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Chapter Two

RADIOLOGICAL WEAPONS

We're bad at balancing risks, we humans, and we live in a world of continual uncertainty. Trying to avoid the horrors we imagine, we risk creating ones that are real [77].

Development of Nuclear Weapons

Early Noble Prize winning investigators of atomic physics recognized the potential of nuclear weapons [38]. Matter must be known not only as mass but also as a storehouse of energy. If a proper detonator could be found, it was just conceivable that a wave of atomic disintegration might be started through matter, which would indeed make this old world vanish in smoke (Rutherford, 1903). Soddy said in 1904: The man who put his hand on the lever by which a parsimonious nature regulates so jealously the output of this store of energy would possess a weapon by which he could destroy the earth if he chose. There is theoretically no limit as to how large a bomb may be developed. Perhaps as big as to shatter the earth into fragments, as Rutherford suggested in 1903. Einstein was alarmed enough in 1939 to write President F.D. Roosevelt about his certainty that such a bomb will be constructed. Craig Nelson in The Age of Radiance [49] presents these early historical discoveries leading to nuclear weapons with a 'you were there' reality.

The International Solvay Institute for Physics and Chemistry hosted in Brussels the first Solvay International Conference in 1911. The conference was considered a turning point in the development of the discipline of atomic physics. The chairman was H.A. Lorentz and the conference title was Radiation and the Quanta. Marie Curie and Albert Einstein were present [83]. The 5th Solvay conference was in 1927 (Figure 1) [84].The Solvay conferences continued with the 25th conference being held in 2011 on The Theory of the Quantum World and the 26th conference being held in 2014 on Astrophysics and Cosmology.

The grand total of deaths due to all wars involving the United States was about 850,000. Combat deaths accounted for 2% of the U.S. population in the Civil War, and 0.1% and 0.3% for World War I and World War II, respectively (Table 1). The number of lives in the world that can be saved and prolonged by low dose ionizing radiation in one year is considerably greater than all the American combat losses in our entire history.

The golden age of triumph of the Enlightenment over darkness giving love, brotherhood, progress and science ended in 1914. World War I saw the first development and use of large scale poisonous gas warfare. Fritz Haber won the Nobel Prize in chemistry for finding a way to make ammonia for fertilizer. During World War One, Haber synthesized phosgene and mustard gases. The Germans first used them followed rapidly by the English, French and Americans in the trenches of France. They included chlorpicrin (vomiting gas), xylyl bromide (tear gas), chlorine, carbonyl chloride (phosgene) and dichloroethyl sulfide (mustard gas that penetrated

rubber and leather). Mixtures were found more effective. Haber's wife committed suicide in despair over her husband's work. Of the 21 million casualties in WW I, about 5% were due to gas warfare. Most died from artillery shells and machine guns. Towards the end of the war, the Germans built large bomber aircraft such as the two engine 'Gotha' and the four engine 'Giant'. They dropped 250,000 pounds of bombs on England killing 835 people. They also developed a ten pound incendiary bomb made out of magnesium which they did not use since they felt it would destroy any hope of a negotiated peace [38]. It was also thought that forty planes carrying tons of poisonous gases could wipe out the population of London [49]. World War II saw nearly an order of magnitude increase in deaths as compared to WW I; most of WW II casualties in the world were found in non-combatants.

War	Years	Deaths	Population (million)
Revolutionary War	1775-1783	25,000	2.5
War of 1812	1812-1815	2,300	8.0
Mexican War	1846-1848	13,000	21
Civil War	1861-1865	420,000	31
Spanish-American War	1898	2,900	70
Philippine War	1899-1902	4,300	72
World War I	1917-1918	117,000	100
World War II	1941-1945	411,000	130
Korean War	1950-1953	54,000	150
Vietnam War	1957-1975	58,000	180
War on Terror	2001-2013	5,300	310

Table 1. American deaths from major wars of the United States (1775-2013) [37]

A deep fear of nuclear war and of radiation have served as containments for future wars. The potential deaths from a full-scale nuclear war between the U.S. and U.S.S.R. was estimated by the World Health Organization (WHO) in 1984 at about 2 billion people. Most would be non-combatants and many of those were projected to have died from acute radiation exposure and a wave of cancer and other late appearing diseases. However, the radiological hazard estimates were deliberately exaggerated to promote radio-phobia [2-3].

The plan to build an atomic bomb was placed under the name Manhattan Engineer District. About 52,000 acres of land along the Clinch River in eastern Tennessee was purchased by the U.S. government, later known as Oak Ridge National Laboratory (ORNL). A large track of land in the desert surrounded on two sides by the Columbian River was obtained at Hanford, Washington for the construction of uranium-fueled nuclear reactors used to produce plutonium. Another piece of property was purchased in Los Alamos, New Mexico, to be used for the construction of the first atomic bombs, both the U-235 bomb dropped on Hiroshima and the Pu-239 bomb dropped on Nagasaki. Robert Oppenheimer was its director and General Leslie Groves in overall military command.

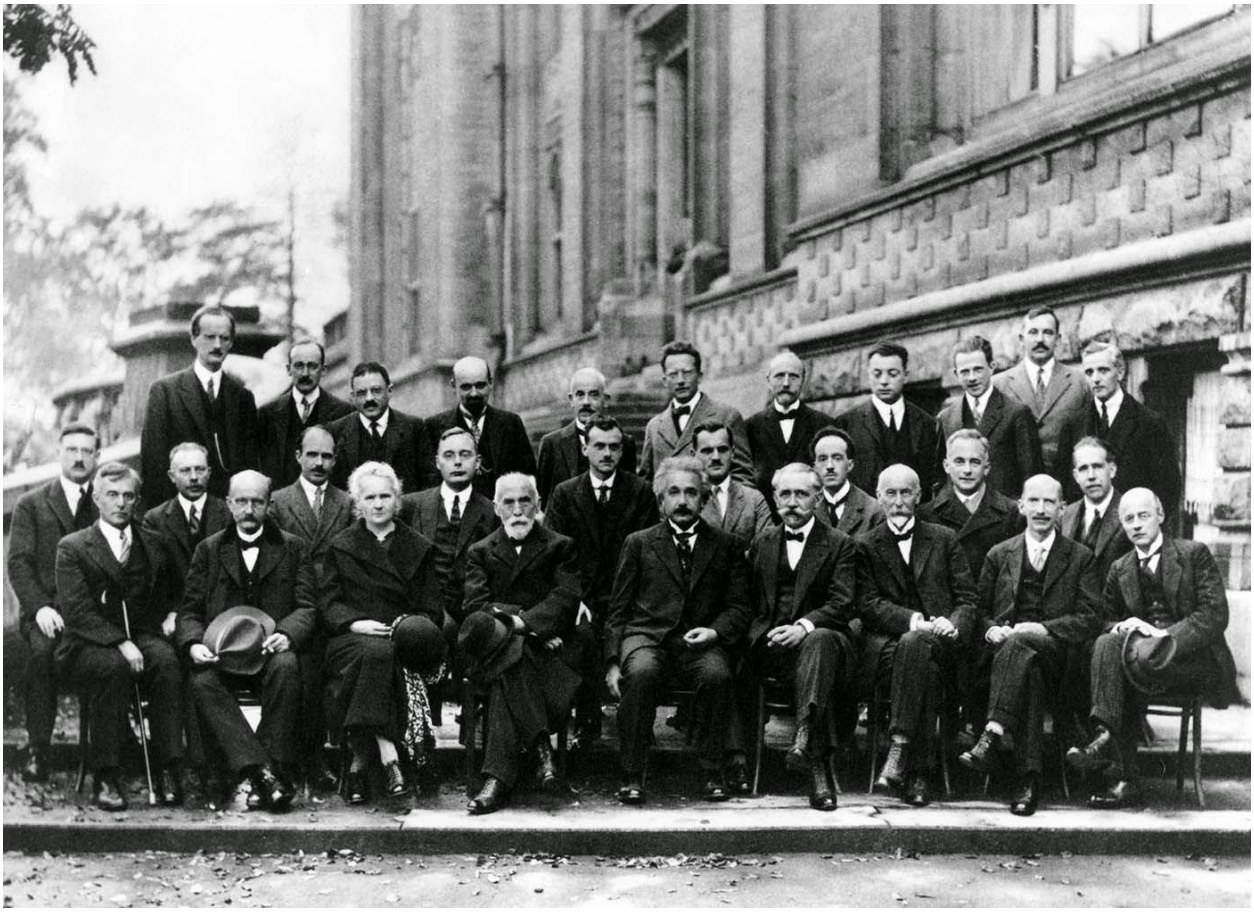

Figure 1. The Fifth Solvay Conference was also held in Brussels in 1927. The subject of the conference was Electrons and Photons. Seventeen of the 29 participants were or later became Nobel Prize winners. Marie Curie remained as the only woman and also the only person to be awarded the Nobel Prize in two disciplines [84].

Participants for the conference were:
Back: Auguste Piccard, Émile Henriot, Paul Ehrenfest, Édouard Herzen, Théophile de Donder, Erwin Schrödinger, JE Verschaffelt, Wolfgang Pauli, Werner Heisenberg, Ralph Fowler, Léon Brillouin.
Middle: Peter Debye, Martin Knudsen, William Lawrence Bragg, Hendrik Anthony Kramers, Paul Dirac, Arthur Compton, Louis de Broglie, Max Born, Niels Bohr.
Front: Irving Langmuir, Max Planck, Marie Curie, Hendrik Lorentz, Albert Einstein, Paul Langevin, Charles-Eugène Guye, CTR Wilson, Owen Richardson

(Photo taken at the 1927 Solvay Conference. With kind permission of the International Solvay Institutes, Brussels, Belgium, photograph taken by Benjamin Couprie)

The first plutonium-producing, atomic pile reached criticality on September 26, 1944, at Hanford. Burning a nuclear reactor for a 100 days transmuted about 1 atom of every 4000 U-238 atoms to Pu-239. The hot slugs were removed and placed in water for 60 days until most short-lived fission products had decayed. The slugs were then taken to a chemical facility for separation of plutonium.

Natural uranium contains >99.2% U-238 and 0.72% U-235. Low-enriched, reactor grade uranium contains 3-4% U-235. Highly enriched, weapons-grade uranium contains ~90% U-235 [40].

On July 16, 1945, the first plutonium A-bomb was tested at Alamogordo, New Mexico, with a yield of 19 KT (Project Trinity). The uranium A-bomb was never tested. The next month a nuclear warhead was delivered from the bomb bay of a B-29, the *Enola Gay*, and detonated at an altitude of 1,700 feet. The largest Catholic Church in Hiroshima was used as the target for the pilots, who were Catholics. This uranium bomb was 28 inches in diameter and 10 feet long, weighing 9,000 pounds. Charles Sweeney was the last man to drop an A-bomb (Fat Boy), a plutonium bomb, this one on Nagasaki from his B-29. Sweeney's job was to drop the bomb on Kokura, but haze from a firebombing raid on a nearby city obscured the target. Low on fuel, he flew on to the alternate target, the manufacturing town of Nagasaki. The bomb detonated directly over the Christian quarter at 11:02 A.M. on August 9, 1945, three days after the Hiroshima bomb. From then on the survivors of both Japanese cities were called ‘hibakusha’ or 'explosion-affected persons'. About 20,000 enslaved Koreans also died in Hiroshima from the bomb; no one has bothered to study the health of surviving Koreans in Hiroshima and Nagasaki. In fact, very little historical study has been given to their fate. In June 1946, the U.S. arsenal contained nine Fat Man type bombs. In late 1949, the U.S. had increased its arsenal to 200 atomic bombs.

The two A-bombs dropped on Japan were detonated by radar altimeter above grade to maximize the free expansion of the fireball, so as to set the maximum amount of these two wooden cities on fire. This created carbon soot "black rain" which may have mingled with fission product ash particles to create hotspots of radioactivity. The second atomic weapon was so crude that only about 1% of Pu-239 mass was burned amounting to a couple hundred grams which became actual fission-product fallout. The fireball at the Trinity Site was centered only about 33m above grade causing the fireball to touch the desert sand. The molten sand turned into plutonium-laced green glass latter called trinitite.

The distribution of energy from an A-bomb is approximately 50% blast, 35% thermal, 5% prompt gamma and neutron radiation and 10% residual radioactive fallout. The effects of a nuclear warhead detonation depends on the warhead yield and the distance from the surface of the earth at which it was detonated. In the first millisecond after a 0.5 MT nuclear warhead is detonated the temperature of the fireball is about 400,000 ^{o}C and the overpressure is over 100,000 pounds per square inch (psi). At 50 milliseconds the radius of the expanding fireball has grown to 1350 feet and the fireball temperature has cooled to 75,000 ^{o}C. The overpressure shock wave is coincident with the fireball creating a wind of over 1,000 miles per hour. At one second the fireball has a radius of 2500 feet and a surface temperature of 6,000 ^{o}C. The shock wave is now expanding faster than the fireball providing a 40 psi front at 3800 feet with a wind of 750 mph. After 10 seconds the fireball has a surface temperature of 2,000 ^{o}C while the shock wave radius is 2.6 miles with a 5 psi front. Winds of over 300 mph are beginning to suck up debris from the ground into the stem of an ascending mushroom cloud. At one minute the characteristic cloud has grown to a radius of 1.5 miles and reached an altitude of 3.5 miles. The cloud continues to grow to over 8 miles in height and drift downwind. Later effects are due to fallout of radioactive fission products and neutron induced radioactive material. Blast waves can destroy the sturdiest built homes while thermal radiation can melt the eyes and rot the flesh of those residing many miles away. The only potential health hazard from nuclear war for those residing outside the limited regions of damaging sub-lethal and lethal blast, thermal and prompt radiation effects is radioactive fallout. Radioactive fallout from megaton level detonations will carry hundreds of miles downwind.

Arthur Eddington (1882-1944) concluded that at high temperatures in the interior of a star, its atomic nuclei could penetrate other nuclei and cause nuclear fusion reactions, releasing energy. The energy would be released when fast moving hydrogen nuclei collided with enough force to overcome their respective electrical barriers and fused together, making helium nuclei and giving up the binding energy in the process. These events were later named thermonuclear reactions. Fermi believed an atomic bomb might serve to heat a mass of deuterium sufficiently to begin thermonuclear fusion.

A H-bomb would potentially be orders of magnitude more energetic than a fission bomb. Teller considered the possibility of a hydrogen bomb and made extensive calculations. He named his new hydrogen bomb, The Super, and used an atomic bomb for ignition and a cubic meter of liquid deuterium and an indefinite amount of tritium for the thermonuclear phase in the first H-bomb test. The design of the Super is still a secret. The first experimental thermonuclear device, coded Mike and weighing 65 tons, was detonated at Eniwetok Island in the South Pacific on November 1, 1952. Its yield was a thousand times more violent than Little Boy dropped on Japan. The U.S.S.R. Tsar Bomba tested a 60 megaton H-bomb in the atmosphere using lithium deuteride powder.

> The 60-megaton Tsar Bomba shattered the notion in 1961 that there are any technological limits as to how big a bomb might be built; science does not impose any limits as to yield. The mushroom cloud reached to 37 miles. The ring of absolute destruction would have a 28-mile radius. The fireball was over 5 miles in diameter [41].

There was a vigorous controversy between Linus Pauling (1901-1994) and Edward Teller fifty years ago during the height of atmospheric testing of nuclear weapons. Herman Muller's earlier work on genetics influenced Pauling, who had received Nobel Prizes in 1954 and in 1962. Other than Pauling, only Marie Curie was awarded separate Nobel prizes in different scientific fields. Pauling was a member of the Emergency Committee of Atomic Scientists chaired by Albert Einstein. Pauling sent a disrespectful hand written letter to John F Kennedy, president of the United States, in 1962 to give his adamant anti-nuclear views based in large part upon his radiobiological ignorance and the false data of Muller. The letter reads: To: President Kennedy: Are you going to give an order that will cause you to go down in history as one of the most immoral men of all time and one of the greatest enemies of the human race? In a letter to the New York Times I state that nuclear tests duplicating the Soviet 1961 tests would seriously damage over 20 million unborn children including those caused to have gross physical or mental defect and also the stillbirths and embryonic, neonatal and childhood deaths from the radioactive fission products and carbon 14. Are you going to be guilty of this monstrous immorality, matching that of the Soviet leader, for the political purpose of increasing the still imposing lead of the United States over the Soviet Union in nuclear weapons technology? [89].

Andrei Sakharov (1921-1989) was awarded a Ph.D. in particle physics in 1948 and immediately joined the U.S.S.R.'s nuclear weapons project; he became the key figure in the development of the Soviet hydrogen bomb. The genie unleashed by Sakharov and the other pioneering nuclear scientists will never be put back into the bottle. By 1957 Sakharov felt personally responsible for the problem of radioactive contamination from nuclear tests, writing scientific papers on Non-threshold Biological Effects and The Radioactive Danger of Nuclear Tests. Sakharov's belief in the LNT assumption played a great role in limiting testing of nuclear weapons in the air, space and the oceans of the world. Sakharov said: the treaty has saved the lives of hundreds of thousands,

possibly millions, of people who would have perished had testing continued. Today lasers and computer simulations have replaced the need for most nuclear tests [50]. Sakharov in the mid-1970s predicted the development of the World Wide Web (www), almost 20 years before it first appeared: Far in the future, more than 50 years from now, I foresee a universal information system (UIS), which will give everyone access at any given moment to the contents of any book that has ever been published or any magazine or any fact. The UIS will have individual miniature-computer terminals, central control points for the flood of information.

Atmospheric Tests

The official stance of the U.S. and the U.S.S.R. with respect to nuclear tests is that they represent the development and testing of nuclear weapon reliability. In fact, such tests also suggest a surrogate nuclear war among the superpowers and radical governments, a war of intimidation by proxy. Jaworowski [2] described the exaggerated fear of ionizing radiation that arose during the Cold War period with incessant testing of nuclear weapons. Radioactivity from the atmospheric tests spread over the whole planet, mostly in the northern hemisphere. People feared the terrifying prospect of a global nuclear war and 'large' doses of radiation from fallout. However, it was the leading physicists responsible for inventing nuclear weapons, who instigated the fear of small doses. In their endeavor to stop preparations for atomic war, they were soon joined by many scientists from other fields. Subsequently, political opposition developed against atomic power stations and all things nuclear.

The LNT has played a critical role in influencing a moratorium and then a ban on atmospheric testing of nuclear weapons. The United Nations Committee on the Effects of Atomic Radiation (UNSCEAR) was concerned mainly with the effects of nuclear tests, fulfilling a political task to stop weapons testing. False arguments of physicists were effective in stopping atmospheric tests in 1963. However, the price paid created a radio-phobia of demanding near zero radiation doses for future generations. This worldwide societal radio-phobia was nourished by the LNT assumption. A video called The Inheritance of Trauma: Radiation Exposed Communities around the World, claimed that half of background radiation comes from past nuclear weapons testing [3]. This type of fear mongering in the midst of abundant and easily available data to refute this outrageous statement is one of many that caused radio-phobia in the American public. President Clinton promoted his anti-nuclear campaign by grossly exaggerating the radiation risk from nuclear testing fallout based on the use of the LNT. The truth is that radiation exposure from nuclear weapons tests never amounted to more than 100 μGy per year in 1962 to those living in the northern hemisphere. The exposure from nuclear testing dramatically decreased in 1963 due to the test ban; today, test fallout contributes much less than 10 μGy per year. Mean background dose in the U.S. and the world today is 2500 μGy per year, with natural environmental exposures ranging up to 700,000 μGy per year in regions of Iran. In 1945, Stalin ordered the U.S.S.R. to develop its own nuclear weapons; by 1949, they had developed the A-bomb. However, this crash program cost the lives of many Soviet scientists and technicians who had ignored hazards of very high radiation doses [4].

Over 1500 nuclear weapon tests have been carried out since 1944, the majority up to 1963 in the atmosphere [85]. No evidence of cancer risk increase has been found in inhabitants of the world due to nuclear test fallout. The Standardized Mortality Ratio (SMR) for all-cause mortality and all cancer mortality was 0.71 and 0.74, respectively, for 250,000 participants at U.K. and U.S.

nuclear test sites [1]; that means that about 25-30% of normal expected mortality may have been protected by low dose radiation from fallout.

U.S. nuclear tests have been carried out at the Nevada Test Site, at Eniwetok and Bikini Atolls in the South Pacific and at Johnson Island, Christmas Island and at Amchitka, Alaska. There were 30 nuclear weapons tests at the Nevada Test Site in 1957 as part of the PLUMBOB test series. A cohort study of 12,219 military participants, who received a mean red bone marrow dose of 3.2 mGy and a maximum of 500 mGy, showed that the participants lived longer than the general population [92].

Twenty-three nuclear tests were carried out in the Bikini Atolls (Figure 2). The first H-bomb test was by the U.S. (code named Mike) on October 31, 1952 at Eniwetok Atoll. It had a yield of 10.4 MT and left a crater one mile in diameter and 175 feet deep. Its mushroom cloud shot up to 25 miles into the stratosphere and spread out over 100 miles downwind. The largest U.S. test (Bravo) was of a 15 MT H-bomb at Bikini Atoll on February 28, 1954, with a fireball greater than three miles in diameter.

Operation Crossroads in 1946 at Bikini Atoll involved 235 nuclear bomb tests which exposed about 40,000 U.S. Navy, 6,400 Army, and 1,100 Marine personnel. Because available data were not considered suitable for epidemiologic analysis, a risk study was based on exposed surrogate groups [42]. There were 32,000 U.S. observers in the later (1951-57) nuclear tests. Both solid cancer and leukemia mortality rates decreased as exposures increased [43]. The median dose received by military personnel was <4 mGy. The military in the late 1940s sent personnel to clean contaminated ships within a few hours' after warhead detonations. The General Accounting Office rebuked the Pentagon's assertions of low whole- body doses to military personnel in Operation Crossroads tests at Bikini Atoll.

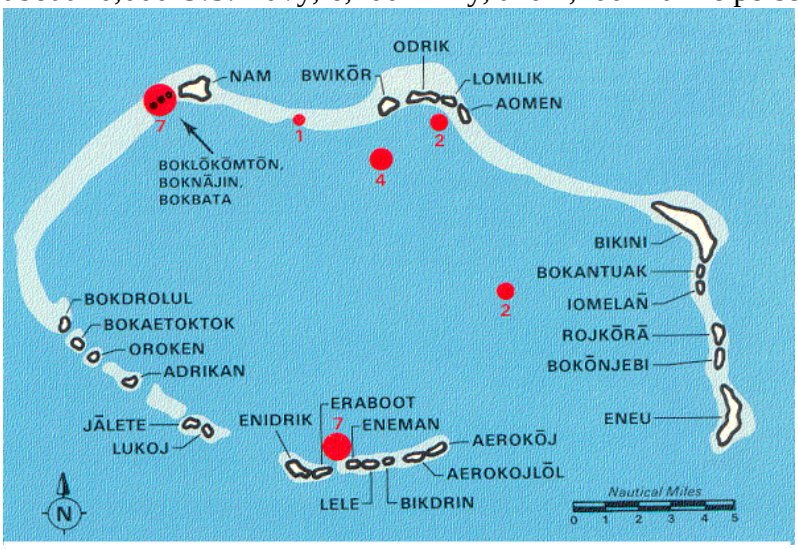

Figure 2. Bikini Atolls in the South Pacific. The red spots indicate where nuclear tests were carried out and the red numbers the number of tests at that site (Committee on Radiological Safety in the Marshall Islands [79]).

The AEC (Atomic Energy Commission) miscalculated the yield and weather conditions of its 1954, 15-megaton H-bomb test (Bravo) in the Bikini Atolls. As a result, 64 inhabitants of the nearby Rongelap Atoll received high radiation doses (mean γ-dose, 1.8 Gy) from fallout about 150 miles from the test site [12]. None died from acute radiation effects, although all developed beta skin burns and the children experienced thyroid damage (nodules, hypothyroidism) from uptake of I-131 into the thyroid gland. One case of leukemia was reported in this group. The Bikini ash also fell on a Japanese fishing boat, the Lucky Sea Dragon, at sea 80 miles east of the

test site, causing the death of Aikichi Kuboyama among the 23 crew members while all others experienced radiation sickness (mean γ-dose, 3 Gy). An additional 714 islanders and Americans received cumulative gamma doses of <0.05 to 0.8 Gy [39,79].

Massive plutonium production reactors and extraction chemical plants at Hanford, WA, the half-mile long uranium enrichment facility at Oak Ridge, TN, a laboratory at Los Alamos, NM for designing and building A-bombs, a plutonium bomb building facility in Golden, CO, nuclear test sites in Nevada and the South Pacific, and scores of nuclear power plants spread over the U.S., employed millions of people, often for the major time of their working careers [47]. Multiple epidemiological studies of workers in the U.S. and over the world have failed to demonstrate a significantly increased risk of cancer or any other disease among workers at cumulative doses of <100 mGy [36].

President Eisenhower gave a speech on Atoms for Peace in 1953, which was followed with congressional authorization for construction of the first nuclear power plant at Shippingport based upon the light water steam reactor used in the first nuclear submarine, the *Nautilus*. That same year Eisenhower asked the UN to create the IAEA to promote nuclear power.

The Russian test site at Novaya Zemlya near the city of Semipalatinsk, the Soviet equivalent to Los Alamos, was the site for 456 tests carried out from 1949-1989 with 700,000 people living downwind exposed to fallout. In 1957, a very large piece of land (20,000 km^2) downwind from Kyshtym, Ural Mountains, U.S.S.R., was contaminated by the release of 700 PBq from the explosion of a nuclear waste storage tank. Twenty villages with 7500 inhabitants were permanently evacuated. Later epidemiological studies failed to demonstrate an increased mortality risk in either locations, but did show fewer than expected cancer deaths [36].

Predicted Radiation Effects of Strategic Nuclear War

Soviet Premiere Nikita Khrushchev initially wanted to test a 100-megaton weapon. Miniaturization was a far more important technical hurdle for a would-be nuclear power, which needed bombs that were small and light enough to fit on ballistic missiles far more than it needed ones that produce an impressive yield. The Cuban Missile Crisis, and the consequent Soviet removal of nuclear weapon delivery systems from the western hemisphere came about a year after the Tzar Bomba test. Both the U.S. and U.S.S.R. realized that such a bomb had no strategic significance; no further tests of such magnitude was ever attempted by either side nor by anyone else.

The National Academy of Sciences issued a report, Long-Term Effects of Multiple-Nuclear Weapons Detonations, in which they concluded that the impact of a nuclear war between the U.S. and NATO countries and the U.S.S.R. and Warsaw Pact countries would not be as catastrophic upon non-combatant countries (not directly hit by nuclear weapons) as had been previously feared. The report was kept classified in order to maintain the state of radio-phobia needed to obtain the political objectives of the two military sides. The report analyzed the likely effects of a 10,000 MT nuclear exchange on populations in the northern and southern hemispheres. Nuclear fallout would be very high in many regions of the United States (Figure 3). In one attack scenario, 1440 warheads with 5050 MT surface and 1510 MT air burst total yields would potentially expose all remaining survivors to significant radiation exposures if unprotected. Nuclear fallout would be complicated by multiplicity of detonations, timing of detonations and

mix of surface and air detonations, making it difficult to predict fallout patterns in local areas of the country [20-22].

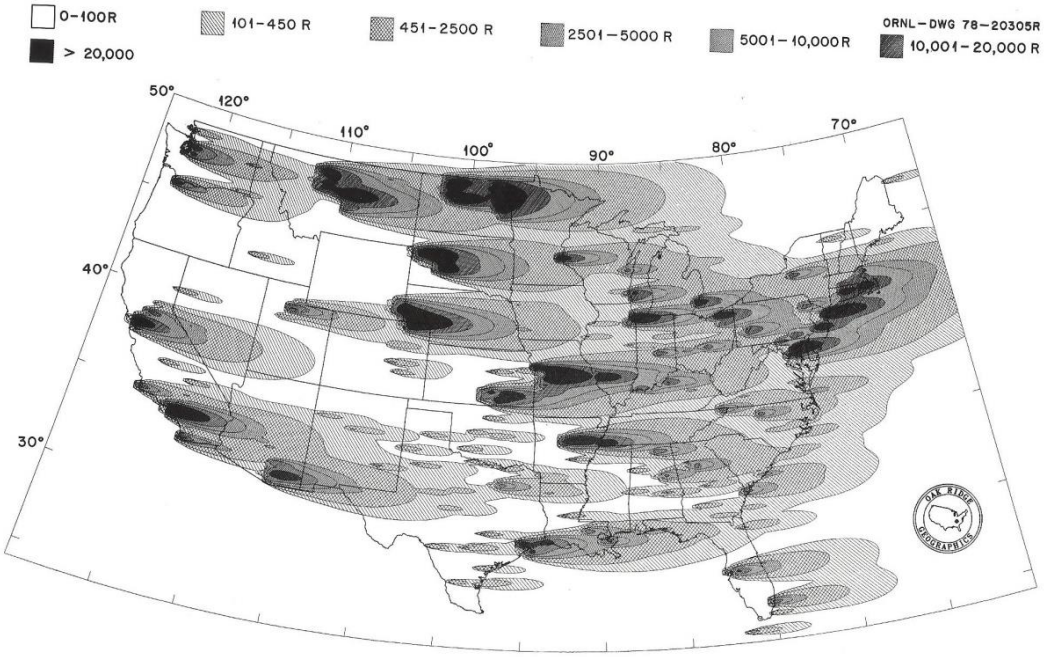

Figure 3. Cumulative radiation doses resulting from a strategic nuclear strike on the United States (Oak Ridge National Laboratory [90]).

At Hijiyama High School, 51 girls were outdoors playing on the school grounds about 0.5 miles from hypocenter of the first A-bomb detonated over Japan in WW II. All were dead within a few days from severe burns. At one mile, the mortality among unshielded school children was 84% and 14% among shielded children. The damage to Hiroshima, and to Nagasaki a few days later, was enormous, even by WW II standards of destruction. Overall, more than 75,000 died and 100,000 were injured in Hiroshima's 245,000 population. Of the injured survivors, 70% suffered from blast injuries, 65% from serious burns and 30% from prompt radiation effects. About 90% of all building within the city limits were destroyed. In Hiroshima, 270 out of the city's 298 doctors and 1,645 of its 1,780 nurses were killed while 42 of the city's 45 hospitals were destroyed [81]. The yields of the two warheads were so low as not to cause significant nuclear fallout of any immediate health hazard concern to survivors. Yet all this death and destruction was from a primitive, puny (by today's standards) uranium bomb with an equivalent explosive power of about 13 KT.

The physical effects of the atomic bomb were described in vivid detail by many authors, including this account by a Methodist missionary who was in Hiroshima right after the bomb fell:
He was the only person making his way into the city; he met hundreds and hundreds who were fleeing, and every one of them seemed to be hurt in some way. The eyebrows of some were burned off and skin hung from their faces and hands. Others, because of pain, held their arms up as if carrying something in both hands. Some were vomiting as they walked. Many were naked or in shreds of clothing...Almost all had their heads bowed, looked straight ahead, were silent, and showed no expression whatever…It was at

that moment...the sound...the lights out...all was dark...How I got out, I don't know...the sky was lost in half-light with smoke...like and eclipse...The window frames began to burn; soon every window was aflame and then all the inside of the building...There were eight of us there...The fire spread furiously and I could feel the intense heat...The force of the fires grew in violence, and sparks and smoke from across the river smothered us... and barely managed to escape [82] Parents, half-crazy with grief, searched for their children. Husbands looked for their wives, and children for their parents. One poor woman, insane with anxiety, walked aimlessly here and there through the hospital calling her child's name [80].

Fallout radiation levels from modern nuclear warheads are very high near the site of detonation, decreasing and increasing with distance due to radioactive decay and from fallout. Prompt fallout occurs during the first day producing the greatest radiation levels. Geography, wind conditions and precipitation can greatly influence early radiation fallout patterns, causing local 'hot spots' of radioactivity, even hundreds of miles downwind. The fallout pattern of volcanic ash following the May, 1980, eruption of Mount St. Helens is similar to what one might anticipate from a multi-megaton surface blast. Uncertainties in bomb effects and radionuclide fallout patterns depend far more on local topography and weather conditions than on bomb design. For example, more than 50% of radioactivity in a cloud will be washed out by a heavy rainfall of 2 hours duration. Radioactive particles will also settle to the earth by dry deposition. Particles >10 microns in diameter settle promptly by sedimentation; smaller particles are more readily dispersed by wind updrafts and turbulence. In regions of low to moderate rainfall, dry deposition of radioactive particles may account for a greater total deposition than washout in precipitation.

The acute radiation syndrome in humans was known and described in reasonably good detail by Pfahler as early as 1918 and by others two decades later who called the syndrome 'radiation sickness'. The largest body of data concerning radiation sickness in humans is from the Japanese A-bomb survivors. The Japanese exposures were instantaneous to a mixture of γ-rays and limited neutrons. Fallout of fission products was minimal in the Japanese. Ionizing radiation from nuclear weapons fallout can produce a variety of biomedical effects, whether the exposure comes from external or internally deposited α, β,γ-emitting radionuclides. External γ-rays cause acute radiation sickness when they are delivered over a substantial portion of the whole body.

Biological damage is related to dose and dose-rate. A lethal dose of external, whole-body, Co-60, 1 MeV gamma rays delivered in one hour is 3000 to 6000 mGy. This is about 10 million times greater than the mean background dose-rate for the world of 0.20 μGy per hour. The dose-rate in Japanese A-bomb survivors near hypocenter was 6000 mGy per second, which is 2×10^{15} times greater than the highest dose-rate from Chernobyl fallout.

An acute whole-body, external γ-ray exposure to humans has rapid biological effects at a high dose-rate and as the dose increases. At 1 Gy, blood changes are observed but little or no evidence of acute radiation disease. At 2 Gy radiation sickness occurs with few deaths. At 3.5 Gy, death occurs in 50% of the population within 60 days due mostly to failure of the blood forming tissues in the bone marrow. At 10 Gy, death occurs in about a week in 100% of the population due to gastro-intestinal damage as well as severe bone marrow failure.

For humans the median lethal radiation dose is about 4.5 Gy if given in one day. There is some disagreement as to what is the $LD_{50(60)}$ dose for humans exposed under the expected conditions of nuclear war. Most believe that the $LD_{50(60)}$ lies between 3.5 and 4.5 Gy, when the dose is

delivered to the whole-body within a period of less than a day. There is a sharp steepness in the radiation dose-lethality curve. A dose that is only 20% greater than the $LD_{50(60)}$ may result in death of over 90% of the population while a dose that is 20% less than the $LD_{50(60)}$ may result in death of only 5% of the population.

Dose-Rate at 1 Hour (rad/hour)	Survival Prognosis
10	No acute lethality if unshielded
100	Lethal if unshielded; not lethal if take minimal protection
1,000	Lethal unless substantially shielded
10,000	Lethal unless in best of fallout shelter

Table 2. Influence of dose-rate on human survival following radiation exposure from nuclear weapon fallout.

The number of deaths from the acute radiation syndrome in the first 60 days and the number of cancer deaths during the next 50 years have been exaggerated by both the U.S. and U.S.S.R. to achieve a political agenda in their nuclear war scenarios. Local fallout from a 1 MT surface burst would result in a patch of about 200 square miles (oval area 6 miles at its widest and 45 miles at its longest for a continuous unidirectional wind of 15 mph) where radiation levels would be lethal to anyone not protected. It is important to remember that as radiation levels in the cloud are decreasing due to radioactive decay they may be increasing for a period of time on the ground due to fallout accumulation.

The $LD_{50(60)}$ is the lethal dose in humans that will kill half the exposed population within 60 days

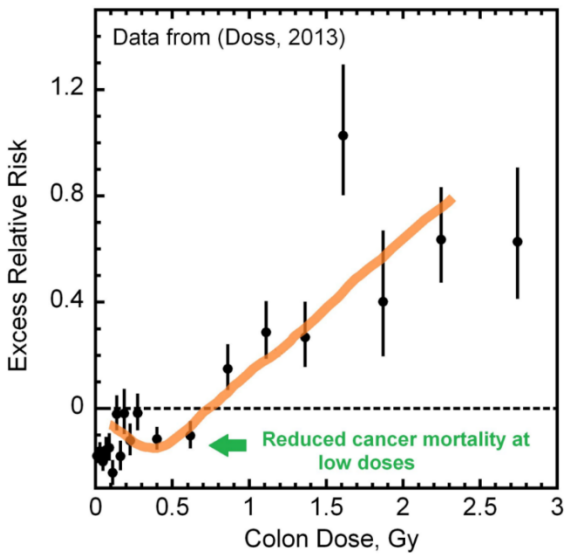

Figure 4. Excess relative risk of solid cancer mortality in Japanese A-bomb survivors [52]. The threshold dose was about 500 mGy. (With kind permission of Dr. Mohan Doss [91]).

Radiation levels near the detonation site will be rapidly decreasing, while those hundreds of miles downwind will be increasing for the first few days (Table 2). In this example, the radiation dose-rate would decrease to about 15 Gy/hr at about 1 hour to about 1.5 Gy/hr after 12 hours to about 0.15 Gy/hr after 4 days and to about .01 Gy/hr after 40 days [11]. The rate at which fallout radioactivity decreases can be estimated: The estimate is fairly accurate for times from 1 hour to about 6 months after detonation, assuming the fallout is completed by t = H + 1. As a rule of thumb, the

radiation levels from fallout will decrease by a factor of 10 for every 7-fold increase in time. This rule is applicable for the first 6 months after detonation. This means that radioactivity in fallout will decrease to 1/10th of the one hour level by 7 hours and to 1/100th at 49 hours. The shape of this dose rate curve is similar to that near Fukushima, where after a week or two, dose-rate had fallen to near baseline; the dose-rate never reached the background dose rate at Ramsar, Iran (260 mGy/y), even at its peak which was at about 180 mGy/y.

Residual radiation results from neutron-activation of elements in the soil and buildings and from fission product fallout. Neutron related gamma doses were negligible in Japanese cities. Gamma doses from fission product fallout were less than 25 mGy [78]. Today Hiroshima and Nagasaki are modern cities of 2.5 million people with no residual radiation attributed to A-bomb detonation. The Life Span Study (LSS) of the Japanese atomic bomb survivors is considered the 'gold standard' for radiation epidemiology; nevertheless these studies are filled with significant limitations at low doses, which are of great interest to radiation protection agencies and the EPA [54]. The threshold based on the LSS data is very conservative: 100 mGy/y. The actual threshold is likely 200-700 mGy/y with hormesis effects being seen below these doses. It appears that there was significant misunderstanding, misinterpretation or even possible deliberate scientific misconduct in the 1956 NAS paper concerning use of the LNT in evaluating A-bomb survivor data[70-73].

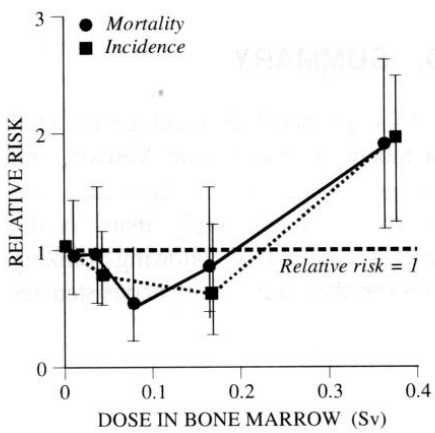

Figure 5. Relative risk of leukemia in Japanese A-bomb survivors [67]. Diagram shows details of expanded view for the low dose region. The threshold for leukemia incidence and mortality is about 200 mGy (With kind permission by Springer, Charles L Sanders: Radiation Hormesis and the Linear-No Threshold Assumption, © 2010).

The Radiation Effects Research Foundation (RERF) data show more evidence of hormesis than adverse effects at low doses (Figures 4-5). However, thresholds and radiation benefits are not considered by radiation protection agencies. Use of the RERF results for LNT modelling of harmful health effects is well known to be inappropriate, because A-bomb exposures do not apply to radiation protection for workers or for the public exposed to chronic and highly fractionated and low dose-rate radiation, especially for extreme costly cleanup and decommissioning standards [62]. Dr. Gunnar Walinder believed the "expectation" that UNSCEAR members would manipulate the RERF data to produce "expected" results that supported the LNT [63].

The all-cause death-rate in the United States for 2013 was 730 per 100,000, or about 2.2 million deaths per year. A moderate dose of radiation increases longevity [74]. Longevity is a better measure of health effects than is cancer mortality. A-bomb survivors had a small added risk of cancer at high radiation doses. And this high dose cohort lived only a few months less than their children and those not exposed to radiation. No health effects related to radiation exposure of their parents has been found in survivors [55]. The life expectancy in Japan in 2015 was 80.5 years for males and 86.8 years for females; mean for both sexes was 83.7 years. Japan is ranked number 1 in the world for life expectancy. The United States is ranked number 31 with life

expectancy of 76.9 years for males and 81.6 years for females; mean for both sexes was 79.3 years. Australia has a cancer death rate of 314 per 100,000 per year that is about 50% higher than for low dose Japanese A-bomb survivors (201 per 100,000 per year). A-bomb survivor cancer death rates at the highest doses was comparable to living in Australia. This means that Japanese A-bomb survivors are living significantly longer than non-exposed Americans and Australians [56-57].

Following the dropping of two A-bombs on Japan in 1945, researchers exaggerated the radiological risks as a result of politics and not science. Only about 500 of the hibakusha died a premature death from cancer (0.5% of the exposed Japanese population) and most of them received high dose exposures. The high dose data is primarily derived from extensive studies of the survivors of the atomic bomb exposure in Japan with doses estimated according to the distance from the epicenters of the explosions. A threshold of about 500 mGy in Japanese A-bomb survivors was found for formation of birth defects of the nervous system irradiated *in utero* at 8-15 weeks [58]. No hereditary disorders were found in 40,000 children of A-bomb surviving parents. No increase in adult-onset hypertension, diabetes, hypercholesterolemia, ischemic heart disease and stroke was observed in offspring of A-bomb survivors [75].

RERF studies of Japanese atomic bomb survivor data at low doses have not been adequately evaluated [60.] Many independent studies of the RERF data contradict the official RERF analyses, even when limited to using the RERF's own processed data in the absence of the ability to access the raw data. Even BEIR V consultants were unable to obtain the data to undertake an independent analysis. BEIR V states that there are no adverse effects below a high dose, but then presumes a straight line from the high dose to zero. Atomic bomb survivor data shows a significant reduction in cancer mortality rate in the dose-range of 300 to 700 mGy. Nevertheless, BEIR applies the linear model down to zero [61].

Leukemia incidence was initially determined in 195,000 survivors of the combined populations of Hiroshima and Nagasaki (Table 3). The threshold dose for radiation-induced leukemia base on 96,800 A-bomb survivors was 500 mGy [59, 69]. Ozasa claimed that the risk of cancer mortality among Japanese A-bomb survivors was significantly higher for several major organs [52]. The data from low dose groups (extrapolated to zero dose) were used in determining baseline cancer rates causing a negative bias. Correcting for this negative bias produces a J-shape curve consistent with radiation hormesis [53].

Cases	Persons	Dose (mGy)	Cases/10,000	% Controls
9	32,963	0	2.7	100
3	32,692	20	0.9	34
8*	20113	500	4.0	150
33	8810	5,000	37	1400
15	1241	13,000	120	4400

Table 3. UNSCEAR in 1958, p. 165, proposed a threshold of 500 mGy for leukemia induction in Hiroshima A-bomb survivors [68]. There were only 68 cases of leukemia found in 95,819 survivors. The cases found in the 500 mGy cohort appeared to be mostly from much higher doses *. Therefore, the threshold from this 'gold standard' database must be about 500 mGy [68-69].

UNSCEAR (1958) reported an incidence of leukemia in Japanese A-bomb survivors that was three times lower than in controls at a mean dose of 20 mGy and with a threshold of 500 mGy. The significant reduction in leukemia incidence for the 32,692 survivors in the low dose region was far below the leukemia incidence of the 32,963 survivors in the controls. This data disproved the LNT dose-response model, and UNSCEAR should have rejected the LNT model in its report [65]. UNSCEAR (1958) found that almost all of cases of leukemia occurred in residents that had severe radiation complaints (doses >0.5 Gy).

The 1958 UNSCEAR report on Japanese A-bomb survivors deleted the lowest exposed group from analysis to obscure a hormetic effect [65]. UNSCEAR 1958 made conflicting statements. Jaworowski states: hormesis is clearly evident . . . in a table showing leukemia incidence in the Hiroshima population, which was lower by 66.3% in survivors exposed to 20 mGy, compared to the unexposed group. This evidence of radiation hormesis was not commented upon by UNSCEAR. Since then, the standard policy line of UNSCEAR and of international and national regulatory bodies over many decades has been to ignore any evidence of radiation hormesis and to promote LNT philosophy [64]. The Hiroshima leukemia data strongly contradict the LNT model, which predicts increasing risk as the radiation dose increases. The threshold for leukemia incidence and mortality is about 200 mGy [67, 69]. Jaworowski estimated a threshold for leukemia incidence of 400 mGy for A-bomb survivors [64]. The leukemia data fit a hormetic J-curve; they do not fit a straight line. UNSCEAR (2012) did state that no radiation-induced health effects, including leukemia, have been found as a result of the Fukushima accident [66].

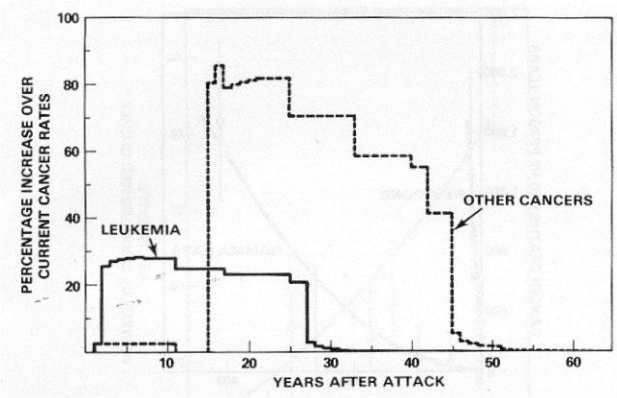

Figure 6. Predicted excess deaths from leukemia and other cancers expected following a hypothetical 5,000 MT nuclear attack on the United States using the LNT model (Adapted from Gant KS and CU Chester, Minimizing excess radiogenic cancer deaths after a nuclear attack, Health Physics, © 1981) [31].

Global fallout is not expected to result in many survivors of blast and thermal effects exhibiting prodromal symptoms of fatal acute radiation syndrome in a 5,000 MT attack because of the magnitude of cumulative acute exposure and later chronic exposure rate from fallout [32]. The projected number of radiation-induced cancers in survivors of a nuclear war would be much fewer than would be affected by acute effects of fallout if given warning of only a few minutes and if educated as to what to do by providing personal shielding. Leukemia would appear earlier than solid cancers (Figure 6). A 8,000 MT nuclear exchange between the U.S. and the U.S.S.R. would result in long-term residual radioactivity in the northern hemisphere that is 40 times greater than the highest level seen during the period of most intense atmospheric weapons testing in the 1960s. A 3,500 MT attack on the U.S. would cause only a small 1-2% increase in cancer mortality from fallout [32]. Even with a 5,000 MT attack the average reduction in American lifespan from radiation-induced cancer would be only 1.2 years, or considerably less than is experienced today by the average cigarette smoker [31].

The current maximum accepted radiation dose allowed for radiation workers is 20 mGy/y or ten times greater than that allowed for the general public. A 1 MT warhead surface burst would deliver a dose greater than 20 mGy/y at one year after detonation to a surface area of about 5,700 square miles. A 1 MT warhead exploded on a 1,000 megawatt electric nuclear power reactor would increase the inventory of radioactive fallout of mostly long-lived radionuclides. The added (from the reactor) early radiation dose would not be substantial; however, at time periods longer than one month after detonation, a significant portion of residual radioactivity would be contributed by reactor fission product inventory and not from the bomb. Detonation of a 1 MT warhead on radioactive waste storage facilities, like those found at Hanford, Washington, would increase the 20 mGy/y fallout area to >100,000 square miles more than from a detonation over a nuclear power reactor [32]; this low dose-rate delivered to very large regions of the U.S. would be beneficial.

Nuclear Winter

The political philosophy of MAD (Mutually Assured Destruction) deterrence doctrine has encompassed the idea of nuclear winter that will follow an all-out nuclear war involving 10,000 or more nuclear warheads. The nuclear winter scenario was anticipated in the 1964 movie, Dr. Strangelove, where a mountain range in the Soviet Union was mined with nuclear warheads, triggered to explode at the onset of nuclear war, hurling debris into the stratosphere and destroying all civilizations. The hypothesis of nuclear winter was a central fixture in the nuclear weapons debate during the 1970s. If the concept is correct, then the U.S. and the U.S.S.R. cannot make total nuclear war on each other without counting the environmental cost within its own borders from its own attack. To accept the worst about nuclear winter would be to conclude that civil defense would be useless and a first strike would be suicidal.

The possibility of nuclear winter was suggested by the observations of dust storms on Mars and resultant temperature changes seen with the Mariner space probe. One report predicted a drop in earth's surface temperature due to absorbance of solar light and heat by dust particles injected into the stratosphere by surface nuclear detonations. The amount of debris injected into the air from a surface burst was estimated at 5 million tons per MT; an air burst would cause little dust injection into the stratosphere. Dust particles absorb sunlight, reducing the temperature on the earth's surface. In the worst proposed scenario, surface temperatures would drop for a period of several months before temperatures returned to normal. The soot produced by forest fires, burning urban and industrial centers would add an estimated 225 million tons of soot into the atmosphere in addition to ash and other particles initially entrained in mushroom clouds of surface bursts. All entrained material would fall out downwind at rates dependent upon altitude attained, wind conditions, precipitation patterns and particle size and density [33].

Rain and other natural scavenger processes would likely cleanse the atmosphere of 66-95% of the particulate material over a period of a few weeks. Soot, may create its own defense against atmospheric cleansing. Warmed by the sun due to its higher solar absorbance than ash particles and because of its lower density, soot particles could become buoyant and rise above cleansing rain. Once in the troposphere, soot particle concentration would decrease by a factor of 3 every 180 days. Maximum summertime cooling would occur over the northern hemisphere during the first two weeks after a nuclear war, assuming an initial release of 170 million metric tons of smoke and soot particles [34]. The potential for nuclear winter suggests that a protracted nuclear

war involving very large numbers of nuclear weapons used over a period of several months would minimize nuclear winter effects, whereas a maximum first strike and counter strike would maximize these effects. However, nuclear winter may be much less severe than originally proposed [35].

Survival of Nuclear War

The penetrating nature of γ-rays requires substantial shielding with denser materials in high dose-fallout regions. No lethality is expected from a radiation dose-rate of 100 mGy/h. An initial dose-rate from fallout of 1.0 Gy/h would not be lethal if minimum protection is taken (e.g., staying indoors). An initial dose-rate of 10 Gy/h is lethal unless substantially shielded. A shelter providing a protection factor of 100 would suffice. A dose-rate of 100 Gy/h would be lethal unless in the best of radiation shelters that give a protection factor of ≥ 500. However, the area downwind from a nuclear detonation with these high dose-rates would be limited.

To protect yourself from fallout, it is essential to find shelter. The dose protection factor of a shelter is the protection afforded someone inside the shelter from radiation originating from the outside. For example, a dose protection factor of 5 means that the radiation level inside the shelter is 5 times less than the radiation level outside the shelter at the surface of the ground. Dose protection factors vary widely according to building construction, floor level in a multi-story building and proximity to other buildings. A dose protection factor of 5 can be assumed for most wood-frame buildings. Most basements provide protection factors of about 50 in at least one area. Building a simple six-foot trench shelter in your backyard, covered with a few feet of dirt on a door would provide protection from thermal and blast effects and a protection factor of 500 from radiation fallout (Table 4). Provision of shelters that can withstand 100 psi blast waves, such as subway and utility tunnels could save nearly 70% of the American urban population from a 9,000 MT attack. U.S. ICBM silos are built to withstand up to 2,000 psi [19].

Americans are dreadfully ignorant on the subject of civil defense against nuclear war. Americans don't want to talk about shelters. Most who take shelters seriously are considered on the lunatic survivalist fringe. The current U.S. rudimentary fallout shelter system can only protect a tiny fraction of the population. There are probably less than one in a hundred Americans who would know what to do in the case of nuclear war and even fewer with any contingency plans. The civil defense system should, instead, provide stockpiles of food, water, medical supplies, radiological instruments and shelters in addition to warning systems, emergency operation and communication systems and a trained group of radiological monitors and shelter managers. There is a need for real-time radiation measurements in warning the public to seek shelter and prevent panic [76].

Structure	Protection Factor
Multistory – Upper	20-100
Multistory – Lower	10
Frame House – Ground Level	2-5
Frame House – Basement	10-50
Concrete with two feet walls and ceiling	500-1000
Six feet deep trench with 3 feet dirt on top	500

Table 4. Protection factor for γ-ray exposures from nuclear fallout in various habitations.

Shelters and a warning system providing sufficient time to go to a shelter are the most important elements of civil defense. The purpose of a shelter is to reduce the risks of injury from blast and thermal flux from nearby detonations and from nuclear fallout at distances up to hundreds of miles downwind from nuclear detonations. There are several requirements for an adequate shelter: (1) Availability- Is there space for everyone? ; (2) Accessibility- Can people reach the shelter in time? ; (3) Survivability- Can the occupants survive for several days once they are in the shelter? That is, is there adequate food, water, fresh air, sanitation, tools, clothing, blankets and medical supplies? ; (4) Protection Factor- Does the shelter provide sufficient protection against radiation fallout? ; (5) Egress- Is it possible to leave the shelter or will rubble block you?

There are several good publications that provide information for surviving nuclear war [13-15]. Two that offer good practical advice are Nuclear War Survival Skills by Kearny [16], and Life after Doomsday by Clayton [17]. Fallout is often visible in the form of ash particles. The ash can be avoided, wiped or washed off the body or nearby areas. All internal radiation exposure from the air, food and water can be minimized by proper ventilation and use of stored food and water. Radioactivity in food or water cannot be destroyed by burning, boiling or the use of any chemical reactions. Instead it must be avoided by putting distance or mass between it and you. Radioactive ash particles will not induce radioactivity in nearby materials. If your water supply is contaminated with radioactive fallout, most of the radioactivity can be removed simply by allowing time for the ash particles to settle to the bottom and then filtering the top 80% of the water through uncontaminated clay soil which will remove most of remaining soluble radioactivity. Provision should be made for water in a shelter; one quart per day or 3.5 gallons per person for a nominal 14 day shelter period. A copy of a book by Werner would be helpful for health care [18].

During the 1950s there was firm governmental support for the construction and stocking of fallout shelters. In Eisenhower's presidency the National Security Council proposed a $40 billion system of shelters and other measures to protect the civilian population from nuclear war. Similar studies by the Rockefeller Foundation, the Rand Corporation and MIT had earlier made a strong case for shelter construction. President Kennedy expected to identify 15 million shelters, saving 50 million lives. Even at that time there were many who felt this was a dangerous delusion giving a false sense of security. However, the summary document of Project Harbor (Publication 1237) concerning civil defense and testimony before the 88th Congress (HR-715) both strongly supported an active civil defense program by the U.S. government. A latter 1977 report to Congress concluded that the U.S. lacked a comprehensive civil defense program and that the American population was mostly confused as to what action to take in the event of nuclear war.

President Carter advocated CRP (Crisis Relocation Planning) as the central tenet of a new civil defense program. President Reagan in 1981 announced a new civil defense program costing 4.2 billion dollars over a seven year period; this program included CRP and the sheltering of basic critical industries in urban and other target areas. President Reagan believed that civil defense will reduce the possibility that the U.S. could be coerced in time of crisis by providing for survival of a substantial portion of her population as well as continuity for the government. Stockpile, sheltering and education could be a relatively cheap insurance policy against Soviet

attack [26]. With the fall of the U.S.S.R. came a lack of continuing interest in preparation to survive a nuclear war in subsequent administrations.

The Pentagon recommended to the Reagan administration that the U.S. adopt a Soviet-style-civil defense program, combining evacuation with fallout shelters. It was suggested that American use doors wrapped in plastic to cover hastily dug trenches in their back yards. U.S. strategy is like poker while the Soviets' is like chess. If we bluff and lose, we lose the game. If the Soviets bluff and lose, they only lose one piece. The Soviets have prepared for 'social control' following nuclear war, while many Americans believe that all would die. Thus, a prerequisite for any substantial change in U.S. civil defense policy requires a change in popular attitude about survival. Reagan planed for a hypothetical post-war future society in almost bizarre detail. In one additional touch worthy of Dr. Strangelove himself, it was proposed that a select group of volunteers-men and women with a carefully chosen range of skills and talents-live on the continuously moving, subterranean train, and that the underground community be equipped with nuclear reactors and hydroponic gardens to sustain life in what was termed 'the post-attack environment' [46].

Carl Sagan called for rejecting civil defense, appearing on television to denounce SDI military weapons [23]. Some would prefer surrender to any risk of nuclear war [24]. In 1986 the states of Oregon and Washington withdrew from an emergency drill organized by FEMA as a protest against 'planning for nuclear war'. The drill involved a hypothetical attack on these two states with 48 warheads. According to Oregon Rep. Wayne Fawbush*:* If you lead people to believe that a nuclear exchange can be survived, you promote the possibility of it happening. If the U.S. was better prepared to survive a nuclear attack, then others would be less likely to launch one. Thus civil defense does not signal a willingness to wage war, but a willingness to deter war by making it less tempting to a potential aggressor. It was to the Soviets politically advantage to hyperbolically emphasize the ‘dreadful’ effects of nuclear weapons to promote American disarmament. The consequences of using nuclear weapons defy human imagination...all-out nuclear war would cause the death of more than 200 million people and 60 million more would be mutilated...Such a nuclear war would inevitably lead to global catastrophe...80 percent of doctors would perish, 80 percent of hospital beds would be destroyed as would nearly all supplies of blood, antibiotics and other medicines...epidemics would start, radiation will remain a threat...Understand me well. We do not wish to frighten the world with these apocalyptic figures and facts. No, we wish to show the realities of a nuclear war and what needs to be done to prevent it [25].

The Federal Emergency Management Agency (FEMA) was formed in 1979, consolidating in one agency the various federal bureaucracies involved in disaster management. The 1986 FEMA plan calls for sheltering local, state and federal officials from nuclear war, while everyone else will have to shift for themselves. Land records will be taken into shelters. The federal government denies that this is an elitist strategy but that it is rather to insure that emergency-management infrastructure survives to direct the recovery of the surviving general population. FEMA admits that as many as half our citizens or more would be lost to the direct and indirect effects of the weapons themselves, and millions more would die in the chaos of the post-attack environment. Current FEMA strategy also calls for return to the traditions of the 1950s when school children were instructed to curl under their desks when they saw a bright flash of light.

The U.S. is woefully unprepared for nuclear war because of radio-phobia (Table 5). FEMA is absent before the American public about advice. To be politically correct FEMA just assumes that it will never happen. To educate the public in their mind is to enhance the probability of

nuclear war. A false emphasis is on prevention of nuclear war not on preparation. The National Radiological Defense Agency of FEMA is responsible for providing radiation detection instruments, training of personnel in their use and in education of large segments of the American population about radiation hazards. A low budget and even lower public visibility has made this program largely ineffectual.

Myths	Facts
Nuclear fallout will kill everyone	Common sense sheltering will protect most people
Radiation from fallout penetrates everything	All of β-particles and half of high energy γ-rays will be shielded by 3.6 inches of dirt, less for more dense materials
H-bombs are a 1000 times more destructive than A-bombs	Destructive potential is not a linear function of warhead yield
All that live in a bombed city will die	Most in underground shelter will survive not only from radiation but from blast and thermal effects
The living will envy the dead	Life for survivors will be dismal at first but preparation will lead to more rapid recovery
An epidemic of cancer will be seen in survivors	Cumulative radiation-induced cancer risk will increase in survivors by only a few percent of population over a 50-year period
All radiation exposures are harmful	Exposures to < 1 Gy may result in improved health and longer lifespan due to hormesis

Table 5. Myths and facts about surviving nuclear war.

FEMA had actively promoted CRP as a method to move these more vulnerable populations prior to a war. The current goal of CRP is 80% survival of the U.S. population following a 6559 MT attack on the U.S.; according to this scenario, 45 million Americans would die. During the initial phase of CRP, 150 million people would be expected to travel from 50 to 300 miles to designated low-risk areas. They will join about 75 million, totaling a shelter population of 195 million. For some the concept of CRP is flawed, unworkable and dishonest, being in itself a significant threat to instigating a war since its implementation would be a sign to an enemy that we are preparing to fight a total nuclear war. To others it is common sense that we should plan for all contingencies. No one disagrees that to achieve 80% U.S. survival will require several days to carry out evacuation and a whole lot more preparation, organization and staffing than now exists. Richard Beal, former director for crisis management systems and planning under President Reagan believes that "national security planning is a myth" because information uncertainty is the normal course in a crisis, and that no one has devised a reliable system for tracking the implementation of presidential decisions in crises. The current White House executives have little or no experience with previous crises, making it very difficult to swiftly and accurately analyze crises using available intelligence and information.

Some experts believe that civil defense will have no effect on initiation or outcome of a nuclear war. Lauriston Taylor wrote: Nobody in his right mind believes that a nuclear war can be won by anyone-civil defense or no civil defense. No worse tragedy can befall man. Unfortunately, the worst situation that can be computed today, involving a maximum mutual attack by two opponents, will not

destroy man, in spite of all the nonsense that has been written to the contrary...On the basis of the worst double attack scenario that can be visualized today, it is anticipated that about 80% of the U.S. population would die within 30 days of the attack. That means that 20% will be left in survivable condition...in varying degrees of distress, almost beyond our imagination to comprehend. Incidentally, this is almost exactly the American population just 100 years ago...Civil defense is in no sense a preparation for war. The existence or nonexistence of civil defense preparations by any party to nuclear war will have no influence on such a war coming about [27]. Paradoxically, it was Taylor who received an accidental whole-body exposure of 10 Gy and believed that 2 mGy/d (730 mGy/y) was safe, while living to 102 years (Chapter 1). Nevertheless, Taylor had gotten taken up by doomsday frenzy.

During the Cold War the U.S. was wanting to exaggerate the effects of nuclear weapons testing to deter the U.S.S.R. from nuclear expansion and other countries from developing nuclear weapons. The U.S.S.R. did the same exaggeration when they had achieved the same capability as the U.S., emphasizing that there would be no winners in a nuclear war. Their motivation was not to prevent radiation harm to its population but was political to discourage others to develop nuclear weapons.

Exaggerations of the effects of nuclear war will paralyze us. We could accomplish much for so little, spending only 1% of our defense budget on civil defense. The U.S. has carried out little public education on how to survive nuclear war. In contrast, the U.S.S.R. had carried out an extensive educational program for all its citizens on how to survive a nuclear war. Its citizens are instructed on how to construct a simple, underground trench shelter in less than a day. The Soviets had a highly organized civil defense program, with planned for evacuation of cities, construction of underground shelters for some of their industries and for governmental personnel. Civil defense in the Soviet Union was part of everyday life as well as a propaganda tool. In peacetime, the U.S.S.R. civil defense program employed 115,000 people under military control; this could be rapidly expanded during wartime to 15,000,000. The first priority of Soviet civil defense is the survival of its political leaders. Because of this emphasis, part of U.S. strategy was to target Soviet leaders. The CIA predicted 25-35 million deaths in the U.S.S.R. if they had less than a week to evacuate their cities prior to total nuclear war with the U.S., and 100 million deaths if no warning was given [28]. Only 10 million Soviets would die in total war with the U.S. if given 7-10 days for total evacuation and preparation [29].

In general, Europeans have in the past taken a much more serious and professional view about civil defense than do Americans. American shelters are often considered socially divisive, even though Americans are the most heavily insured people in the world. The reality is that Europeans believe with much justification that simple shelters are remarkably effective in protecting from the effects of nuclear weapons. European countries have extensive civil defense programs. Before 1990 in Switzerland, nearly two-thirds of their population had been provided shelter protection; by 1990, all their population was sheltered. Civil defense training is compulsory for all Swedes with significant support from volunteer agencies [30].

Dirty Bomb

Several internet articles appeared on December 21, 2016, concerning Congress and the firing of a top DOE scientist by the Obama administration to advance climate change plans [86-87]. That scientist was Dr. Noelle Metting, a former graduate student at the University of Washington/Tri-Cities campus in Richland, WA. Noelle was a student in my Radiobiology class about 35 years

ago, followed with a PhD from Harvard University. Dr. Metting went to work for DOE and in 2000 became program leader and senior radiation biologist for the Low Dose Radiation Research Program (LDDRP) which sponsored research on the biological effects of low dose ionizing radiation. LDRRP concentrated on biological effects at doses that were less than 100 mGy. LDRRP had an annual budget from 1999 to 2015 of 15-20 million dollars. Sponsored researchers published over 700 papers during this time. The Million Man study and the Fukushima study showed preliminary results indicating fewer than expected cancers than the unexposed control groups at doses <100 mGy. Both programs had 4-5 more years until completion. The programs were terminated in 2015, and the funding given for climate change research.

In 2014 Congress introduced the Low Dose Radiation Act to help regulate the program. In a October, 2014 briefing with the U.S. House of Representatives Committee on Science, Space & Technology (Lamar Smith, Chairman) the committee was briefed by senior DOE staff and by Dr. Metting. Less than a month later the Obama administration officials had 'removed' Dr. Metting from federal service for providing too much information in response to questions by the committee. She was dismissed from DOE on May, 2015, whereupon she appealed and was subsequently reinstated. Dr. Metting plans on retiring from DOE in 2017. The Congressional committee filed misconduct charges against DOE [88].

The charges against Dr. Metting by DOE were insubordinate defiance of authority for not communicating the department's management positions and for inappropriate workplace communication during discussions of funding and policy in her presentation before Congress; that is, she did not censor information nor give only the DOE's talking points.

The House committee conclusions were that: Instead of providing the type of scientific information needed by Congress to legislate effectively, senior department officials sought to hide information, lobbied against legislation, and retaliated against a scientist for being forthcoming. The report went on to say that: DOE management worked to kill LDRRP because it did not further the administration's goals to advance climate research. DOE deliberately withheld information from Congress and removed an agency scientist from federal service for providing complete answers to committee staff with respect to the LDRRP and H.R. 544, the Low Dose Radiation Research Act of 2014.

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Table 1 – Protective Action Guides for RDD and IND Incidents

Phase	Protective action recommendation	Protective action guide
Early	Sheltering or evacuation of public [a]	1- 5 rem (.01-.05 Sv) projected dose
Intermediate	Relocation of public	2 rem (.02 Sv) projected dose 1st year, subsequent 0.5 rem/yr (.005 Sv/yr)

Figure 7. Department of Homeland Security, Federal Emergency Management Agency. August 1, 2008. Planning guidance for protection and recovery following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) incidents.

In questioning DOE staff about the LNT and possible health benefits from LDR, the staff claimed either ignorance or they did not know. One senior DOE staff member in response to a committee question stated that DOE: have not been able to resolve a threshold level of radiation that does not cause cancer, ignoring clear evidence of thresholds and radiation hormesis in LDRRP publications.

The trigger radiation doses of 10-50 mGy for public sheltering, evacuation and relocation were demonstrated to be beneficial in many of the former DOE, LDRRP studies (Figure 7). In addition the use of the LNT assumption to predict health risk was shown to be inappropriate. The current RDD and IND dose guides will produce radio-phobia hysteria and loss of life, particularly when applied to forced evacuation orders following the nefarious use of a dirty bomb, also called a radiation dispersal device.

Dirty radionuclide-containing bombs are what you may choose to build if you're unable to create a real nuclear bomb. A dirty bomb contains a conventional chemical explosive salted with radioactive isotopes in order to spew out that nuclear material and contaminate a wide area. There is little or no military usefulness of such devices. The chemical explosive in such a bomb is quite likely to be more dangerous than the radioactive material. A dirty bomb is much easier to build than a nuclear bomb. The radiation associated with a dirty bomb is unlikely to kill anyone but would set off Geiger counters that would terrify a whole city. It is only useful as a terror weapon because radiation protection agencies believe in the LNT and ignore radiation hormesis. The low dose levels of radiation associated with a dirty bomb are more likely to save and prolong lives. Folk should make personal decisions in case of radiological terrorism rather than depending upon radio-phobic, radiation protection professionals [51].

Dirty bombs elicit mass fear reaction. Dirty bombs are weapons of mass disruption, not destruction. The cost of decontamination of a region in a large city would be very high when using the LNT, if to the levels suggested by the EPA, ICRP and NCRP. Thus, dirty bombs become economic bombs, a political weapon, not a military weapon. The reality of nuclear terrorism, using current EPA and ICRP radiation standards, is that a tiny dirty bomb explosion in an American city would cause the evacuation of tens to hundreds of thousands of people. In response to this potential issue, EPA raised its historical radiation limit 350-fold to 50 mGy for a one-time event.

There is a strong incentive for radiological terrorism. What do you think would happen if a terrorist detonated a dirty bomb spewing gamma ray emitting radio-cesium or radio-cobalt over many square blocks of the financial district of New York City? Radio-phobia would cause panic and government regulators would issue evacuation orders and the center of the American economy would be in shut down mode. For example, President Obama recommended evacuating all American military personnel within 50 miles of the Fukushima reactor in Japan. The fact is that many of the most contaminated areas of New York City would be turned into potential health zones where therapeutic cumulative doses of less than 500 mGy may be given.

Stolen radioactive material can be used by terrorists to make a RDD (Radiological Dispersive Device). Chechen terrorists in 1995 placed a small amount of Cs-137 in Moscow’s Izmaylorsky Park only as a psychological weapon. In 1998 and 1999 Chechen militants were not successful in detonating a radioactive bomb in a land mine. Old discarded radiotherapy units containing undispersed cesium-137 or cobalt-60 that emit high energy gamma rays, can have lethal effects.

In 1987, a junk dealer in Goiania, Brazil, opened an abandoned radiation therapy source which contained about three ounces of Cs-137 (chloride) powder. About 250 persons were contaminated of which four died from acute radiation sickness. They were attracted to the therapy unit because it emitted a blue glow. In 1961 some Mexican boys played with a discarded cobalt-60 medical therapy source; four died from radiation sickness.

In the 1970s mobile radiation sources containing cesium-137 were used in Russia to stimulate plant growth and grain production. Recently, ten of these old 'Gamma Kolos Fractors' were found in Georgia, Moldavia and the Ukraine. The radiation sources had partial shielding and were housed in secret storage. About 900 small Russian electric generators (mobile nuclear power plants in titanium-ceramic containers about one cubic foot in size) were used for radio-transmission in lighthouses in remote areas; fewer than 30 have been found [45]. . No one has ever exploded a dirty bomb in anger, but there has been at least one close call. In November 1995, a security alert in Moscow unearthed a package of radioactive material, wired with explosives. The Russian authorities kept the incident from the public.

The evidence suggests up to 200 times our background radiation would be optimal for health. Predictably, over 90% of the exposed survivors of a dirty bomb will have beneficial, or no detectable harmful or beneficial effects from ionizing radiation. This is the crux of triage for dirty bombs. Persons who receive low-dose irradiation become healthier and live longer than non-irradiated persons [44]. Delivery methods could also include detonation of a 'smoky bomb' in a confined space or insecticide sprayer on a truck to disperse polonium-210 dissolved in water. The death of a Soviet spy, Alexander Litvinenko, resulted from a very high concentration of Po-210 in his tea [79].

A very small amount of radioactive material turns into a weapon with psychological and economic impact because of radio-phobia. A dirty bomb is a radiological weapon whose purpose is to contaminate and disrupt rather than destroy. It's ultimately a pure terror weapon.

Unexpected Resources

Nuclear warheads have become emblems of national power and place in the international community. Most industrial nations have considered acquiring nuclear weapons and surely many have secretly developed simulations and efficient pathways to rapidly build them following significant provocation. Both South Korea and Japan, surrounded by the potentially belligerent countries of China and North Korea, must have made plans and simulations. We are not distant in space or time from nuclear war. There is no evidence in history where a country who thought they had a military advantage did not eventually use it for their advantage. To this we add terrorist groups who may use nuclear weapons to promote their agendas and theological ideologies. The U.S.S.R. invasion of Afghanistan, the Cuban missile crisis, the shooting down of a Korean airliner by the Soviets, and a NATO field exercise each came close to triggering a full nuclear war. The belief that man's goodness or common sense will prevent nuclear war is utter foolishness. There is no historical evidence to support this notion. As long as any state has nuclear weapons, others will seek to acquire them. Those who have nuclear weapons for security reasons do not want others to have them for their security reasons. The containment of nuclear proliferation will continue to be an illusion since the hypocrisy of the 'haves' is monumental. The historical conclusion is that the use of nuclear weapons by nations or terrorists is inevitable.

What are the odds that the world will experience a nuclear war, either limited or total? Most agree that nuclear war is unthinkable. Then why do most experts believe that it will happen or that it is inevitable? The human race is rushing toward its suicide. The events of history hardly justifies any other conclusion. Since 650 B.C., there have been 1,656 arms races; all but 16 of them have ended in war, with these 16 countries ending in economic collapse before war could occur. In the 20th century alone, 140 million people have perished as a result of war and its aftermath. There are only 12 nations in the entire world who have not been involved in war since 1945. In 1986, the world's total standing armies amounted to 32,000,000 persons with 570,000,000 reserves. It is sheer fantasy to believe that governments will yield their power and authority to more responsible people.

About 100 of the world's governments are ruled by some form of totalitarianism and pragmatism, having limited political constraints. Muslim terrorists and a few Islamic nations may be motivated to obtain atomic weapons for theological purposes to bring on the twelfth Iman by world conflagration. Nuclear weapons have been around for 65 years since World War II, giving us a dangerous illusion that there is permanence in their deterrence and non-use. Political instability results from highly accurate nuclear-tipped missiles, multiple methods of delivery, decision-periods of a few minutes, hair-trigger readiness and the use of computers to sort out the spurious from the real.

Writers of fiction allude to the development of nuclear weapons. Theodor Seuss Geisel in The Butter Battle Book, writes a pictorial parable of the nuclear arms race with an ambiguous ending. The Yooks and the Zooks are enemies because the Zooks eat their bread with the down side buttered while the Yooks keep their buttered side up. The trouble begins when a Zook uses a slingshot against the Yook's best weapon, a Snick-Berry switch. A rapid arms escalation ensues, until inevitably they both come up with the Bomb, the Bitsy Big-Boy Boomeroo. At the end there is a confrontation at the wall separating the two countries. Each is holding a pink hand-sized bomb that can obliterate the other, while a Yook grandson is watching. As the last page reads in its entirety: "Grandpa! I shouted. 'Be careful! Oh, gee! Who's going to drop it? Will you...Or will he?' 'Be patient, said grandpa. We'll see. We'll see' ".

In Milton's, Paradise Lost, Adam is told by the angel Raphael about an 'absolute weapon' that the angels loyal to God had used against Satan and his followers in Heaven's civil war after the Fall. The weapon is so powerful, according to Milton, that it "tears the seated hills of Heaven from their roots". Unfortunately, the absolute weapon is captured by Satan and turned against heaven. If it were not for the intervention of the Deity, Paradise itself would have been destroyed. Raphael predicts that the absolute weapon would appear among men "in future days, if malice should abound". H.G. Wells in The World Set Free (1912), described a war where most of the world's capitals were consumed in fire from a new type of bomb. Millions of people were killed and all forms of government came to a virtual end. Wells wrote of how ‘a man could carry about in a handbag an amount of latent energy sufficient to wreck half a city’. Wells said: …the liberation of atomic energy on a large scale for industrial purposes, the development of atomic bombs, and a world war which was apparently fought by an alliance of England, France and perhaps including America, against Germany and Austria, the powers located in the central part of Europe. He placed this war in 1956, during which the major cities of the world would all be destroyed by atomic bombs.

The Bible is comprised of 66 Books, 39 Books in the Old Testament and 27 Books in the New Testament. Despite the disbelief of most scientists and politicians, the Bible does contain

descriptions of nuclear physics and nuclear war. The end time battle described in the book of Revelation speaks of cataclysmic judgments and battles that kill at least another order of magnitude more people on the earth than occurred in WW II. In this final war preceding the coming of Jesus Christ, billions will die [50]. The writer (John) of Revelation wrote about 21st century events using 1st century vocabulary. Even so the biblical events are easily understood using modern vocabulary of nuclear physics and warfare.

The heavens and earth have been 'stored for fire' for a time when the 'elements will be dissolved' (melt, split) with fire (2 Peter 3:10-13). The Greek word for element, *stoicheion*, means a basic unit of matter. The text describes quite concisely fission with a release of atomic nuclear binding energy, in anticipation of the creation of a new heaven and a new earth. It is God who holds each atom in the universe together by binding energy (Colossians 1:17) [48].

A great, powerful weapon will destroy and kill throughout the whole earth, something that has never happened before in the history of the world (Revelation 6:3-4; Isaiah 54:16). Pillars of smoke will be seen (Joel 2:30). The entire world will be involved with cataclysmic events. One of the last battles of time will last for only one day but its effects will remain for seven years (Ezekiel 39:1-16). The battle will be preceded by thirty minutes of silence following the opening of seventh seal (Revelation 8:1; 18:10, 19).

The prompt effects of nuclear detonations include a blast or shock wave, an initial pulse of gamma rays and neutrons and a pulse of thermal or heat energy. Later effects are due to fallout of radioactive fission products and induced radioactive material. A description given by John Hersey in his book, Hiroshima: There were about 20 men...all in exactly the same nightmarish state: Their faces were wholly burned, their eye sockets were hollow, the fluid from their melted eyes had run down their cheeks...their mouths were mere swollen, pus-covered wounds, which they could not bear to stretch enough to admit the spout of a teapot. These thermal effects are also described in the Bible (Zechariah 14:12-13; Isaiah 13:8; 24:6). Shock waves from nuclear blasts will push the air apart like an unrolling scroll (Revelation 6:12-14; Isaiah 34:1-4).

The slaughter will be so great that sufficient people will not be alive or available to bury the dead before they decomposed into skeletons (Jeremiah 25:31-33; 30:24; Psalm 110:5-6). Smoke and dust will turn the sun into darkness (Acts 2:16-21; Revelation 6:12; Joel 2:30-31). The dead will not be buried until a wait of seven months (Ezekiel 39:12-15). He (John) describes how a third of mankind is killed by a 'vehicle' possibly like ICBMs with multiple heads (Revelation 9:17-19) [48].

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