An Epistemology of Nuclear Weapons Effects

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Nuclear war has been called unthinkable, and thus we may have suspected it is also unknowable. If it cannot be known, then it can be more easily dismissed from conscious concern. It may haunt our dreams and our art. It may exert a powerful pervasive influence on the values and psychology of our culture. But, believing it is unknowable, we have remained ignorant while its threat has grown year by year and day by day. So it is important that we learn something about nuclear weapons and nuclear war, and that we challenge that ignorance.

In fact, much is known about the effects of nuclear weapons. The "experiments," if we may use that word, of Hiroshima and Nagasaki contributed a great deal of information about the atomic bomb, its medical consequences and its social and human significance. In Hiroshima, a lively city of 300,000 people was turned into a desolate radioactive desert by a single 13-kiloton bomb,[1] which is relatively small by today's standards.

While we use these historical events to help us understand the effects of nuclear weapons, it is essential to remember that any use of thermonuclear weapons today will be different in several important ways. One difference is that the Hiroshima and Nagasaki bombs were fission devices with a destructive force comparable to 13,000 to 18,000 tons of TNT (trinitrotoluene). Within a few years after the war, fusion bombs—what we know as hydrogen or thermonuclear bombs—had made the atomic bomb obsolete. The hydrogen bombs, which make up most of today's arsenals, are orders of magnitude more powerful and more destructive than the atomic bombs. The world's arsenals today contain about 50,000 nuclear warheads.[2] Most strategic warheads are of greater destructive power than the Hiroshima bomb, many of them in the megaton range. A megaton is comparable to a million tons of TNT, which has been described as enough explosive to fill a freight train 200 miles long. World War II lasted for six years and claimed 50 million lives. The combined firepower exploded during that war, including the two atomic bombs dropped on Japan, equaled 3 million tons of TNT, or 3 megatons. Many of today's weapons have destructive yields as great as 10 or 20 megatons, many times the entire firepower of World War II. This is a quantitative difference so large as to be in fact a qualitative difference. These are not weapons of war, but weapons of a form of annihilation that is almost impossible to comprehend.

Even if it cannot be comprehended, annihilation of this sort can be computed. Scientific analyses of nuclear weapons and their explosions have produced a copious literature, complete with graphs, formulae and even small plastic bomb effects slide rules that predict the effects for any given set of conditions (Figure 1). There are carefully developed models from which projections can be made. In fact, the US Arms Control and Disarmament Agency has worked out the likely effects of nuclear weapons targeted at every city in the country with a population of 50,000 or more. Some smaller towns are also included depending on their strategic significance. Calculations can be adjusted for whether a device is exploded in the air, which maximizes blast effects, or on the ground, which maximizes radioactive fallout. Physical characteristics have been calculated for every possibility of yield, height of explosion, time of day, weather conditions, terrain or kinds of city buildings to be bombed.

Nuclear weapons produce many kinds of destructive effects, which fall into three main categories: heat, or thermal radiation; blast and ionizing radiation, and immediate and long-term effects. At the moment of the explosion, when the energy inherent in the binding forces between the subatomic particles in atoms of plutonium, deuterium and tritium is released in an almost instantaneous chain reaction, the bomb parts themselves are instantly gasified at a temperature in the range of 10 million degrees centigrade or more, comparable to the center of the sun. Immediately radiation, primarily in the form of gamma rays, is released as a flash of intense bluish white light visible for hundreds of miles. The fireball then begins to form, still fractions of a second from the time of the explosion, and the air absorbed by it radiates a thermal pulse—a wave of blinding light and intense heat—which is a third of the energy and destructive force of a nuclear weapon. When the fireball touches the ground, it vaporizes or incinerates everything within it. The thermal pulse lasts for about ten seconds and can cause second-degree burns to exposed human beings miles away.

Also at the moment of the explosion, pressure within

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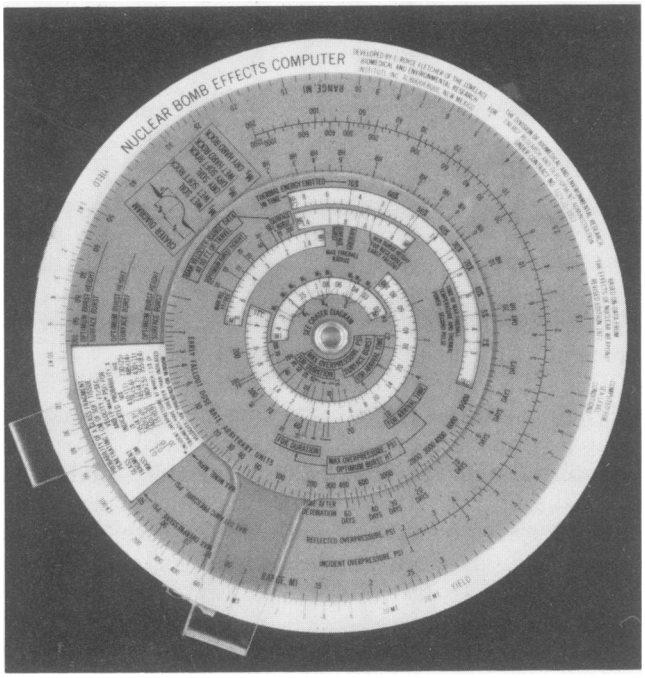


Figure 1.—The Nuclear Bomb Effects Computer, developed by the Lovelace Biomedical and Environmental Research Institute, Inc., Albuquerque (from Glasstone S, Dolan PT[8]).

the gaseous space is millions of times atmospheric pressure. A fusion bomb essentially duplicates the mechanism by which the sun's radiant energy is produced. It is confined initially into a very small space and generates enormous explosive pressure. As the fireball expands (to a mile in diameter for 1 megaton) this pressure is transmitted to far beyond the limits of the fireball in a blast wave, which is the major immediate destructive force of a nuclear weapon.

What, then, do we know about the effects of these phenomena on human beings? To answer this question, let us consider the example of a one-megaton airburst over Portland's Burnside Bridge. It is of course unlikely that a single nuclear weapon would be targeted at Portland—much more likely that there would be several,[3] perhaps staggered over the course of a day. Still, one must pick an arbitrary set of conditions to make the necessary calculations. This is a somewhat conservative, therefore useful, model to understand the medical realities of the use of nuclear weapons.

A Model of a Nuclear Attack

Imagine that at a specific time, perhaps during a period of increasing tension between the United States and the Soviet Union, perhaps during debates about the advisability of first-strike tactics, Portland is hit by a 1-megaton explosion eight times the destructive power of the Hiroshima bomb.*

It would produce within microseconds a dazzling white light, continuing for as long as 30 seconds. Simultaneously, a searing, silent heat flash would melt windows, cars, lamp posts and everything else within a radius of 3 miles (4.8 km), igniting everything flammable miles beyond. Within a radius of 1½ miles (2.4 km) people would be instantly vaporized or burnt into charred black corpses. Within this circle, everything would be utterly destroyed and all people would be killed.

Much like thunder follows lightning, a few seconds after the flash the blast wave would hit. Because it travels at a speed just slightly above the speed of sound, moving outwards from the explosion at 1,150 ft (350.5 m) per second, it would take about 15 seconds to reach a person standing 3 miles (4.8 km) away, or to the general vicinity of The Oregon Health Sciences University.

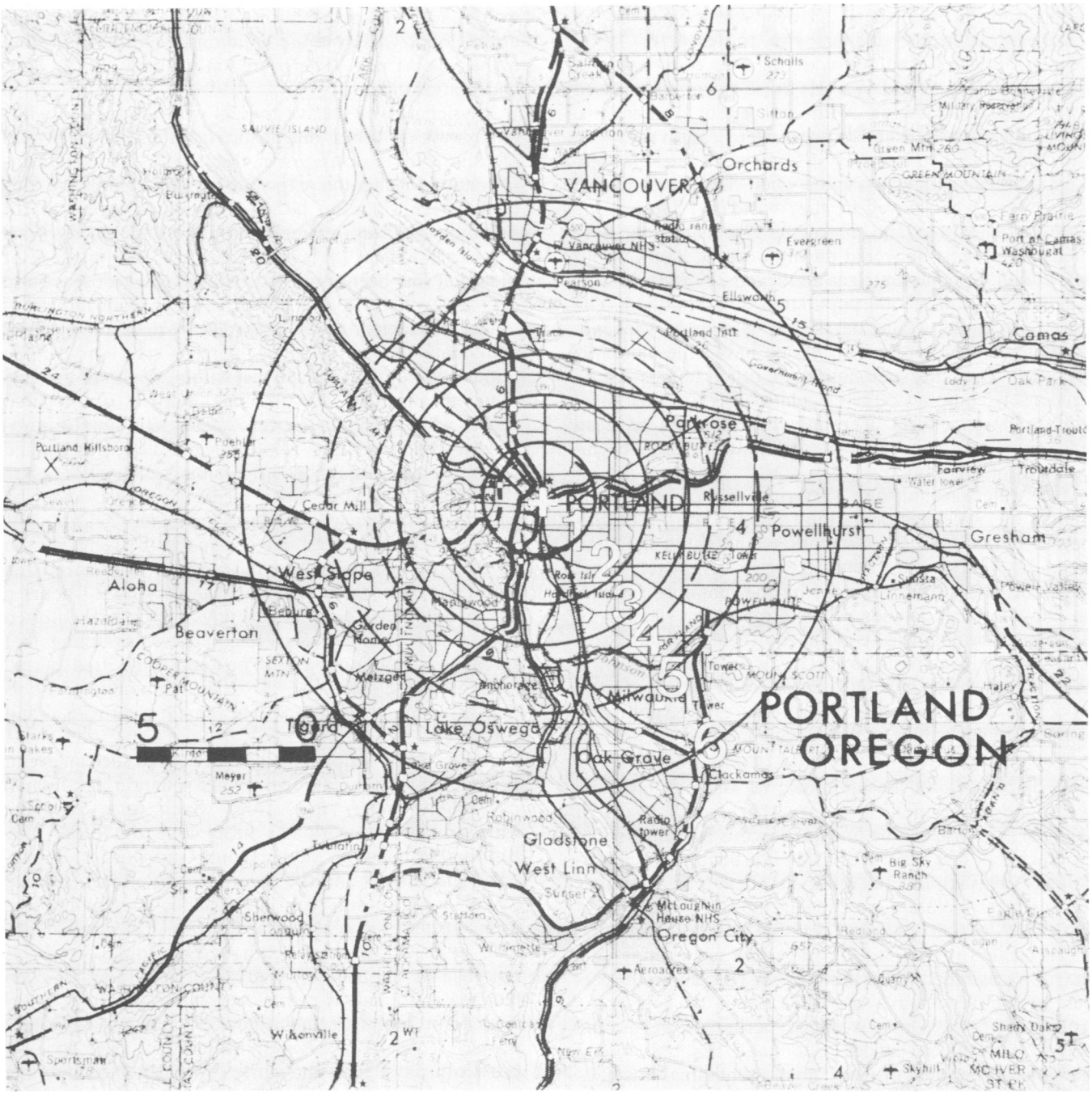
The pressure of the blast is measured in pounds per square inch (psi) above the atmospheric pressure. At two to three miles (3.2 to 4.8 km) from ground zero, the overpressure would be 9 psi, which is enough to flatten most buildings and cause lung hemorrhage and rupture in many exposed persons. Only seconds after the shock front passes, leaving a trail of destroyed buildings, uprooted trees and broken bodies, it would be followed by a reverse or negative-pressure phase. The combined effect of these two pressure phases would be first to squeeze or implode and then to expand or explode structures and human tissues. Winds in the range of 300 mph (482.8 km per hour) would follow the shock waves, causing additional damage by hurling debris, including broken glass, metal and human beings themselves through the air.

At Lewis and Clark College, we would see the flash—those looking directly at it being instantly blinded—but we would not feel a thing . . . for 20 seconds. When the shock wave hits it would be accompanied by winds strong enough to kill people by flinging them into nearby objects. High temperatures would continue to inflict third-degree burns on all those exposed. While these things are happening, the fireball would continue to burn in the sky. Soon, huge thick clouds of dust and smoke would darken the air as the mushroom cloud is sucked in and rises into the atmosphere. The darkness would be similar to that experienced by the victims of Mount St Helens' first eruption. Within one minute, in Gresham and Oregon City windows would shatter and roofs would be torn off houses. Damaged oil and gasoline tanks would fuel spreading fires.

As happened at Hiroshima, the individual fires would coalesce into a mass of fire, driven by the violent and turbulent winds, which would either become a fire storm or a conflagration—depending on the nature of the winds.[4] In a conflagration, prevailing winds spread a wall of fire as far as there is any combustible material to sustain it. In a fire storm, a vertical updraft caused by the fire itself sucks the surrounding air in toward a central point, and the fires converge in extreme heat, in the range of thousands of degrees, burning for days. A fire storm can increase the size of the lethal area five times.[5]

In either case, shelters would become death traps

*This format was developed and used by H. Jack Geiger, MD, in Physicians for Social Responsibility symposia in many different cities.



Circle	Radius	Atmospheric Conditions	Effects
+	Ground zero		
1	1½ miles	20 psi overpressures	All life and buildings pulverized.
2	3 miles	9 psi, winds 260 mph	Lung hemorrhage, third-degree burns.
3	4 miles	5 psi, winds 160 mph	Brick and frame houses destroyed, ear drums rupture.
4	5 miles	4 psi, 25 cal/sq cm	Spontaneous ignition of clothing and combustibles, fire storms likely, 50 percent of the people dead.
5	6 miles	3 psi, 12 cal/sq cm	Third-degree burns of all exposed skin, multiple trauma and lacerations.
6	8½ miles	2 psi	Exposed people burned and blinded by flash, all windows broken, second-degree burns, trauma.

Scale: 5 0 = 5 miles to ground zero.

Abbreviations: psi = pounds per square inch; cal/sq cm = calories per square centimeter.

Figure 2.—Area of Portland and surrounds that would be affected by a 1-megaton nuclear weapon air burst over Burnside Bridge.

because the fires consume all available oxygen as the temperatures in the shelters rise to levels of 1,500 degrees, roasting and asphyxiating the occupants. In Dresden during World War II, a fire storm was caused by intensive bombing with conventional weapons. The only persons who survived were those who fled their shelters.[6] The interiors of some of the shelters were so superheated that days later when they were opened and oxygen was allowed in, they burst into flame.

For greater Portland, it can be calculated that a 1-megaton airburst delivered during working hours would kill 466,000 people outright and leave 247,000 seriously injured out of a total population of 1.2 million. The initial casualties would be slightly less on a weekend. And, remember, present scenarios have cities multiply targeted. The later detonation of other bombs would immensely complicate the calculations of the blast, heat and radiation effects. Certainly the numbers of dead and injured and the area of devastation would be increased considerably.

For miles around the surviving injured would lie amidst the wreckage, suffering from second- and third-degree burns, fractures, lacerations and acute radiation sickness. Many would be partially or completely blind from the retinal burns caused by the luminous fireball. In the Marshall Islands when atmospheric testing of hydrogen bombs was conducted, focal retinal burns were found in animals as far away as 300 miles from the site of the explosion.[7] In addition, many people would be deaf. Threshold overpressures for rupture of tympanic membranes is 5 psi, which would occur anywhere within five miles of ground zero.[8]

Perhaps it would be optimistic to assume that there would be no further retaliatory strikes. What sort of medical response can be imagined in this awesome scene of blackness and destruction? In Portland, as in Hiroshima, Nagasaki and any other city, health professionals and medical facilities are concentrated in the center of the city. A major difference between this strike and that of Hiroshima is that in 1945 they had no warning. We may have as much as 30 minutes. In Hiroshima 90 percent of the physicians were killed within the first hours or day.[1(pp503-513)] On a weekend perhaps fewer would perish in the initial stages. But major hospitals would be gone. The one or two small remaining hospitals would be overwhelmed with tens of thousands of the dumbstruck, ambulatory injured who would find their way there. No transportation would exist to move the wounded through what streets could even be found.

"Imagine the familiar landscape turning suddenly into a sea of destruction: Everywhere smoldering banks of debris; everywhere the sights and sounds and smells of death. Imagine that the other survivors are wandering about with bleeding wounds, broken limbs, and bodies so badly burned that their features appear to be melting and their flesh is peeling away in great raw folds" (Lifton RJ, Erickson K: Nuclear war's effect on the mind. *New York Times,* March 15, 1982, p 14). The major immediate life-threatening injuries would be severe burns—tens of thousands of cases—which would overwhelm the burn treatment facilities of the entire country even in the ludicrous event that Portland alone was struck. There are only about 2,000 burn beds nationwide.

Physicians would have to deal with the injured without x-ray or other diagnostic facilities. They would face impossible decisions of triage with inadequate information. Radiation exposure would complicate this dilemma enormously, because the initial symptoms of radiation sickness—namely vomiting and bloody diarrhea—are almost the same regardless of what dose of radiation has been absorbed. At very high doses, those exposed would die in a matter of days from radiation-induced encephalopathy, preceded by delirium, seizures and coma. At lesser levels, persons may survive the initial symptoms, only to die within weeks of hemorrhage or infection due to bone marrow suppression. Some, who might have been saved with simple intravenous fluid therapy, would die of dehydration and shock. It will be almost impossible to know for sure who might survive, if given medical support, and who will die no matter what is done for them.

Sidel and associates[9] have calculated, using Boston as their model, that surviving doctors who spend ten minutes with each injured patient, working 20 hours a day, would need eight to ten days to see each injured person just once for only ten minutes, assuming that somehow the injured could be found and transported to a protected location.[9(p1139)] The assumption also is that surviving physicians would remain clearheaded and competent.

Again, we have not actually experienced such an event. But we have a great deal of information on human psychology under stress from which to extrapolate. Much important work has been done by Robert Jay Lifton in studies of atomic bomb survivors in Japan. "The suddenness and the sheer ferocity of such a scene would not give survivors any chance to mobilize the usual forms of psychological defense. The normal human response to mass death and profound horror is not rage or depression or panic or mourning or even fear: It is a kind of mental anesthetization that interferes with both judgment and compassion for other people" (*New York Times,* March 15, 1982, p 14). Certainly physicians and nurses would not be immune to this psychological devastation.

Here I must mention yet another major difference between nuclear attacks in the 1980s and those of 1945. The cities of Hiroshima and Nagasaki within days began to receive help from the outside world. The probability of nuclear war today remaining "limited" is quite small.[10] We cannot in our scenarios assume that there will be an outside world in any meaningful sense. Survivors will struggle in a meager and poisonous world in which everything that once mattered to them has been destroyed.

If areas to the south of Portland (such as Salem) were spared from an initial attack, I find it hard to imagine that doctors, nurses and emergency relief workers would come streaming northwards toward the

smoking remains of Portland. Even if they did, they would soon encounter thousands of dazed and injured refugees. There would certainly be enough of these people to quickly overwhelm the physical and psychological capabilities of the rural towns.

All of these projections assume that the physicians and nurses who survive would be willing to risk significant radiation exposure to help the wounded. Indeed, what is the ethical obligation of our profession in this nightmarish situation? Even to refer to scattered and confused persons as a "profession" is absurd in this setting. Would it not seem more important to doctors and nurses to be with their families—or to seek them in the rubble? Should physicians seek shelter in outlying areas where shelters may offer a chance of prolonging survival to some degree? Physicians claiming—as some have[11]—to be saving themselves and their skills, are also thereby negating the value of those skills, because while inside the shelter they can be of no use to those tens of thousands who are suffering and dying without comfort on the charred surface of the earth.

If some physicians and nurses of extraordinary altruism, or simply obsessively patterned behavior, were to set about to care for the injured, what would be the objectives of treatment? What could be done? It appears the most important medication would be narcotics to ease the pain of the dying, and yet these are not among the drugs stocked even in government shelters.[9(p1140)] Blood products, antibiotics and cardiovascular drugs would all be scarce or nonexistent. Diabetic persons would all finally die because there would be no insulin. The data can only lead to one conclusion: Beyond simple human solace, there can be no meaningful medical response in a nuclear war.

What about the fate of those who were in outlying areas where it may be possible to shelter oneself from the immediate effects? They would have to stay in those shelters for weeks before radiation levels allowed emergence for more than just a few minutes. Have provisions been made to treat those in whom acute radiation sickness develops once inside the shelter? How does one deal with severe protracted vomiting and copious bloody diarrhea in such a confined space? If there are deaths, and there will be, is it worth the risk of radiation exposure to remove corpses from the shelters?

Simple sanitation becomes impossible. Water would be a scarce resource. In the postattack period, survivors would be fortunate to have as much as the quart a day necessary for biologic survival. And there would be no guarantees that such water would be uncontaminated.

For those who emerge from their shelters, disposal of hundreds of thousands of human and animal corpses would be an unnerving and probably impossible task. A report by the Office of Civil Defense Mobilization states: "It is logical to assume that most combustibles as well as the dead on the surface within a 10 or 11 mile radius . . . will be either vaporized or incinerated through the resultant firestorm. . . . Intense radiation will prevent little more than heroic rescue in the 10 to 20 mile zone for several weeks. What cadavers might be recovered are those on the fringe of this area and upwind."[12]

This creates a situation that is ideal for the epidemic spread of infectious disease. Insects and bacteria are more radioresistant than humans, and will multiply easily in the wasteland of decomposing bodies. Radiation-induced immunosuppression among survivors will render them even more susceptible to infection. The lack of any organized social systems precludes anything resembling public health efforts. Abrams and Von Kaenel[13] synthesized the results of seven major studies to conclude that typhoid, dysentery (bacterial and viral), measles, hepatitis, plague and other infections are likely to kill at least 25 percent of those who survive the postattack period.

Finally, there are effects of nuclear weapons that call into question the survival of the earth itself as we know it. The National Academy of Sciences report of 1975[14] summarizes previous studies pointing to a consideration that makes survival a species question rather than an individual one. Megaton-range thermonuclear bombs release oxides of nitrogen into the stratosphere where they would promote the conversion of ozone into molecular oxygen. The ozone layer filters the ultraviolet rays of the sun, making it possible for humans to be exposed to the sun without incurring severe skin burns, blindness or—under milder conditions of ozone depletion—increased risk of skin cancer. The 10,000-megaton model used by the National Academy of Sciences projects a 50 percent depletion of ozone in the northern hemisphere and a 30 percent depletion in the southern hemisphere. Under these conditions it would be unsafe to be unprotected for more than 20 to 40 minutes. All mammalian eyes are at risk of blindness under such conditions—an eventuality that would mean utter and complete destruction of the ecosystem, for wild animals cannot survive without sight. Thermal alteration of the upper atmosphere could lead to global temperature shifts. The peak depletion of the ozone layer does not occur until well into the first-point attack year, and recovery could not be expected for at least six to eight years.

Nuclear weapons thus not only kill directly and violently but also kill indirectly and persistently by destroying the ecologic and social systems on which our individual lives depend.

Summary

To conclude, I want not to add still more to this analysis of horror, but to reflect on the significance of this kind of knowledge. All of what I have described is based on projections and probabilities. Some are open to more dispute than others, but all are attempts to use our extensive theorizing capabilities, together with the evidence of the use of nuclear weapons in war and in testing, to describe a range of probabilities for the unimaginable. With the expertise of physicists, physicians,

political analysts and others, we can construct possible scenarios—some of which you have just heard. Calculations may differ somewhat; some may prefer the 6,559-megaton model of the Federal Emergency Management Agency,[15] while others find the 10,000-megaton model of the National Academy of Sciences more credible. Population centers or industrial and military installations may be primary targets (with the understanding that there is significant overlap). Missiles as yet untested under actual war conditions may be more or less accurate. The rate and extent of ozone depletion varies depending on how many of the various-sized weapons are used in a given model. Weather conditions determine the characteristics of fallout distribution.

Much debate goes on today about such projections and even the facts on which they are based. As a physician I can only conclude that it is essentially irresponsible to point to those debates in supporting a claim of ignorance. We do not know it all, but we know all we need to know. For if any of what has been described as probable is even remotely possible, then there is no political reason on earth that can morally justify the continued uncontrolled existence of these weapons.

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