Nuclear Preparedness require Accurate Modelling and Simulation for Prediction of Nuclear Weapons Effects on Facilities and persons

According to the U.S. National Security Strategy, the potential use of nuclear weapons poses the greatest danger to U.S. security. Apart from countries like North Korea that threaten to use nuclear weapons, the world is facing many nuclear threats because of nuclear arms race in asia, modernization of nuclear arsenal by global and regional powers, s, ongoing missile and nuclear proliferation risks in the Middle East and acquiring of Nuclear weapons by terrorists.

Al Qaeda and other Islamist terrorist groups have explored the possibility of acquiring nuclear weapons to be used against their enemies. In May of this year, Islamic State used its propaganda magazine Dabiq to suggest the group is expanding so rapidly it could buy its first nuclear weapon within a year. "The Islamic State has billions of dollars in the bank, so they call on their wilayah (province) in Pakistan to purchase a nuclear device through weapons dealers with links to corrupt officials in the region," the article, attributed to British photojournalist John Cantlie held hostage by Islamic State for over two years, said. Once the Islamic State buys the bomb in Pakistan, according to the article, it would transport it through Libya and Nigeria to the West.

Apart from terrorists, there is also threat of accidents involving nuclear material. The government of Kazakhstan said in Sept 2014 that it was searching for a container of radioactive cesium-137 that fell off a truck in the western part of the country. The material was recovered, but the incident highlighted the risks of radioactive material falling into the wrong hands.

A 2006 RAND paper for the U.S. Department of Homeland Security (DHS), examined the response to a catastrophic terrorist attack, which posited a 10-kiloton nuclear explosion in a cargo container in Long Beach harbor. The report predicted about 60,000 deaths even though harbor region has relatively low population density, Nevertheless, about 6 million people would be evacuated, and losses would amount to $1 trillion, writes Richard L. Garwin.

For the survivors of the atomic bombs on Japan, exposure to radiation increased their risk for many forms of cancer for the rest of their lives. Based on epidemiological studies (Preston et al, 2007, Richardson et al, 2009), the number of cancer cases attributable to radiation in survivors of the atomic bombs is approximately 1% of the number of acute deaths, including those who passed away because of leukemia.

Nuclear defense requires accurate analysis and quantitative decision making tool. Tools that deal with hazard prediction and impact analysis due to unpreventable incident play an important role in hazard mitigation, rescue and evacuation plan. Mathematical and simulation models are of paramount importance for developing such a tool. Analytical, numerical and empirical models are employed to predict the damage due to blast, thermal and fallout during nuclear explosion. CFD and

FEM based numerical techniques are employed for detailed modeling of fallout effects and surface nuclear weapon effect on deeply buried targets.

Today big data analytics tools are available that can even predict the potential nuclear disasters. Recently a chinese scientist has predicted that the single mountain under which North Korea most likely conducted its five most recent nuclear bomb tests could be at risk of collapsing, a Chinese scientist said. The team from the seismic and deep earth physics laboratory made the claim in a statement posted on their website.

Terrorist employment of Nuclear Weapon

Terrorist possession of a nuclear weapon will result in its use against a “highest-value” target – most likely a large city with major economic value, cultural and/or religious significance, and a dense population in which high casualties will result, writes Harney, Robert.

For example Manhattan (New York City) is arguably the highest probability target in the United States. It has the highest workday population density, it is the economic capital of the country, and it is a symbol of freedom and American might and prosperity.

Terrorists are not state-operated military forces. A terrorist bomb is unlikely to be mounted on a missile. It is unlikely to be man-portable. It is likely to be large and heavy. Delivery by aircraft will probably require a multi-engine aircraft, although aircraft of sufficient size are readily available in the general aviation community. Transport by truck, however, is relatively easy and difficult to prevent. Thus, it is more likely for a terrorist weapon to be detonated at street level.

North Korea’s nuclear test site at risk of imploding, Chinese scientist says

Recently a Chinese scientist has warned that the single mountain under which North Korea most likely conducted its five most recent nuclear bomb tests, including the latest and most powerful on Sunday, could be at risk of collapsing. Wang Naiyan, the former chairman of the China Nuclear Society and senior researcher on China’s nuclear weapons program, said that if Wen’s findings were reliable, there was a risk of a major environmental disaster. Another test might cause the whole mountain to cave in on itself, leaving only a hole from which radiation could escape and drift across the region, including China, he said.

Its leader, geophysicist Wen Lianxing, said that based on data collected by more than 100 earthquake monitoring centers in China.

Based on the fact that North Korea has a limited land area and bearing in mind the sensitivity of its nuclear program, it most likely does not have too many suitable peaks to choose from. How long the mountain would continue to stand would also depend on where the North Koreans placed the bombs, Wang said.

“If the bombs were planted at the bottom of vertically drilled tunnels, the explosion would do less damage,” he said. But vertical tunnels were difficult and expensive to build, and it was not easy to lay cables and sensors to collect data from the explosion, he said. Much easier was to bore a horizontal tunnel into the heart of the mountain, but this increased the risk of blowing off the top, he said.

The increasing size of North Korea’s nuclear bombs was also making “topping” more likely, Wang said. “A 100 kiloton bomb is a relatively large bomb. The North Korean government should stop the tests as they pose a huge threat not only to North Korea but to other countries, especially China,” he said. Wang added a caveat, however, saying that the calculations made by Wen and his team could be wrong. Quake waves travel at different speeds through different rocks, so it was not easy to make precise predictions based on seismic data, he said.

Wen’s team estimated that the energy released in the latest test was about 108.3 kilotons of TNT, or 7.8 times the amount released by the atomic bomb dropped by the US on the Japanese city Hiroshima in 1945. It also dwarfed all previous bombs tested by the North Korean military.

Devastating impact of 10 kiloton explosive in a densely populated modern city

Richard L. Garwin has analysed a scenario under which terrorists or criminals have managed to assemble a gun-type device of highly enriched uranium and to detonate it with a yield of 10 kilotons at a location and time of peak population density in a major city. Because of the heavy local fallout of radioactive material associated with a ground burst, a groundlevel detonation would greatly increase the number of deaths and injuries from radiation.

“A surface burst of a nominal 10-kiloton explosive in a densely populated modern city would be even more devastating than even Hiroshima city in October 1945 that was destroyed by a 13-kiloton nuclear explosion at an altitude of about 570 meters (m). The blast knocked down buildings, and the radiant heat from the explosions ignited fires and burned or incinerated people. Because the fireball did not touch the ground, there was essentially no radioactive material (“fallout”) on the city. “Prompt radiation” (i.e., radiation emitted within a few seconds of the explosion) added relatively little to the death toll, but it was a new and frightening phenomenon.”

A blast of invisible nuclear radiation would be released within microseconds, followed within milliseconds by thermal radiation from the surface of the expanding fireball. About six seconds later, the nearest potential survivors would feel an enormous blast and wind. The intensely bright fireball would be long gone by then and some fires would be burning, but more would later be ignited by broken gas mains and the ignition of combustible materials from buildings. In addition, there would be a fallout spot, or plume, delayed by, perhaps, 30 minutes, at a distance of 5 to 20 kilometers (km) from the ground burst.

Winds and destructive overpressure would follow, knocking down buildings in the destroyed area, breaking windows out to a radius of 5.3 km (at 0.5 psi = 0.03 bar overpressure from a surface burst of 10 kiloton yield), and converting people and objects into lethal missiles (Glasstone and Dolan, 1977). Another new phenomenon would be a crater, which, on dry soil or dry soft rock, would have a diameter of about 75 m and a depth of about 17 m (Glasstone and Dolan, 1977).

The crater material would give off intense, but unfelt, radiation in the immediate area; a total dose of 4 Sieverts (4 Sv or 400 rem) would be lethal to at least 50 percent of the people exposed. The bomb debris, mixed with hundreds of thousands of tons of material from the crater, would rise in the prototypical mushroom cloud into the stratosphere from which coarse debris particles, along with much of the radioactive material, would fall out over a period of 30 minutes or so. With a nominal wind speed, there would be a fallout plume about 2 kilometers (km) wide to a downwind distance of about 20 km. The area affected by lethal fallout might be on the order of 20 km2.

Not much could be done to help people in the area of the 50-percent blast-casualty distance of 590 m. People within the 1.8 km radius, where there would be 50 percent mortality from thermal burns, would be lucky if they had been indoors and not in the direct line-of sight of a window. But the realization that there had been a nuclear explosion would raise concerns about family members and others, and many people would be on the streets trying to gather their families or to leave the area. In tens of minutes a firestorm could develop, accompanied by strong in-rushing winds from the unaffected area, and evacuation by vehicle would be impossible except, perhaps, in areas where streets were not blocked by rubble.

Beyond the blast-damage area, the power and communications infrastructure would be largely intact, but the instantaneous loss of load on the electrical system would be likely to cause a blackout of uncertain duration; in principle, it need not last for more than a few seconds. The electromagnetic pulse from a ground-burst explosion would cause little damage outside the blast area, so cell towers in the suburbs and beyond should be capable of carrying traffic.

Nuclear Weapon Effects

The effects of Nuclear Bomb depend on type and size of bomb, materials used, detonation altitude from the air versus ground, population density, and even wind direction.

Immediate effects

Blast wave The blast wave is a pulse of pressure emanating from the explosion. For a 10-kiloton airburst, the blast wave would destroy most buildings to a radius of approximately one mile. For a surface explosion, the radius is reduced to approximately 0.6 miles.

Thermal or Flash radiation Electromagnetic radiation, over a broad spectrum, emanates from the explosion. Nuclear weapons emit large amounts of thermal radiation as visible, infrared, and ultraviolet light, to which the atmosphere is largely transparent. This is known as “Flash”. The chief hazards are burns and eye injuries. Because it is attenuated by air, the intensity decreases with distance. For a 10- kiloton airburst, everyone will be killed by lethal doses of flash radiation to a distance of 0.7 miles. These effects would be attenuated by ground burst.

Delayed effects

Radioactive fallout The extent of fallout is sensitive to local wind conditions. If the fireball from the explosion does not touch the ground, fallout is limited to the particulate matter in the atmosphere. In contrast, ground bursts create large amounts of fallout by entraining surface materials in the nuclear reactions of the explosion. This fallout can be deposited over hundreds of square kilometers, creating regions that would be uninhabitable for at least several years.

Fire Fires are started by flash radiation and by disruptions from the blast wave. The spread of fire is largely controlled by the nature of local construction and geographic factors on the ground. Although the nuclear explosion in Nagasaki was almost twice as large as that at Hiroshima (22 kilotons compared with 12.5 kilotons), the area devastated by fire was four times as large in Hiroshima.

The energy released from a nuclear weapon detonated in the troposphere can be divided into four basic categories:

Blast—40–50% of total energy
Thermal radiation—30–50% of total energy
Ionizing radiation—5% of total energy (more in a neutron bomb)
Residual radiation—5–10% of total energy with the mass of the explosion

Modelling and Simulation

Effective planning will require realistic modeling of the specific potential local impact of an explosion, as outlined above, but also of the effects on the larger society. Sophisticated modeling can be used now to determine if the concentration of talent, data, or capability among those 300,000, just 0.1 percent of the total population of 300 million Americans, could imperil the functioning of the entire society.

The distribution of radioactive material in an attack will not be uniform. Given the location and magnitude of the release of radioactivity, the National Atmospheric Release Advisory Center (NARAC) at Lawrence Livermore National Laboratory is capable of predicting, within a few minutes, the distribution of radioactive material on the ground as determined by the wind profile of the moment.

Standard Effects Analysis

Robert Harney describes the standard weapons effects prediction process as follows. The desired type of nuclear explosive, its yield, and its height of burst are selected. The distances at which specific effects levels are expected to be achieved are estimated using relations derived from comparison of theory to measurements obtained during nuclear testing. Using these distances, areas are calculated that are associated with each effects level. The effects levels are then correlated with percentages of casualties. This correlation is somewhat subjective, but in the best cases is based on modeling that has been validated by the results from Hiroshima and Nagasaki. Once a target has been selected, population density data, the calculated effects areas, and the casualty correlations are multiplied to estimate the total numbers of casualties expected.

With the exception of nuclear attacks on missile silos, deeply buried command centers, naval targets, and similar targets, an optimum altitude airburst is assumed in military nuclear-effects analyses. The optimum altitude airburst is far and away the most common analytical assumption in nuclear effects analysis.

The range at which each effect level occurs can be estimated from simple relations that scale with the nuclear explosive yield W (in kilotons, abbreviated kT). Scaling relations allow the experimentally verified ranges at which specific effects are produced for a reference explosion of known yield (typically 1 kT) to be extrapolated to the ranges at which those same effects would be produced by an explosion with a different yield. Hundreds of atmospheric nuclear tests at Nevada Test Site, Enewetak Atoll, and elsewhere have contributed to the verification of these scaling relations.

Explosion Damage and Injury Assessment

Modeling

“Explosion Consequence Modelling (ECM) techniques vary widely in complexity, from very simple algorithms relying only on distance and explosive type to computational fluid dynamics (CFD) techniques which model the physics of an explosion in great detail. While the most basic pressure-impulse (P-I) curve-based techniques, such as TNT equivalency models, are most appropriate only for explosions of certain materials occurring in flat, open areas, more advanced techniques such as CFD can account for shielding, channeling, reflection, and vapor cloud explosion characteristics such as ignition location, flame speed, and congestion/confinement. However, the time, effort, and expertise required to effectively utilize a model is significantly higher for these more complex modelling approaches” write Brian Holland and others.

Each type of model is appropriate for certain circumstances. For example, a simple hazard assessment of a chemical stockpile, such as that mandated by the U.S. EPA’s Risk Management Program (RMP) could be conservatively performed using several simple models and does not require the refinement of a CFD analysis. Accurate analysis of a vapor cloud explosion in an offshore platform compartment, on the other hand, requires the consideration of complex geometry that a CFD model can provide.

Article References and Resources also include:

- Explosion damage and injury assessment modelling: balancing model sophistication with finite resources, Brian Holland, Qiguo Jing, Weiping Dai, Tiffany Stefanescu

- Harney, Robert. “Inaccurate Prediction of Nuclear Weapons Effects and Possible Adverse Influences on Nuclear Terrorism Preparedness.” Homeland Security Affairs 5, Article 3 (September 2009). https://www.hsaj.org/articles/97
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