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Projected Casualties Among U.S. Military Personnel and Civilian Populations from the Use of Nuclear Weapons Against Hard and Deeply Buried Targets

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Abstract

Over the last decade, some U.S. political and military leaders have expressed increasing concerns about the potential use of nuclear, biological or chemical (NBC) weapons against the United States and its allies. This potential threat has led to an increasing willingness of American strategists to consider the use of nuclear weapons for counterproliferation. To this end, the President's budget requests have proposed funding for the Robust Nuclear Earth Penetrator (RNEP) a "bunker-busting" nuclear bomb, intended to penetrate hard surfaces such as rock and explode underground. To fulfill plans for development of an RNEP to be ready for deployment by 2013, the administration has pursued the adaptation of an existing bomb, the B83, with a yield of 1.2 megatons (approximately 80 times the explosive power of the bomb used on Hiroshima). Yet recently published analysis by both the National Academy of Sciences and independent physicists, echoed in Congressional testimony by the head of the National Nuclear Security Administration, concludes that nuclear earth penetrating weapons cannot penetrate deeply enough to contain underground a nuclear explosion and the resulting radiation. Using a computer model developed by the Department of Defense, Physicians for Social Responsibility (PSR) calculates that the use of such a weapon against targets in Iran or North Korea could cause millions of deaths, and lead to millions more acute and long-term health effects for U.S. military personnel and local populations in the affected regions. In one scenario, use of the RNEP against Isfahan in Iran, as many as 20,000 US military personnel stationed in Afghanistan and 35 million innocent civilians in Iran, Afghanistan, Pakistan and India could receive doses of radiation high enough to cause a significant health impact, including as many 3 million deaths. These factors should weigh heavily against proceeding with the RNEP program.

Introduction

Over the last decade, some U.S. political and military leaders have expressed increasing concerns about the potential use of nuclear, biological or chemical (NBC) weapons against the United States and its allies. This threat is seen as a response by states and non-state actors to the emergence of the United States as the sole superpower. Military concerns also center on the proliferation of Hard and Deeply Buried Targets (HDBTs), or "bunkers", which can be used to store NBC weapons, facilities to produce such weapons, and command and control centers.

This potential threat has led to an increasing willingness of American strategists to consider the use of nuclear weapons during both the first Bush and Clinton administrations. Such strategic considerations have led to the development of counterproliferation policy and doctrine, including plans to use nuclear weapons against Iraqi chemical weapons targets during the first Gulf War, as well as plans and veiled threats under President Clinton to use nuclear weapons against nuclear weapons facilities in North Korea in 1994 and against the Tarhuna chemical weapons plant in Libya in 1996 (Butcher, 2003). These concerns have found voice in the Bush Administration's *Nuclear Posture Review* (NPR), as well as the *National Strategy to Combat WMD*. *Joint Publication 3-40, Joint Doctrine for Combating Weapons of Mass Destruction* (an official document of the Joint Chiefs of Staff), calls for the use of the "full range" of military capabilities to eliminate enemy WMD. To this end, the President's budget requests have proposed funding for the research of new nuclear warheads, notably the Robust Nuclear Earth Penetrator (RNEP), a "bunker-busting" nuclear bomb, intended to penetrate hard surfaces such as rock and explode underground (Burns, 2002).

There is much debate over the effectiveness and necessity of such weapons. Little concern has been expressed to date about the medical consequences of the use of bunker-buster nuclear weapons by the United States for its own military personnel, let alone potentially affected civilian populations. In this paper we demonstrate that personnel would be exposed to the risk of death or severe injury from blast, burn, or radiation effects of nuclear weapons. Longer-term consequences would include increased incidence of cancer, thyroid disorders, and other diseases in affected personnel. We first examine the RNEP research program, and then the nuclear weapons employment policy and doctrine which might lead to its use. We then examine the effects of nuclear weapons use in general, before elaborating two specific scenarios for the possible use of the RNEP – one against a target in Iran and the other against a target in North Korea, both associated with the respective nuclear weapons development programs in those two countries. As Congress decides whether to fund the RNEP program, we believe all these factors should be taken into consideration.

Bunker Busting Nuclear Weapons: The RNEP

The Robust Nuclear Earth Penetrator (RNEP), or nuclear bunker buster, has been touted by the Bush Administration as necessary for HDBT defeat. In the FY2004 budget, the Bush Administration requested $15 million to continue research on the Robust Nuclear Earth Penetrator and requested $27.6 million for the FY2005. Ultimately this was rejected, but the administration has renewed its request in the FY2006 budget, asking for $4 million in the National Nuclear Security Administration budget for Phase 6.2 research work, and a further $4.5 million in the Air Force budget for a drop test of a new casing for the RNEP.

According to the NPR, completed in January 2002, there are an estimated 10,000 hard and deeply buried targets (HDBTs) in over 70 nations. The purpose of the proposed RNEP is to destroy targets of this nature. (Medalia, 2004).

Initial research was undertaken into the suitability of the B83 and B61 bombs for use as the RNEP. The B83 has now been chosen as the B61 already exists in an earth-penetrating version, the B61-11. The B83 has a yield of 1.2 megatons, a huge explosive power. The administration has suggested that an RNEP could be ready for deployment by 2013, if they choose to pursue the program.

Employing Nuclear Weapons

Strict guidelines on the appropriate situations warranting the use of nuclear weapons are outlined in the Joint Chiefs of Staff's *Doctrine for Joint Theater Nuclear Operations*. According to the doctrine, employment suitability is determined by the following:

- Relative Effectiveness
- Nuclear Collateral Damage
- Enemy Responses
- Advance Planning
- Execution Planning to Deconflict [avoid] Friendly Casualties
- Other Considerations

In military doctrine, the use of nuclear weapons is warranted only if they offer a clear and substantial advantage over the use of conventional weapons. Advanced planning in such a situation is critical, as the decision to use nuclear weapons is one with significant repercussions. The effectiveness of nuclear weapons must be such that they are the only option for striking a particular target. Commanders and their staff must consider deploying nuclear weapons in a way that minimizes civilian casualties and must take into consideration the responses of enemy forces related to such an attack. The anticipation of delays in ground force effectiveness also must be calculated.

The doctrine emphasizes the need to minimize casualties among U.S. forces in range of a nuclear detonation. It is then noted that *all forces* are vulnerable to a nuclear attack and it is "increasingly likely" that closer forces would be within striking distance of an explosion. Commanders deciding to use a nuclear weapon are advised to ensure that all other military commanders have been informed so that areas can be cleared and resulting immediate casualties of friendly troops are reduced. However, as will be discussed in more detail below, the effects of the use of the proposed RNEP would require evacuation of a huge area to achieve this goal.

It is therefore unlikely, despite this doctrine, that all casualties, particularly those from the long-term effects of radiation, can be avoided. This is especially the case with a strike on a potential enemy NBC weapons site. Intelligence follow-up will be essential, and U.S. personnel would almost certainly be exposed to radioactive contamination over at least the short- to medium-term. It is likely, as in Japan after World War II, that U.S. troops would be required to secure an area after nuclear weapons use, thus exposing many personnel to significant radiation doses.

The Effectiveness of Earth Penetrating Nuclear Weapons (EPWs)

From the standpoint of nuclear weapons designers and nuclear strategists, the bunker buster seems the perfect concept, a nuclear device that buries so deep into the ground that nuclear fallout is contained and chemical/biological agents are neutralized. However, a recently published analysis concludes that nuclear EPWs cannot penetrate deeply enough to contain underground a nuclear explosion and the resulting radiation:

> As tests at the Nevada Nuclear Test site have shown, a 1-kiloton explosion must be buried and carefully sealed more than 300 feet (100 meters) below the surface to fully contain the radioactive products. Yet a missile made of the hardest steels cannot survive severe ground impact stresses at velocities greater than about 900 meters per second without destroying itself. This limits the maximum possible penetration depth of the missile into reinforced concrete to about four times the missile length—approximately 12 meters for a missile three meters long. Even for the strongest of materials, impact velocities much greater than one kilometer per second will crumple and destroy the penetrator and its warhead. At this relatively shallow depth, the explosion will inevitably breach the ground surface and throw out radioactive dirt and debris. The resulting base surge of radioactive fallout will extend over an area of several square kilometers. Anyone remaining in this area for more than a few hours would receive a fatal dose of radiation and shorter exposure would cause significant injury ... (Sidel, 2003)

Robert Nelson, Senior Science and Technology Fellow for the Council on Foreign Relations and Princeton University physicist, questions the effectiveness of the bunker buster weapons on underground targets and their ability to destroy a chemical or biological weapons cache. Nelson concluded in his study for the journal *Science & Global Security*, "The scenarios for bunker busting [and] agent defeat that proponents use to justify new weapons are either ineffective, or only marginally more effective, than conventional alternatives." He also points out that using a bunker buster to destroy chemical and biological weapons (CBWs) would be more liable to scatter the active agents into the atmosphere than effectively killing the germs or dissipating the chemical material (Schmitt, 2003).

Nelson's conclusions have been largely validated by the National Academy of Sciences. In an April 2005 report, NAS estimates that, with reasonably accurate delivery, a nuclear EPW with a 300 kiloton yield could allow destruction of a target buried at around 200 meters. A full megaton burst would be necessary to destroy a target buried at 300 meters. They conclude that such a weapon could not destroy stocks of chemical or biological agents, and that the danger of venting to the surface of agents such as anthrax, Vx, lewisite of mustard gas would remain. Anthrax or other biological agents would present a more serious threat than chemical agents whose effects would be localized and less persistent. They also conclude that a nuclear EPW would have massive collateral effects over a wide area. (NAS, 2005)

Nelson's conclusions have also been mirrored by administration statements to Congress. Ambassador Linton Brooks, head of the National Nuclear Security Administration, told Congress on March 2, 2005 that:

> "**I really must apologize for my lack of precision if we in the administration have suggested that it was possible to have a bomb that penetrated far enough to trap all fall-out. I don't believe the laws of physics will ever let that be true. It is certainly not what we're trying to do now.** What we are trying is to get in the ground far enough so that the energy goes deep into the ground to hold at risk the deeply buried facilities. But it is very important for this committee to recognize what we on our side recognize.... **There is a nuclear weapon that is going to be hugely destructive over a large area.** No sane person would use a weapon like that lightly... **I do want to make it clear that any thought of ... nuclear weapons that aren't really destructive is just nuts**." (Emphasis added)

Indeed, as indicated above the current RNEP candidate weapon, the B83, has a much larger nuclear yield than the current nuclear EPW, the B61-11, at a maximum yield of 1.2 megatons for the B83 against 10 - 340 kilotons for the B61. A B83-based RNEP would make a crater approximately 1000 feet across, leading to associated destruction and casualty effects discussed below (Oelrich, 2005).

Blast Damage and the Immediate Medical Consequences of EPWs

If EPWs were dropped on a target, the initial heat and blast damage would be much more extensive than from a conventional weapon. Prompt radiation effects (see discussion below on health effects of radiation) and initial heat and blast damage would be less severe than from an air-burst nuclear weapon, but would still be substantial. Initial injuries suffered by troops or civilians on the ground would be immense and deadly. These effects are well-known and predictable from range effect tables for blast, burn, and radiation (Glasstone and Dolan, 1977).

Thermal burns would be the most common injuries. Thermal radiation produces two types of burns – flash burns and flame burns. Flash burns are caused by the direct absorption of thermal energy, whereas flame burns are the result of secondary fires sparked by the same energy (Jacocks, 2003).

Though troops could be partially protected from thermal effects, the complex patterns of overpressure resulting from the blasts cannot be mitigated. Crush injury and laceration are the most common form of injury from the blast effect and from flying debris (Jacocks, 2003). Drag forces – the pressures resulting from blast winds – are powerful and have the ability to collapse buildings and displace vehicles. This would add to the trauma injuries suffered by people in the vicinity of the blast.

In the scenarios detailed below, the presence of U.S. troops on the ground near the target is unlikely, and so these injuries would be suffered primarily by civilians. Hospitals would likely be destroyed or badly damaged by the blast, and therefore any potential treatment that could be given would be inaccessible. Field medical personnel would be unable to operate in the area near the site of the EPW use because of immediate radiation as well as continuing fallout. Evacuation from the site of an EPW detonation would rely on the availability of transport and the accessibility of roads and pathways out of the affected area. Furthermore, as stated in the *Army Handbook*, responsiveness to medical treatment would be complicated to a debilitating degree due to irradiation leading to immune suppression in those affected (Jacocks, 2003).

Effects of Radiation

A common misconception is that because these weapons are detonated underground the fallout would be significantly less, and that the RNEP will be a small nuclear weapon to allow this to happen. This confusion started with the Nuclear Posture Review, and continues because of administration statements on the nature of the planned RNEP. Secretary of Defense Donald Rumsfeld and others have talked about the need for a smaller nuclear weapon for HDBT defeat. For example, Secretary Rumsfeld told a Senate hearing on April 28, 2005 that:

> .... more than 70 countries have programs to build facilities under-

> ground, and have available to them equipment that can, in a single day, dig out of rock a chamber the size of a basketball court. "We can't go in there and get at things in solid rock underground," Rumsfeld said. "The only thing we have is very large, very dirty nuclear weapons. So the choice is: Do we want to have nothing and only a large, dirty nuclear weapon, or would we rather have something in between? That is the issue." (IHT, 2005)

This clearly implies that the RNEP will be a small nuclear weapon, whose effects could be easily contained. However, the possibility of containing a nuclear explosion underground is not supported in published scientific literature.

A nuclear EPW would actually create *more* fallout than a ground-burst or air-burst weapon, due to the increased distribution of radioactive debris from detonation at a shallow depth in soil or rock (Medalia, 2004). The National Academy of Sciences reports that achieving earth penetration of a few meters depth allows the use of a smaller weapon than would be necessary with a surface burst, due to the enhanced ground-shock coupling of a weapon exploding below the ground. (NAS, 2005) . This does not mean the effects of the explosion could be contained, or that the planned RNEP is a small weapon.

As Michael May, former head of the Lawrence Livermore National Laboratory, observes, penetrating weapons do not bury themselves in the ground at a depth suitable to contain even a low-yield explosion (May, 2004). Most of the radiation and the biological and/or chemical agents contained within the targeted bunker will fall to the top of the crater at the site of impact and, consequently, will cause the area to become highly radioactive. The remainder of agents and radiation will rise into the atmosphere and drop eventually in other areas in a pattern of dispersal dependent upon the weather at the time, influenced by such factors as wind and rain.

According to the Armed Forces Radiobiology Research Institute, a burst of acute high-dose radiation with resulting adverse health effects occurs predominantly during the first 60 seconds after detonation of a nuclear weapon. In the case of a nuclear EPW detonation, within that first minute, troops and civilians in the immediate area could be exposed to a significant enough amount of radiation to attack and irreversibly damage the hematopoietic and gastrointestinal systems, causing cell death and the failure of organs in those systems. In addition, as will be described in the scenarios below, significant morbidity and mortality would likely result from radioactive fallout in the days following the detonation (Jacocks, 2003).

If nuclear EPWs were to be used to destroy underground stockpiles of chemical or biological weapons, the mortality rate could be much higher due to complications resulting from the types of targets hit. Though radiation doses smaller than the lethal dose would likely leave many soldiers still alive, the potential for subsequent fatal opportunistic infections from biological agents released in the blast would be increased because radiation suppresses the immune system (Jacocks, 2003). Alternatively, soldiers could be affected by nerve agents and other chemical weapons released by the explosion.

Long-term effects are much more difficult to measure, but based on past experience are likely to be devastating. A report by the National Cancer Institute warns that the risk of developing thyroid cancer is much greater for those who have been exposed to I-131, a radioactive form of iodine released during a nuclear explosion (NCI, 2002). Through studies conducted on people exposed to radiation from the atomic bombings of Hiroshima and Nagasaki, we know that thyroid cancer is a grave concern for those vulnerable to the byproducts of nuclear explosions. The exact risks are not completely known for adults exposed to I-131, but studies done on children indicate that the risk of developing this form of cancer is significantly higher than the national average (Rush and Geiger, 1997).

The history of Bikini Atoll provides further insight into the kinds of health problems those exposed to the fallout from an RNEP might expect to suffer. In 1946, the United States Navy took control of the Bikini Islands and established them to be the prime testing facility for nuclear weapons. Over a half-century later, this tropical paradise remains devastated by nuclear fallout. Immediate radiation sickness was clearly diagnosed, but the expected lingering effects of radiation exposure were never adequately explained by U.S. authorities to the downwinders of Bikini's nuclear tests who had no historical experience of such devastation. In 1963, almost two decades after testing began, the first signs of depressed immune systems emerged. Radiation had lowered white blood cell counts and blood marrow cell counts in the population living around Bikini Atoll. Hypothyroidism and nodular goiters, as well as malignant and benign tumors, began to emerge in the community, and an unusually high rate of miscarriages and stillbirths were experienced throughout the 1970s. Even today, the physical and psychological damage of weapons testing on the island is acutely felt. As one member of the Bikini Community reflects, "What radiation does psychologically tends to supersede the fear and the reality of cancer. You can't really see it or touch it, but it produces a heightened sense of danger (Guyer, 2001)."

Soldiers who either participated in nuclear tests or were stationed or held captive in Hiroshima and Nagasaki during World War II are known collectively as

'Atomic Veterans'. A study of this group provides a basis for understanding likely harm to U.S. personnel from radiation exposure following future nuclear attacks. According to the Japanese Ministry of Foreign Affairs, there are twenty recorded fatalities among American POWs as a result of the Hiroshima bombing. Most were killed instantly and two lingered on for a few days before succumbing to radiation illness (Ishikawa, 1981).

An estimated 195,000 soldiers were involved in the occupation of Hiroshima and Nagasaki, with an additional 210,000 participating in atmospheric nuclear testing from 1945 to 1962 (VA, 2002). While those exposed to nuclear tests have been comprehensively monitored, little or no follow up was in place for U.S. service personnel who were stationed in Hiroshima or Nagasaki. Nodular thyroid goiters, posterior subcapsular cataracts, tumors of the brain and central nervous system, and twenty-one types of cancer are among the afflictions recognized by the Department of Veterans Affairs in its programs for Atomic Veterans.

Two RNEP Strike Scenarios

Using software, the Hazard Prediction and Assessment Capability (HPAC), developed by the Defense Threat Reduction Agency (DTRA) to model nuclear weapons explosions effects and to plan nuclear operations, Physicians for Social Responsibility staff modeled two RNEP attacks on sites that may well be regarded as suitable for nuclear strike. The first is an Iranian underground nuclear materials storage site at Isfahan, currently the subject of much administration concern. Iranian officials have acknowledged the Isfahan facility, a deeply tunneled storage site, is specifically designed to be impervious to conventional attack, making it a prime RNEP target. The second site is at Yongbyon in North Korea, where a number of facilities for the production and processing of plutonium exist. In both cases, a 1.2 megaton explosion (some 80 times the power of the bomb that was dropped on Hiroshima) was modeled. This represents the maximum power of the B83 bomb, which has been selected as the bomb to be adapted for use as a bunker buster, and matches the explosive yield the NAS calculates as necessary to destroy HDBTs buried at 300 meters.

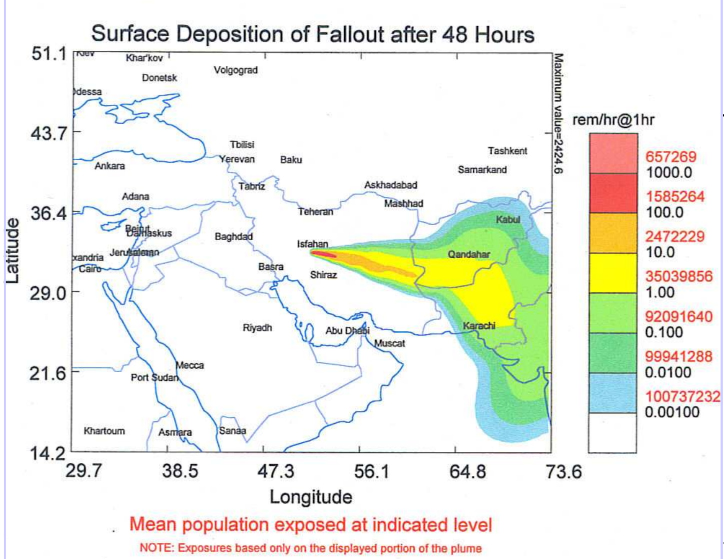
Historical weather patterns built into the software were used to calculate fallout patterns. Prevailing winds in both regions discussed blow in a predominantly easterly direction. The population database used by the HPAC is drawn from official census information dating to the early 1990s. This tends to understate current population and thus casualty figures. As discussed above, an underground explosion would spread much more radioactive debris than an air-burst of a nuclear weapon. The debris from the explosion would rise as high as 30,000 feet, and be spread over very significant distances. This would lead to a significant number of radiation casualties downwind of the attack.

Please note that these models have been prepared for illustrative purposes, and that the RNEP, if fully developed, would not be ready for use until around 2013. The RNEP would not necessarily be chosen to attack these particular targets. For targets down to 200 meters the current "bunker-buster", the B61-11, would have sufficient explosive yield. The B83 RNEP would be likely be used for targets between buried between 200 and 300 meters deep. We have chosen to illustrate the use of the B83 as that is the focus of current RNEP research efforts.

Isfahan, Iran

From the HPAC calculations, we estimate that within 48 hours of an RNEP attack, over 3 million people would die as a result of the attack. About half of those would die from radiation related causes, either prompt casualties from the immediate radiation effects of the bomb, or from exposure to fallout. For example, the entire city of Isfahan would likely be covered in fallout producing 1000 rems of radiation per hour, a fatal dose. Over 600,000 people would suffer immediate injuries of the kind described previously.

Figure 1: RNEP Strike on Isfahan, Iran



From the map on this page, generated by the Defense Department software, we can see that within 48 hours, prevailing winds would spread fallout to cover a large area in Iran, most of Afghanistan and then spread on into Pakistan and India. There is little likelihood, in most seasons, that rain would mitigate the spread of fallout.

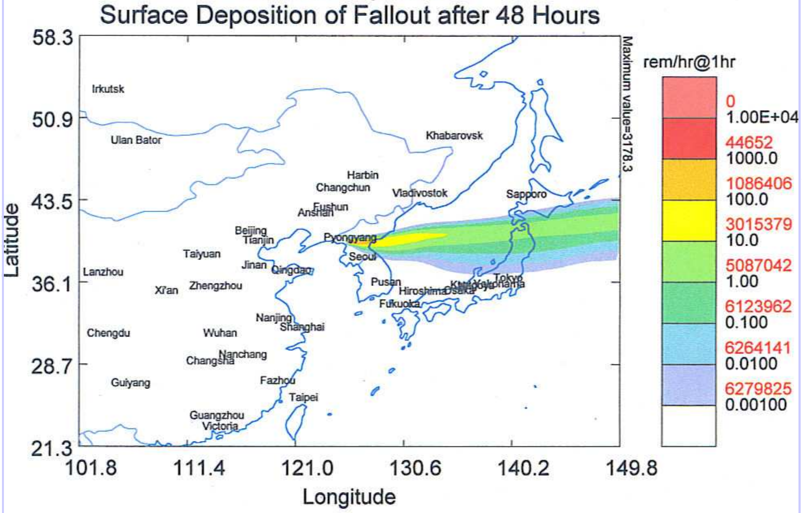
In this scenario, over 35 million people in Iran, Afghanistan, Pakistan, and India would suffer significant radiation exposure of 1 rem per hour or above within four days of the use of the RNEP. At this rate, the 25 rem limit at which physical effects can be expected would be reached within 25 hours of first exposure, and the 100 rem limit at which more severe damage could be caused would be reached in only 4 days. (Given the lack of modern communications in this area, as well as the lack of advanced education available to the affected populations, it is unlikely that warnings would spread quickly enough to allow mitigating measures to be taken). Immediate effects would include skin burns and diarrhea secondary to gastro-intestinal cell damage. Long-term effects could include cancers. Many, if not all, of the approximately 20,000 American armed forces, intelligence and diplomatic personnel deployed in Afghanistan would be at risk of exposure at these radiation levels. While U.S. personnel could be evacuated, and would receive sophisticated medical care if necessary, this would not apply to the local population in most of the affected area.

Yongbyon, North Korea

In an alternate scenario using the North Korean nuclear weapons and power facilities at Yongbyon as a potential target, it is clear that the effects of an RNEP strike, while more limited than a strike on Isfahan, would be significant. Over 500,000 people would be killed immediately, with some 2 million other casualties. Degradation of already limited hospital facilities in North Korea would reduce the chances of survival for the injured.

Assuming historical weather patterns and use of the weapon on a dry day, the plume of fallout would cross North Korea and part of South Korea, and then over significant parts of two Japanese islands. U.S. forces currently in the region would not be directly affected, as the fallout plumes would pass to the north of US bases and facilities in Japan.

Figure 2: RNEP Strike on Yongbyon
Surface Deposition
Surface Deposition of Fallout after 48 Hours



Mean population exposed at indicated level
NOTE: Exposures based only on the displayed portion of the plume

However, millions of people in North and South Korea, as well as Japan, would be at significant risk of radiation exposure. Within two days of the attack, over 5 million people would be at risk of exposures at 1 rem per hour or above. After four days exposure at such levels, as in the Isfahan scenario, the affected population would be at risk of severe long-term effects from this level of radiation exposure. Since warnings would reach the population easily in this area, it is likely that extreme social and economic disruption would be caused in Japan and Korea as people sought to flee to avoid the fallout plume from Yongbyon.

Conclusion

The use of nuclear weapons to destroy Hard and Deeply Buried Targets, or to neutralize chemical or biological weapons, provides a superficially attractive option to proponents of such weapons. Detailed analysis, however, reveals flaws that cannot be remedied.

The realities of physics establish certain functional limitations on such weapons that no engineering design can overcome. At the same time, we know enough about the blast, thermal, and radiation effects of nuclear weapons intended to be detonated after penetrating the earth to predict severe adverse health impacts on civilian and military populations over an extremely wide area.

The political cost of simply developing, testing, and producing such weapons is high enough. Their use, breaching a 60-year old taboo, would be devastating for the reputation of the United States. When added to the wholly predictable, and largely unpreventable, harm to U.S. military personnel on the ground and civilian populations of affected countries even far beyond the strike zone, the analysis strongly weighs against the development of new nuclear weapons for counterproliferation missions.

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