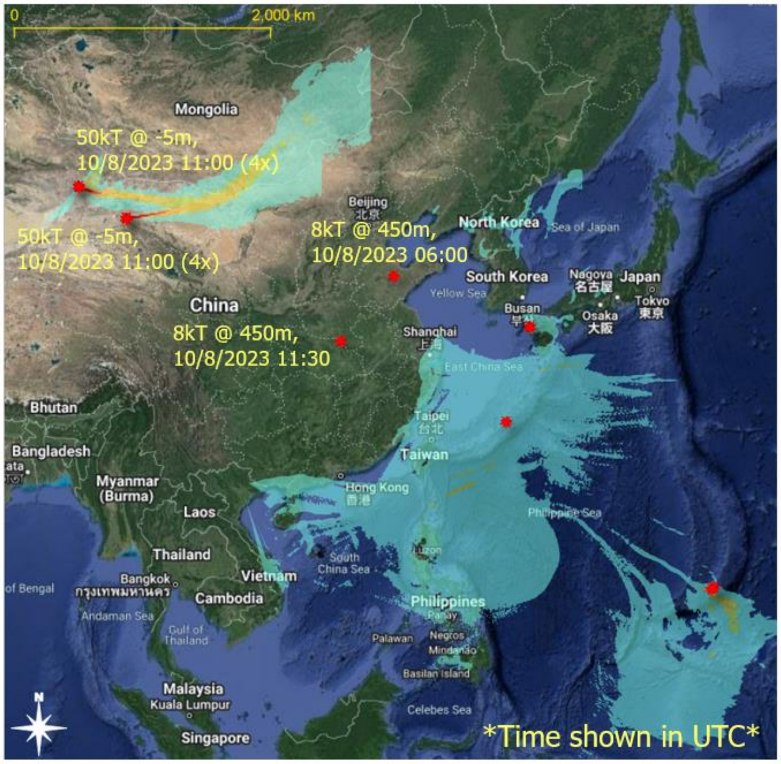
Estimated Likely Deaths: Use Case 5 **Additional Detonations***	
Prompt (days to weeks)	1,500,000
Short-Term (weeks to months)	930,000
Additional Impact: Firestorms	190,000
Total (0.5 psi Zone) (Total Pop., % Lethality)	**2,600,000** (7,600,000, 35%)
High Radiation Fallout Dose (short-term)	**400 - 19,000**
Radiation-Induced Cancer Deaths (long-term)	**96,000 - 830,000**

Nuclear Fallout Simulation Results: Use Case 5: "Not Going Well in Taiwan."



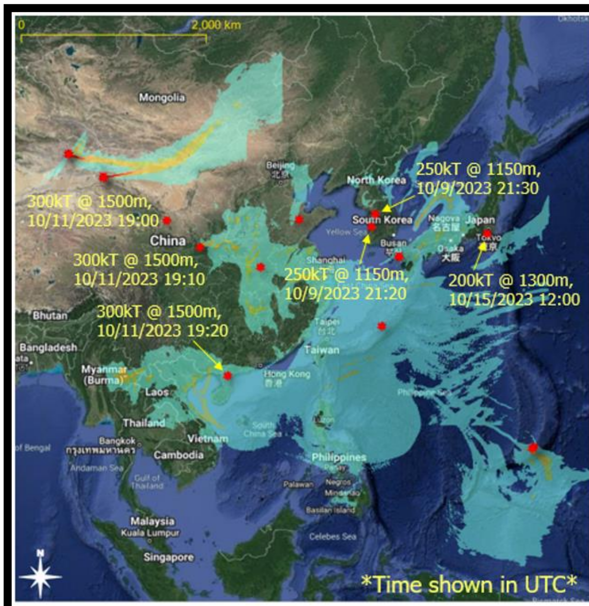
"Not Going Well in Taiwan" First Use Detonations : Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	150,000
10-50	99,000
50-100	0
100-200	0
200-600	0
> 600	0

Figure A3-49: Use Case 5, First Use Detonations, Fallout Modelling Results.



"Not Going Well in Taiwan" First Response Detonations : Cumulative Population Affected by Fallout Radiation Dose	
Dose (rem)	**Population**
5-10	210,000
10-50	510,000
50-100	10,000
100-200	2,000
200-600	18,000
> 600	400

Figure A3-50: Use Case 5, First Use and Response Detonations, Fallout Modelling Results.



"Not Going Well in Taiwan" Additional Detonations : Cumulative* Population Affected by Fallout Radiation Dose				
Dose (rem)	**Population**			
	Mainland Asia / Pacific	**Southeast Asia**	**North America**	**Japan**
5-10	53,000,000	9,600,000	340,000	2,800,000
10-50	14,000,000	2,600,000	47,000	340,000
50-100	64,000	19,000	8,000	0
100-200	0	0	0	0
200-600	0	0	0	0
> 600	0	0	0	0

Figure A3-51: Use Case 5, All Detonations, Fallout Modelling Results.