Anticipated Consequences of a Terrorist Attack Using a Small Nuclear Weapon

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Introduction

This is the second in a series of short articles describing possibilities for a terrorist-initiated attack involving radioactive material or a small nuclear fission weapon. The series will also include information about fallout, anticipated post-attack dose rates resulting from various scenarios, suggested individual preparations for such an attack, and many other topics. Much of the information for these articles comes from Civil Defense information published in the 1950s and 1960s, but a lot of it is also based on common sense and 40 years of experience in health physics.

Types of Nuclear Detonations

Several types of detonation circumstances are described in the Civil Defense literature from the 1950s and 1960s:

- Surface bursts,
- Airbursts,
- Subsurface bursts,
- Underwater bursts, and
- High altitude bursts.

The last three are not considered to be likely terrorist scenarios.

In a *surface burst*, the weapon is detonated on or slightly above the surface of the earth so that the fireball touches the earth. Under these conditions, the area affected by blast, thermal radiation, and initial nuclear radiation will be less extensive than for an air burst of similar yield, except in the epicenter where damage will be massive. A surface burst is considered to be the most likely scenario for a terrorist weapon since the residual fallout will create problems for a long time after the explosion. In a *ground burst*, roughly half of all the weapon's energy is directed down into the ground where it will be absorbed to a large extent. Fallout will be a major hazard over a large downwind area that was not affected by blast and thermal radiation. The higher the weapon is off the ground at the time of detonation, the more energy is directed outward, and less is absorbed by the earth.

In a true *airburst*, the weapon is detonated at an altitude below 10,000 feet (1.9 miles) but high enough so that the fireball does not touch the surface of the earth. In this case the blast will cause the maximum damage and injury. Burns to exposed skin and eye injuries will be produced over several square miles, but there will be virtually no fallout in the blast area. Most of the fission and activation products are carried up with the mushroom cloud. The larger pieces will fall back to earth fairly quickly while somewhat smaller ones will be carried in a down-wind direction and fall to earth over a period of hours. The smallest particles will potentially be carried into the stratosphere and be dispersed over a large area of the world. Some neutron-induced radioactivity would be present at the epicenter in building materials and minerals. An airburst is considered to be unlikely (but not impossible) in a terrorist attack. For comparison, the Hiroshima and Nagasaki bombs (see Figures 1 and 2) were *airbursts*, exploded at 2,000 feet and 1,650 feet

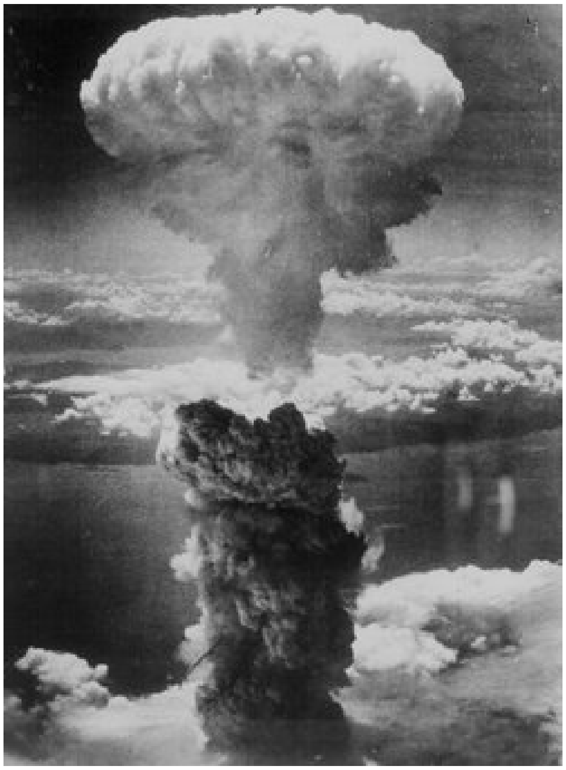

Figure 1. *The mushroom cloud of the atomic bombing of the strategic port city of Nagasaki in 1945 lifted nuclear fallout some 60,000 feet (18 km) above the epicenter.*

Figure 2. *The bombing of Hiroshima delivered the force of 12,000 tons of TNT, leveling buildings and killing over 100,000 people.*

respectively, and are, therefore, not excellent models for a terrorist event.

The First Three Minutes

Upon detonation of a fission weapon, temperatures of several tens of millions of degrees Celsius are produced. Compare this to the few thousand degrees of a conventional explosion. At these very high temperatures, the fissioned and unfissioned parts of the nuclear weapon are vaporized. The atoms do not directly release the energy as kinetic energy but release it in the form of large amounts of electromagnetic radiation and neutrons. This electromagnetic pulse (EMP) will disable all “unhardened” electronic components in the vicinity.* In an atmospheric detonation, a large component of this electromagnetic radiation consists of soft x-rays. These are all absorbed within a few meters of the point of detonation by the surrounding atmosphere, heating it to extremely high temperatures and forming a brilliantly hot sphere of air and gaseous weapon residues–the so-called fireball. Immediately upon formation, the fireball begins to grow rapidly and rise like a hot air balloon. Within a millisecond after detonation, the diameter of the fireball from a 1-megaton (Mt) air burst is 500 feet. This increases to a maximum of 7200 feet within 10 seconds, at which time the fireball is also rising at the rate of 325 feet per second. The initial rapid expansion of the fireball severely compresses the surrounding atmosphere, producing a powerful blast wave. In the case of a surface burst, the fireball would be smaller because the earth and surrounding structures would absorb significant energy and not allow the fireball to fully develop.

As it expands toward its maximum diameter, the fireball cools, and after about a minute, its temperature has decreased to such an extent that it no longer emits significant amounts of thermal radiation. The combination of the upward movement and the cooling of the fireball give rise to the formation of the characteristic mushroom-shaped cloud. As the fireball cools, the vaporized materials in it condense to form a cloud of solid

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* Many military devices are hardened or shielded against this burst of electromagnetic radiation.

Figure 3. *Projected area of total devastation from a 15-megaton airburst (left) and from a 15-megaton surface burst (right), if the bomb were detonated at or above the Empire State Building (Fifth Avenue between 33rd and 34th Streets). A one-megaton weapon would do considerably less damage.*

particles. Following an airburst, condensed droplets of water give it a typical white cloudlike appearance. In the case of a surface burst, this cloud will also contain large quantities of dirt and other debris that are vaporized when the fireball touches the earth's surface or are sucked up by the strong updrafts afterwards, giving the cloud a dirty brown appearance. The dirt and debris become contaminated with the radioisotopes generated by the explosion or activated by neutron radiation and fall to earth as fallout.

Outward from the hypocenter, most casualties are caused by burns from the heat and injuries from the flying debris of buildings collapsed by the shock wave. Individuals who survive these effects but who were not shielded from the intense burst of gamma and neutron radiation will probably become debilitated within an hour or two and are not likely to survive. Medical first responders are unlikely to be sent into this are, since the chance of finding survivors is quite limited. Scarce personnel resources would be more effectively expended elsewhere.

Anticipated Damage

The amount of damage caused by the initial detonation and the amount of fallout produced depends on how far above or below the surface of the earth it takes place, and on whether there are large buildings surrounding the point of detonation. Buildings surrounding the epicenter will absorb some of the blast energy and thus limit the area of maximum devastation.

For example, if the hypocenter were the Empire State Building, a 15-megaton airburst would completely devastate midtown Manhattan from Central Park to 14th Street and from the Hudson River to the East River. A surface burst of the same size would flatten everything from 42nd Street to 23rd Street and from 9th Avenue to Park Avenue. See Figure 3.

For a low altitude atmospheric detonation of a moderate sized weapon in the kiloton range, the energy would be distributed roughly as follows (see Figure 4):

- 50% as blast;
- 35% as thermal radiation (i.e., heat rays); made up of a wide range of the electromagnetic spectrum, including infrared, visible, and ultraviolet light and soft x-rays emitted at the time of the explosion; and
- 15% as nuclear radiation; including 5% as initial ionizing radiation consisting chiefly of neutrons and gamma rays emitted within the first minute after detonation, and 10% as residual nuclear radiation from the decay of fission and activation products. Residual nuclear radiation is the hazard in fallout.

Considerable variation from this distribution can be expected with changes in yield or altitude of the detonation.

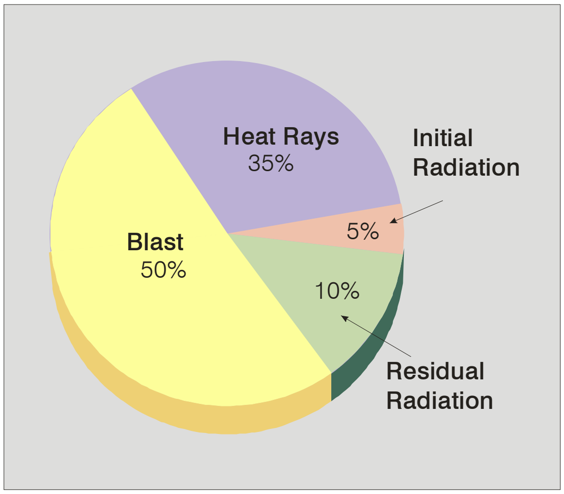

Figure 4. *Estimated energy distribution for a low altitude atmospheric detonation of a moderate sized atomic weapon in the kiloton range.*

The Critical First Three Days

From three minutes to several days after the event, fires will continue to burn and additional building collapses are likely. Fire departments will be overwhelmed and will be excluded from many areas because of high radiation levels. Radioactive fallout (i.e., clouds of radioactive material in sizes ranging from very small particles to rather large pieces of bomb debris that quickly fall back to the ground) will rain down onto the ground, and down wind from the blast site. The most important task of radiological first responders and civil authorities will be to confirm the projected extent and direction of the plume based on meteorological data by identifying the margins of the fallout plume. Since winds are often variable, some hot spots of fallout might be found outside the main plume. These also have to be located promptly and clearly identified so that survivors sheltering in those areas can be advised on protective actions.

Direct gamma radiation levels in the plume and in fallout hot spots will initially be very high. Radiation dose rates from fallout can exceed 30,000 rads per hour immediately downwind of a ground burst during the first hours after detonation. A cumulative whole-body dose of 450 rads would be fatal to half of a population of humans if high-quality medical treatment were not available. At a dose rate of 30,000 rads per hour, a 450-rad dose would be delivered to a person in less than a minute. The maximum survivable dose (MSD) of 1000 rads would be delivered to an unprotected person in about 2 minutes. Individuals in these heavy fallout areas who are not shielded effectively from the gamma radiation are likely to receive lethal radiation doses.

In addition to the external radiation, radioactive fallout particles can be inhaled, can enter the water supply, and can contaminate food at significant distances from the blast. All of these potential dose pathways will contribute to population radiation doses. Information on home fallout shelters and other methods of personal protection will be included in this series of articles.

Fortunately, many fission and activation products have short half-lives. Therefore, three or four days after such an atomic explosion survivors could exit the heavy fallout zone while receiving manageable radiation doses. Unfortunately, if such an event were to occur, individuals outside the blast zone would not have any idea if they were in the fallout plume or not, unless they had an appropriate radiation detector. They would have to assume the worst and take shelter immediately in a basement or other shielded area, then rely on information from civil authorities via radio or television for information on whether to evacuate and where to go for assistance.

Based on the experience of Hiroshima and Nagasaki, ground-zero is not expected to be highly radioactive, although the physical damage would be total. Both Hiroshima and Nagasaki were rebuilt shortly after the end of World War II. The bulk of the extremely radioactive materials will have been carried upward with the mushroom cloud and will be dispersed downwind as fallout. As distance increases from the hypocenter of the blast, the extent of the damage would decrease and the likelihood of finding survivors would increase.

Beyond the First Three Days

Long-term effects, from about 3 days after the blast and lasting for months or years, would be exposure to less intense radiation from the less radioactive (i.e., longer half-life) fallout radionuclides. The primary consideration after the initial period of intense external radiation is ingestion of radioactive materials that may contaminate food, water and air. Direct radiation from the remaining fallout would be much less of a concern.

Editor's Note: Watch for part 3 of this series, "Fallout from a Nuclear Explosion," in our next issue.

The Author

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