NUCLEAR WEAPONS EFFECTS

Introduction:

The energy characteristics and output from nuclear weapons differ significantly from conventional weapons. Nuclear detonations exhibit much higher temperature within the fireball and produce peak temperatures of several hundred million degrees and intense x-ray heating that results in air pressure pulses of several million atmospheres. Conventional chemical explosions result in much lower temperatures and release the bulk of their energy as air blast and shock waves.

In an atmospheric detonation, such as was deployed in Japan, it is the blast and thermal component of the nuclear explosion that is the major factor in destruction and death, not nuclear radiation, as the public believes. The effective range of immediate harm to humans from nuclear radiation from the atmospheric explosion is much less than the effective range from blast and thermal heating.

In order to limit the discussion of weapons effects to elementary terms, this discussion is based upon a single worst-case scenario. Probably the largest weapon that might be employed against a population would have a yield of less than one-megaton (or 1 million tons of TNT equivalent energy or simply 1 MT). However, a crude terrorist nuclear device would probably be in the range of a few thousand tons of TNT equivalent energy or a few KT). The discussion here is based upon a nuclear detonation of 1 MT.

Yield:

The destructive power of a nuclear weapon, when compared to the same amount of energy produced by TNT is defined as the 'yield' of the nuclear weapon. A 20-kiloton (KT) weapon, such as was detonated over Japan in World War II was equivalent in energy yield to 20,000 tons of TNT. A 1-MT yield weapon is equivalent to 1 million tons of TNT.

Types of Nuclear Weapons:

Nuclear Weapons are much smaller in volume and mass than conventional weapons. But nuclear detonation produce energy release thousands of times greater and over a shorter time period (chemical explosion – milliseconds, nuclear explosions – microseconds). The energy from a nuclear detonation can result from two basic nuclear processes—nuclear fission and nuclear fusion.

The first nuclear weapons were only fission devices made from either uranium-235 (a relatively scarce isotope of uranium), or from a man-made isotope of plutonium, namely Plutonium-239.

When certain isotopes of uranium or plutonium (U-235 or Pu-239 or fissile isotopes) are bombarded with neutrons, the nucleus of these isotopes can split apart (fission) releasing about 200 million electron volts of energy. This energy release is about a 100 million times greater than the burning (oxidation) of a carbon atom in a fossil fuel. Furthermore, during the fission process additional neutrons are released (typically two or more) and these neutrons can fission other fissile isotopes. This process if carefully designed can lead to a rapidly increasing chain reaction releasing a great amount of energy before the remaining fissile material is blown apart by the rapid increase of energy. Indeed, the essential design feature in the design of an effective nuclear weapon is containing the fissile material together for sufficient time to liberate the energy yield desired.

The fusion and fission reactions produce energy in different ways. Fusion occurs when two light isotopes (usually deuterium and tritium – heavy isotopes of hydrogen) at very high temperatures and pressures, unite and form a heavier isotope (usually helium). A fission reaction can produce both the high temperature and high radiation pressure required for fusion to occur and so in the design of all fusion weapons (often called thermonuclear systems) a primary fission reaction is used to initiate the secondary fusion reaction. One pound of the hydrogen isotope can release as much energy as is found in 26,000 tons of TNT.

During the fusion process, high-energy neutrons are also liberated as in fission. These high-energy neutrons can cause a fission reaction in the abundant isotope, uranium-238. Some large yield, thermonuclear weapons use this fission-fusion-fission process.

Types of Bursts:

Phenomena from weapons effects vary with the type of burst. The desired effects to be maximized dictate the burst type. The burst types fall into four basic categories:

- Surface Burst
- Air Burst
- High Altitude Burst
- Subsurface & Underwater Bursts

Surface bursts maximize the reach of high overpressures and would most probably be used against hardened strategic targets such as missile launch control centers, harbors and submarine pens, and large airports. Destruction of ICBM silos, and deep underground shelters require ground bursts of 300 KT and greater. Ground bursts are also indicated if a planner wishes to maximize residual fallout radiation.

An airburst is defined as an explosion that occurs below 100,000 feet elevation, but high enough so that the fireball of this explosion does not reach the surface of the earth. Airbursts extend the range of lower overpressures. Maximum blast damage of soft targets (such as cities) would occur from airbursts of MT yield weapons. Smaller yield air bursts exploded at optimum height of burst give more targeting flexibility in destroying important targets in a large city while allowing collateral damage to be held to a minimum.

Bursts occurring above 100,000 feet elevation are defined as ‘high-altitude bursts’. High altitude bursts are designed to cause an electro-magnetic pulse (EMP). These high altitude radiations interact with the atmosphere and cause rapid EM changes and ionization, which seriously effect radio and radar signals and other critical electrical power dependent equipment.

Most of the shock energy in underground or underwater detonations is contained below the surface. Much of the thermal and nuclear radiation is absorbed within a short distance of the explosion, contaminating the earth or water with radioactive fission products.

Subsurface bursts are generally used during testing to minimize radiation fallout, or in wartime by means of burrowing missiles, which penetrate below the surface to destroy underground facilities.

Thermal Radiation Exposure:

Within less than a millionth of a second of the detonation, large amounts of energy in the form of invisible x-rays are absorbed within just a few meters of the atmosphere. This leads to the formation of an extremely hot and luminous ionized mass called the fireball or plasma. Even at a distance of 50 miles from a 1 MT burst, this fireball would appear as many times the brightness of the noonday sun.

The heat from the fireball is emitted in the form of thermal radiation or EM in the ultra violet, visible, and Infrared range. The EM pulse travels at the speed of light and can persist up to several seconds, depending on the yield of the weapon, local clouds, and the height of the burst. The thermal pulse from a 1-MT weapon lasts about 8 seconds. If we were far enough away from the blast, and could drop and cover quickly, we would minimize the burns caused by this pulse. At 8 miles from the detonation, only minimal structural damage takes place, but flash burns caused by the thermal pulse at that distance would cause severe burns if people were unprotected. Every effort should be made to limit exposure time. ‘Drop and cover’ is still a wise exercise to practice during a nuclear attack.

Thermal Radiation Burns:

Burns are the most far-reaching of any of the immediate weapons effects. Thermal radiation can cause burns through absorption of the energy by the skin, or by ignition of clothing as a result of fires started by the radiation.

Skin burns are classified as 1st, 2nd and 3rd degree. Third degree burns can occur out to 8.5 miles from a 1-MT burst.

Second-degree burns occur at about the same range as the 1.4-psi overpressure level, which is about 10 miles from ground zero for a 1-MT airburst. First-degree burns can occur from 10 to 12 miles from ground zero. Evasive actions are required in order to limit harm.

Evasive Actions:

Much burn injury from large yield weapons can be avoided in the low overpressure area (1 psi to 2 psi), if protective shielding is found in the first seconds. The evasive action of ‘drop and cover’ should again be taught and exercised.

If there is any warning of incoming missiles, the best available shelter should be taken. Ditches, culverts, basements, or large structures would provide some shielding against the thermal pulse.

Materials inside rooms of buildings (such as curtains, upholstery, or papers) could be ignited by the thermal pulse of a nuclear blast. If sheltering in the home, efforts must be taken to extinguish fires that may be ignited in the home.

In areas of overpressure less than 2 psi, many residences will remain intact. Test results suggested that if there is adequate warning time, light colored drapes should be closed to shield upholstered furniture and beds from the thermal pulse, and electricity and gas should be turned off to avoid secondary fires.

Experience has shown that ignition, such as would occur in upholstery, might remain smoldering and later rekindled. It is advisable to check for primary fires after the initial blast and then to check again after 15 minutes in order to extinguish any secondary fires that may be rekindled. Fire extinguishers should be supplied in your sheltered area for this purpose.

Care should be taken never to look at the fireball. Because of the focusing action of the eye lens, the eyes can be temporarily or permanently injured and blinding may occur.

Underground shelters will give total protection from the thermal pulse. Of course, this requires an effective warning system to know when to enter the shelter.

f there is an escalating crisis we should enter our shelters and remain there. It is more probable, however, that a nuclear attack would come as a surprise–particularly from a terrorist attack. The only initial warning may come from the electro-magnetic pulse.

EMP Cause:

All nuclear explosives induce sudden electrical currents and voltages, which can damage or destroy unprotected electrical and solid-state electronic equipment within line-of-sight of the explosion. The size of the area affected by an EMP increases with the height of the burst. In a nuclear explosion 50 miles above the ground, the affected area on the earth will have a radius of about 600 miles. A high altitude EMP (HEMP) from a nuclear explosion detonated at an altitude of 200 miles could produce a rapid electrical energy pulse on the order of 60,000 volts per square meter and could affect and even disable equipment within the entire continental United States. Smaller EMP pulses produced at lower altitudes could cause cascading failures in an already stressed electric power infrastructure (transmission lines, transformers, etc) and also telecommunications.

The affects of this type of weapon would not pose an immediate danger to people. However, it could damage satellites, and computerized ignitions in automobiles disrupt telephone and radio communications, destroy navigational aids and computers, and would most probably cause electrical power distribution to be lost for many months. Transportation would be paralyzed, food refrigeration and distribution would cease and water purification and sewer systems might fail. Financial institutions, hospitals, trade and production of goods and services would cease functioning. Key infrastructures and utilities are interdependent and very vulnerable to electrical power interruption. A recent report to the Congress stated "an EMP could have irreversible affects on our country's ability to recover". (Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack; Volume 1: Executive Report 2004).

Terrorist countries and their organizations understand our vulnerability and could use relatively unsophisticated missiles armed with nuclear weapons to produce a high altitude EMP (HEMP).

Many nuclear strategists believe that if our country were attacked in a limited exchange or full-scale nuclear war, the attack would be initiated with a high altitude EMP to disable telecommunications. If this weapon were deployed by a satellite, we would likely have no warning before the explosion occurred. Immediately after the HEMP, missiles would be launched against targets in the United States.

Every occurrence of sudden power failure should be viewed as possibly having been caused by a high altitude nuclear explosion. Certain simple tests will quickly reveal an EMP verses power loss from a natural cause.

EMP Detection:

If an electrical power drop is detected, immediately check a corded phone to see if the telephones are functioning. If there is no dial tone, you should do a second test using a battery-powered radio. Approximately 5% of the radio stations in the United States have been hardened against EMP and could continue transmitting. However, if you are unable to access several radio stations that normally transmit in your area, you should take shelter immediately. Contact radio stations within your area to locate frequencies that may continue to transmit during this kind of an emergency.

A simple power drop alarm can be constructed in the event the EMP was to occur while you are sleeping. Ask a certified electrician to construct such an alarm using a relay switch, a 12-volt gel-cell battery, and a horn. However, no solid-state electronics should be employed in the construction of this alarm.

Protection of Equipment:

During an escalating crises and when not in use, all sensitive equipment should be unplugged from the wall outlets. Power cords should be wound into a coil. Wherever possible, electronic equipment should be stored in an encompassing metal cage called a ‘Faraday cage’. Metal garbage cans with tight fitting lids make good faraday cages. Insulate your equipment with toweling or cardboard before placing it into the can. It is not necessary or even advisable to ground the can. As a further precaution, fold metal screening material over the lip of the can before closing the lid to assure tight metal-to-metal contact. Do not place the can directly on a concrete floor.

Ammunition boxes make good faraday cages. Remove any gasket material from the lid and sand the painted areas where the lid fits to the body of the can. Do not store the can on metal shelves, which contact a concrete floor.

Microwave ovens (not plugged in to an outlet) also make good faraday cages.
Radios should not be attached to any antenna longer than 30 inches. Remove all removable antennas and push all retractable antennas to the shortest possible length.

Blast Effect and Overpressure:
In a 1 MT yield weapon, 10 seconds after the blast, the fireball is over a mile wide. In one minute it has grown to 4 1/2 miles from the point of burst.

At the same time the fireball is forming and growing, a high-pressure wave develops and moves outward from the fireball. This blast wave is a moving wall of highly compressed air called a shock wave. In 10 seconds the blast wave has traveled 3 miles. In 50 seconds, it has traveled 12 miles and is then moving at slightly greater than the speed of sound (1000 feet per second).
We measure this pressure in pounds per square inch (psi). Normal ambient atmospheric pressure is about 15 psi. Any pressure over and above this level is considered to be ‘overpressure’.

Many unsheltered people can withstand and survive this shock wave and blast effect if they are outside the 5-mile radius of the detonation.

Dynamic Effect:
High velocity winds are associated with the blast effect, and the effects from the windblast must be added to the effects of overpressure. This effect is called the dynamic pressure. Dynamic pressure is proportional to the square of the wind velocity and the density of the air behind the shock front.

Divers experience about l0 psi of overpressure at a 23-foot depth and 20 psi at a 45-foot depth. If acclimatization to the pressure increase has been gradual, no ill effects will be experienced even though the pressure differential seems amazingly large. Overpressures experienced in a blast, however, are complicated by the sudden dynamic (blast wind) effect.

A 20-psi overpressure is associated with a wind velocity of 500 mph and without proper shelter; overpressures of this strength cannot be survived. Injuries at overpressures under 20 psi are due almost entirely to this dynamic effect. Blast winds at even 1-psi overpressure can cause injury from flying glass fragments and other small sharp objects.

The overpressure from a 1-MT weapon at 4 miles is approximately 5 psi and the wind velocity is about 160 mph. At this distance it is generally believed people could survive outside a hardened blast shelter if they can find adequate sheltering which would give protection from the blast wind. Structures such as culverts, ditches, tunnels, caves, mines and basements could give adequate protection at this overpressure level if the occupants were protected from falling debris. At overpressures over 5-psi, however, a residential basement would not provide adequate blast protection. A discussion of expedient shelters is given in another lesson.
Many thousands of people live and work in areas considered by planners to be under the 5-psi overpressure range, and would be saved if they can seek shelter in their basements.

Radiation Effect and Fallout:

Radiation is the most far reaching of all the weapons effects. If the fireball of the weapon touches the ground, the blast is defined as a ground burst. In a ground burst, rock, soil, and other material in the area will be vaporized and taken up into the cloud. Strong winds cause dust, dirt, and other particles to be sucked up into the fireball as well. All of this debris is then mingled with fission products and radioactive residues and becomes radioactive itself. As it cools, the debris falls from the cloud onto the ground. This material is what we call radioactive fallout. It has been estimated that for every ton of yield, an equivalent one-half to one ton of matter is vaporized into the fireball. In a one megaton explosion, there could be as much as 500,000 to l million tons of dirt and debris taken into the fireball, which will later fall to the ground as radioactive fallout.

Protection From Fallout:

Time – Radiation diminishes with time in a process called radioactive decay. Each radioactive isotope has a unique 'half-life'. This is defined as the time required for the radioactivity of that isotope to diminish (or decay) to one half of its original value. The passage of 10 half lives for a given radioactive material reduces its activity by a factor of 1000.

During the fission process in a nuclear detonation, hundreds of isotopes with different decay patterns are produced. It has been found that the average decay rate for these radioactive products can be estimated with the 7 / 10 rule. Simply stated, this rule states that for every seven-fold increase in time after detonation, there is a ten-fold decrease in the radiation exposure level.

7/10 RULE – To estimate radiation levels from fallout by this rule, at 7 hours after the detonation, the level of radiation would be expected to be 1/10th of the original level. At seven times seven hours (49 hours or about 2 days), the level would be 1/100th of the original level. At seven times 2 days (or two weeks) the level would be 1/1000th of the original level.

Distance – Radiation levels diminish with distance as well as time. In a localized event, everyone within the area of radioactive fallout should find shelter or evacuate and move as far as possible from the location of the radioactive material.

Shielding – Shielding also decreases (attenuates) radiation levels. Four inches of soil will attenuate half of the gamma radiation from fallout. This is called the 'half-value' thickness for shielding. One 'half value' thickness gives a protection factor (PF) of 2. This rule is multiplicative. A total of 8 inches of soil will provide additional reduction, or a PF of (2 x 2)=4. Four more inches (a total of 12 inches of soil) will provide 3 halving thicknesses, or a PF of (2 x 2 x 2)=8. The half value thickness for concrete is about 3 inches. Ten layers of the halving thickness for any shield provide a protection factor of over 1000.

Alpha Radiation:

Alpha particles have a range of about 2 inches in air, and are completely stopped by the outside layers of the skin. Therefore, alpha particles are not an external hazard. However, they can do considerable damage internally. So it is essential not to breathe in or ingest alpha contaminated materials. Ventilation systems in fallout shelters should be fitted with filters to remove these materials from the breathable air.

Beta Radiation:

Energetic electrons (called Beta Particles) have a range of up to 12 feet. Most fission products are beta emitters. Beta radiation poses a small external hazard if the fission products in the fallout come into actual contact with the skin and remains there for an appreciable time. This contact may result in a skin burn referred to as “beta burn”, which causes damage similar to sunburn. Fallout should be brushed and/or washed from the hair and skin as soon as possible.

Beta emitters cause considerable damage if they enter the body. Alpha and Beta particles in fallout can enter the body through the digestive tract (through consumption of contaminated food and water), through the lungs, (by breathing contaminated air), or through wounds.

Some radioactive elements tend to concentrate in specific organs in the body. The body cannot distinguish between the stable chemical element and the radioactive isotope of that chemical element. Radioactive strontium and barium are similar in chemical nature to stable calcium and may be deposited in the bones.

Care should be taken not to eat food, which has been contaminated with radioactive materials. If the food has been carefully washed, however, it can safely be eaten. Potatoes and carrots can be peeled; apples and other hard skinned fruits and vegetables can be washed clean of surface contamination. Soft foods, such as strawberries, lettuce, bread, and such are not easily decontaminated and should be discarded unless they are known to be uncontaminated. Canned food containers should be washed before opening.

Animals, which have been exposed to radiation, may have significant levels of strontium and barium in fur and in their bodies. These animals, if healthy appearing, may be slaughtered and eaten, if the bones and organs are discarded before the meat is cooked.

Iodine-131 generally poses the largest threat to humans because iodine chemicals are deposited in the thyroid. Iodine can enter shelters in a gaseous form. Ventilation systems must have good high efficiency filters to filter this radioactive element from the breathable air.

Thyroid blocking agents (TBA) are available commercially. They are inexpensive and have a long shelf life. TBA consists of iodine in the form of potassium iodide or iodate. The thyroid fills with the healthy iodide and the radioactive iodine is then removed biologically from the body. Regular iodine is poisonous and should not be taken internally. Use only the commercial TBA at its recommended dosages.

TBA agents have an extremely bitter taste and will need to be consumed with other foods in order to cover the taste. Children, in particular, will find the TBA to be distasteful. The tablet form of TBA is more easily consumed than the liquid from the crystalline form.

Iodine 131 has a half-life of 8 days and will be a threat for 10 half-lives, or approximately 3 months. Enough thyroid-blocking agent should be stored for each person in the shelter for a 3-month period. If there is no warning of an attack, TBA should be taken as soon as possible after a nuclear attack. However, TBA is a strong medicine that has some undesirable side affects. It should not be taken unless a nuclear attack has occurred or is believed to be eminent. TBA should be left in its originally packaging whenever possible until needed.

Gamma Radiation:

Gamma radiation is highly penetrating electromagnetic radiation and poses a sustained exposure threat for the first 2 weeks after a ground burst. Gamma radiation is measured in Roentgens. In a full-scale nuclear attack, over a two-week period, the accumulated radiation dose in some areas can be several thousand Roentgens.

Gamma Radiation is reduced or attenuated by limiting time near the gamma source, distance from the source, and shielding (placing material mass between you and the source). If whole body exposure is limited to less than 175 Roentgens, no medical care should be needed and there will be few if any anticipated deaths. To attenuate the exposure anticipated in a full-scale nuclear attack to this level, a minimum radiation protection factor of 40 would be required. If at any time the dose rate exceeds 10 Roentgens per hour, the total exposure will exceed the 175 Roentgen level. (Note that the value of 1 Roentgen is equivalent to about 1 rad or 1 rem).

TABLE – RADIATION PENALTY TABLE

Acute Effects	**Accum. Exposure 1 Week**	**Accum. Exposure 1 Month**	**Accum. Exposure 4 Months**
Medical Care Not Needed	150 Roentgens	200 Roentgens	300 Roentgens
Some Need Medical Care Few if Any Deaths	250 Roentgens	350 Roentgens	500 Roentgens
Most Need Medical Care 50% + may die	450 Roentgens	600 Roentgens	600 Roentgens
Lethal Dose	600 Roentgens		

The accumulated exposure should not exceed those in the first row. If radiation levels reach 10/R/hr in the sheltered area, the doses in the first row will probably be exceeded.   In this eventuality, the shielding in the sheltered area should be increased. In a full scale attack, about 35% of our population would be expected to exceed the above doses.

EXPOSURE AT 30 MILES DOWNWIND (500 KT surface burst, 15 mph wind)

Time	**In Open**	**In Shelter PF 15**	**In Shelter PF 40**
1 Week	3450 Roentgens	230 Roentgens	86 Roentgens
1 Month	4100 Roentgens	273 Roentgens	103 Roentgens
4 Months	4500 Roentgens	300 Roentgens	113 Roentgens

Initial Radiation:

Initial radiation exposure is considered to take place in about the first minute after the nuclear explosion. During the fission and fusion process, high-energy neutrons, x-rays and gamma rays are expelled from the fireball.

The threat of this initial radiation exposure from the nuclear explosion is confined to a radius of about 1.5 miles from ground zero. A very small percentage of the surviving unprotected population would be within range of this initial radiation. The blast and thermal effects would be fatal within this radius for unsheltered people. However, in a hardened blast and radiation shelter, people could survive all nuclear weapons effects, including initial radiation, at distances of 1/2 mile or more from ground zero. In the absence of a hardened shelter, any practical, available, expedient shelter should be utilized, since some shielding protection is offered from blast, thermal heating, and nuclear radiation.