# Chapter II A NUCLEAR WEAPON OVER DETROIT OR LENINGRAD: A TUTORIAL ON THE EFFECTS OF NUCLEAR WEAPONS

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Chapter II

# A NUCLEAR WEAPON OVER DETROIT OR LENINGRAD: A TUTORIAL ON THE EFFECTS OF NUCLEAR WEAPONS

### INTRODUCTION

This chapter presents a brief description of the major effects of nuclear explosions on the people and structures in urban areas. The details of such effects would vary according to weapons design, the exact geographical layout of the target area, the materials and methods used for construction in the target area, and the weather (especially the amount of moisture in the atmosphere). Thus, the reader should bear in mind that the statements below are essentially generalizations, which are subject to a substantial range of variation and uncertainty.

To convey some sense of the actual effects of large nuclear explosions on urban areas, the potential impact of explosions is described in two real cities—Detroit and Leningrad. To show how these effects vary with the size of the weapon, the effects have been calculated in each city for a variety of weapon sizes.

The descriptions and analysis assume that there is no damage elsewhere in the country. This may appear unlikely, and in the case of a surface burst it is certainly wrong, since a surface burst would generate fallout that would cause casualties elsewhere. However, isolating the effects on a single city allows the setting forth in clear terms of the direct and immediate effects of nuclear explosions. The result is a kind of tutorial in nuclear effects. Subsequent sections of this report, which deal with the effects of larger attacks, discuss the indirect effects of fallout and of economic and social disruption.

Although it is outside the scope of a discussion of "nuclear war," there has been considerable public interest in the effects of a nuclear explosion that a terrorist group might succeed in setting off in an urban area. Accordingly, a discussion of this possibility y is added at the end of this chapter.

## GENERAL DESCRIPTION OF EFFECTS

The energy of a nuclear explosion is released in a number of different ways:

- an explosive blast, which is qualitatively similar to the blast from ordinary chemical explosions, but which has somewhat different effects because it is typically so much larger;
- direct nuclear radiation;
- direct thermal radiation, most of which takes the form of visible light;

- pulses of electrical and magnetic energy, called electromagnetic pulse (EM P); and
- the creation of a variety of radioactive particles, which are thrown up into the air by the force of the blast, and are called radioactive fallout when they return to Earth.

The distribution of the bomb's energy among these effects depends on its size and on

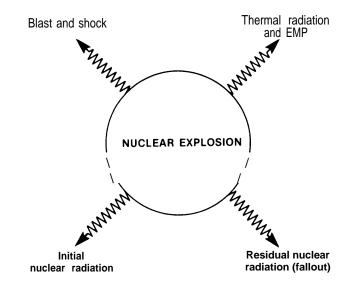
16. The Effects of Nuclear War

the details of its design, but a general description is possible.

#### Blast

Most damage to cities from large weapons comes from the explosive blast. The blast drives air away from the site of the explosion, producing sudden changes in air pressure (called static overpressure) that can crush objects, and high winds (called dynamic pressure) that can move them suddenly or knock them down. In general, large buildings are destroyed by the overpressure, while people and objects such as trees and utility poles are destoyed by the wind.

For example, consider the effects of a 1megaton (Mt) air burst on things 4 miles [6 km]



Effects of a nuclear explosion

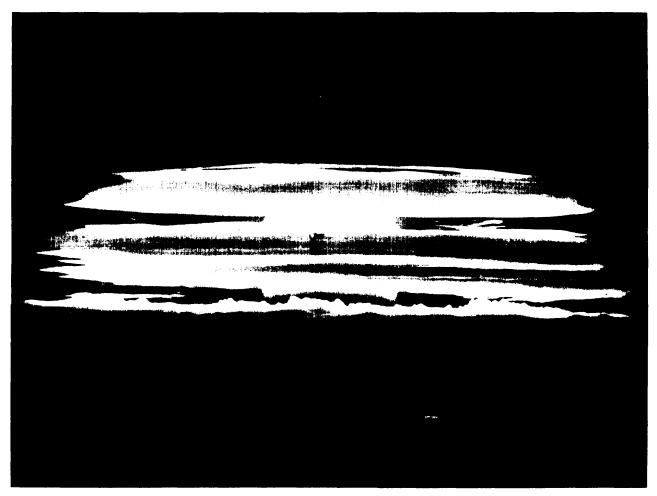


Thermonuclear ground burst

Photo credit: U S Department of Energy

away. The overpressure will be in excess of 5 pounds per square inch (psi), which will exert a force of more than 180 tons on the wall of a typical two-story house. At the same place, there would be a wind of 160 mph [255 km]; while 5 psi is not enough to crush a man, a wind of 180 mph would create fatal collisions is ions between people and nearby objects.

The magnitude of the blast effect (generally measured in pounds per square inch) diminishes with distance from the center of the explosion. It is related in a more complicated way to the height of the burst above ground level. For any given distance from the center of the explosion, there is an optimum burst height that will produce the greatest overpressure, and the greater the distance the greater the optimum burst height. As a result, a burst on the surface produces the greatest overpressure at very close ranges (which is why surface bursts are used to attack very hard, very small targets such as missile silos), but less overpressure than an air burst at somewhat longer ranges. Raising the height of the burst reduces the overpressure directly under the bomb, but widens the area at which a given smaller overpressure is produced. Thus, an attack on factories with a I-Mt weapon might use an air burst at an altitude of 8,000 feet [2,400 m], which would maximize the area (about 28 mi<sup>2</sup> [7,200 hectares]) that would receive 10 psi or more of overpressure.



Fireball from an air burst in the megaton energy range

Photo credit: U S Air Force

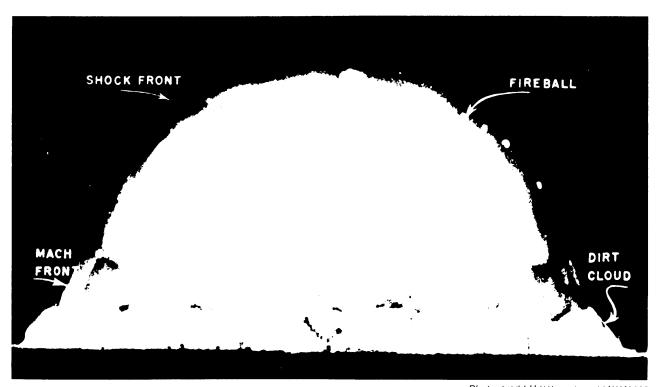


Photo credit U S Department of Detense

The faintly luminous shock front seen just ahead of the fireball soon after breakaway

Table 3 shows the ranges of overpressures and effects from such a blast.

When a nuclear weapon is detonated on or near the surface of the Earth, the blast digs out a large crater. Some of the material that used to be in the crater is deposited on the rim of the crater; the rest is carried up into the air and returns to Earth as fallout. An explosion that is farther above the Earth's surface than the radius of the fireball does not dig a crater and produces negligible immediate fallout.

For the most part, blast kills people by indirect means rather than by direct pressure. While a human body can withstand up to 30

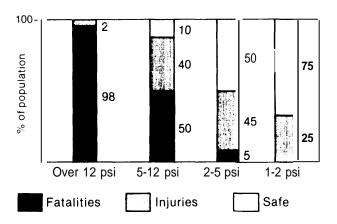
Distance from ground zero		Peak	Peak wind			
stat. miles)	(kilometers)	overpressure	velocity (mph)	Typical blast effects		
.8	1,3	20 psi	470	Reinforced concrete structures are leveled.		
3 0	48	10 psi	290	Most factories and commercial buildings are collapsed. Small wood-frame and brick residences destroyed and distributed as debris,		
4.4	7.0	5 psi	160	Lightly constructed commercial buildings and typical residences are destroyed, heavier construction is severely damaged		
5.9	95	3 psi	95	Walls of typical steel-frame buildings are blown away: severe damage to residences. Winds sufficient to kill people in the open.		
11 6	18.6	1 psi	35	Damage to structures, people endangered by flying glass and debris		

Table 3.-Blast Effects of a 1-Mt Explosion 8,000 ft Above the Earth's Surface

psi of simple overpressure, the winds associated with as little as 2 to 3 psi could be expected to blow people out of typical modern office buildings. Most blast deaths result from the collapse of occupied buildings, from people being blown into objects, or from buildings or smaller objects being blown onto or into people. Clearly, then, it is impossible to calculate with any precision how many people would be killed by a given blast—the effects would vary from building to building.

In order to estimate the number of casualties from any given explosion, it is necessary to make assumptions about the proportion of people who will be killed or injured at any given overpressure. The assumptions used in this chapter are shown in figure 1. They are relatively conservative. For example, weapons tests suggest that a typical residence will be collapsed by an overpressure of about 5 psi. People standing in such a residence have a 50percent chance of being killed by an overpressure of 3.5 psi, but people who are lying down at the moment the blast wave hits have a 50-percent chance of surviving a 7-psi overpressure. The calculations used here assume a mean lethal overpressure of 5 to 6 psi for people in residences, meaning that more than half of those whose houses are blown down on top of them will nevertheless survive. Some studies use a simpler technique: they assume that the number of people who survive in areas receiving more than 5 psi equal the number of peo-

Figure 1 .—Vulnerability of Population in Various Overpres-sure Zones



ple killed in areas receiving less than 5 psi, and hence that fatalities are equal to the number of people inside a 5-psi ring.

#### **Direct Nuclear Radiation**

Nuclear weapons inflict ionizing radiation on people, animals, and plants in two different ways. Direct radiation occurs at the time of the explosion; it can be very intense, but its range is limited. Fallout radiation is received from particles that are made radioactive by the effects of the explosion, and subsequently distributed at varying distances from the site of the blast. Fallout is discussed in a subsequent section.

For large nuclear weapons, the range of intense direct radiation is less than the range of lethal blast and thermal radiation effects. However, in the case of smaller weapons, direct radiation may be the lethal effect with the greatest range. Direct radiation did substantial damage to the residents of Hiroshima and Nagasaki.

Human response to ionizing radiation is subject to great scientific uncertainty and intense controversy. It seems likely that even small doses of radiation do some harm, To understand the effects of nuclear weapons, one must distinguish between short- and long-term effects:

• Short-Term Effects.-A dose of 600 rem within a short period of time (6 to 7 days) has a 90-percent chance of creating a fatal illness, with death occurring within a few weeks. (A rem or " roentgen-equivalentman" is a measure of biological damage: a "rad" is a measure of radiation energy absorbed; a roentgen is a measure of radiation energy; for our purposes it may be assumed that 100 roentgens produce 100 rads and 100 rem. ) The precise shape of the curve showing the death rate as a function of radiation dose is not known in the region between 300 and 600 rem, but a dose of 450 rem within a short time is estimated to create a fatal illness in half the people exposed to it; the other half would

get very sick, but would recover. A dose of 300 rem might kill about 10 percent of those exposed. A dose of 200 to 450 rem will cause a severe illness from which most people would recover; however, this illness would render people highly susceptible to other diseases or infections. A dose of so to 200 rem will cause nausea and lower resistance to other diseases, but medical treatment is not required. A dose below so rem will not cause any shortterm effects that the victim will notice, but will nevertheless do long-term damage.

Long-Term Effects.-The effects of smaller doses of radiation are long term, and measured in a statistical way. A dose of 50 rem generally produces no short-term effects; however, if a large population were exposed to so reins, somewhere between 0.4 and 2.5 percent of them would be expected to contract fatal cancer (after some years) as a result. There would also be serious genetic effects for some fraction of those exposed. Lower doses produce lower effects. There is a scientific controversy about whether any dose of radiation, however small, is really safe. Chapter V discusses the extent of the longterm effects that a nuclear attack might produce. It should be clearly understood, however, that a large nuclear war would expose the survivors, however well sheltered, to levels of radiation far greater than the U.S. Government considers safe in peacetime.

#### Thermal Radiation

Approximately 35 percent of the energy from a nuclear explosion is an intense burst of thermal radiation, i.e., heat. The effects are roughly analogous to the effect of a 2-second flash from an enormous sunlamp. Since the thermal radiation travels at the speed of light (actually a bit slower, since it is deflected by particles in the atmosphere), the flash of light and heat precedes the blast wave by several seconds, just as lightning is seen before the thunder is heard.



Photo credit U S Air force Burn injuries from nuclear blasts



Photo credit' U S Department of Defense The patient's skin is burned in a pattern corresponding to the dark portions of a kimono worn at the time of the explosion

The visible light will produce "flashblindness" in people who are looking in the direction of the explosion. Flashblindness can last for several minutes, after which recovery is total. A I-Mt explosion could cause flashblindness at distances as great as 13 miles [21 km] on a clear day, or 53 miles [85 km] on a clear night. If the flash is focused through the lens of the eye, a permanent retinal burn will result. At Hiroshima and Nagasaki, there were many cases of flashblindness, but only one case of retinal burn, among the survivors. On the other hand, anyone flashblinded while driving a car could easily cause permanent injury to himself and to others.

Skin burns result from higher intensities of light, and therefore take place closer to the point of explosion. A 1-Mt explosion can cause first-degree burns (equivalent to a bad sunburn) at distances of about 7 miles [11 km], second-degree burns (producing blisters that lead to infection if untreated, and permanent scars) at distances of about 6 miles [10 km], and third-degree burns (which destroy skin tissue) at distances of up to 5 miles [8 km]. Third-degree burns over 24 percent of the body, or second-degree burns over 30 percent of the body, will result in serious shock, and will probably prove fatal unless prompt, specialized medical care is available. The entire United States has facilities to treat 1,000 or 2,000 severe burn cases; a single nuclear weapon could produce more than 10,000.

The distance at which burns are dangerous depends heavily on weather conditions. Extensive moisture or a high concentration of particles in the air (smog) absorbs thermal radiation. Thermal radiation behaves like sunlight, so objects create shadows behind which the thermal radiation is indirect (reflected) and less intense. Some conditions, such as ice on the ground or low white clouds over clean air, can increase the range of dangerous thermal radiation.

#### Fires

The thermal radiation from a nuclear explosion can directly ignite kindling materials. In

general, ignitible materials outside the house, such as leaves or newspapers, are not surrounded by enough combustible material to generate a self-sustaining fire. Fires more likely to spread are those caused by thermal radiation passing through windows to ignite beds and overstuffed furniture inside houses. A rather substantial amount of combustible material must burn vigorously for 10 to 20 minutes before the room, or whole house, becomes inflamed. The blast wave, which arrives after most thermal energy has been expended, will have some extinguishing effect on the fires. However, studies and tests of this effect have been very contradictory, so the extent to which blast can be counted on to extinguish fire starts remains quite uncertain.

Another possible source of fires, which might be more damaging in urban areas, is indirect. Blast damage to stores, water heaters, furnaces, electrical circuits, or gas lines would ignite fires where fuel is plentiful.

The best estimates are that at the 5-psi level about 10 percent of al I buildings would sustain a serious fire, while at 2 psi about 2 percent would have serious fires, usually arising from secondary sources such as blast-damaged utilities rather than direct thermal radiation.

It is possible that individual fires, whether caused by thermal radiation or by blast damage to utilities, furnaces, etc., would coalesce into a mass fire that would consume all structures over a large area. This possibility has been intensely studied, but there remains no basis for estimating its probability. Mass fires could be of two kinds: a "firestorm, " in which violent inrushing winds create extremely high temperatures but prevent the fire from spreading radially outwards, and a "conflagration," in which a fire spreads along a front. Hamburg, Tokyo, and Hiroshima experienced firestorms in World War 11; the Great Chicago Fire and the San Francisco Earthquake Fire were conflagrations. A firestorm is likely to kill a high proportion of the people in the area of the fire, through heat and through asphyxiation of those in shelters. A conflagration spreads slowly enough so that people in its path can

escape, though a conflagration caused by a nuclear attack might take a heavy toll of those too injured to walk. Some believe that firestorms in U.S. or Soviet cities are unlikely because the density of flammable materials ("fuel loading") is too low-the ignition of a firestorm is thought to require a fuel loading of at least 8 lbs/ft<sup>2</sup> (Hamburg had 32), compared to fuel loading of 2 lbs/ft<sup>2</sup> in a typical U.S. suburb and 5 lbs/ft<sup>2</sup> in a neighborhood of twostory brick rowhouses. The likelihood of a conflagration depends on the geography of the area, the speed and direction of the wind, and details of building construction. Another variable is whether people and equipment are available to fight fires before they can coalesce and spread.

#### Electromagnetic Pulse

Electromagnetic pulse (EMP) is an electromagnetic wave similar to radio waves, which results from secondary reactions occurring when the nuclear gamma radiation is absorbed in the air or ground. It differs from the usual radio waves in two important ways. First, it creates much higher electric field strengths. Whereas a radio signal might produce a thousandth of a volt or less in a receiving antenna, an EMP pulse might produce thousands of volts. Secondly, it is a single pulse of energy that disappears completely in a small fraction of a second. In this sense, it is rather similar to the electrical signal from lightning, but the rise in voltage is typically a hundred times faster. This means that most equipment designed to protect electrical facilities from lightning works too slowly to be effective against EMP.

The strength of an EMP pulse is measured in volts per meter (v/m), and is an indication of the voltage that would be produced in an exposed antenna. A nuclear weapon burst on the surface will typically produce an EMP of tens of thousands of v/m at short distances (the 10-psi range) and thousands of v/m at longer distances (l-psi range). Air bursts produce less EMP, but high-altitude bursts (above 19 miles [21 km]) produce very strong EMP, with ranges of hundreds or thousands of miles. An attacker

might detonate a few weapons at such altitudes in an effort to destroy or damage the communications and electric power systems of the victim.

There is no evidence that EMP is a physical threat to humans. However, electrical or electronic systems, particularly those connected to long wires such as powerlines or antennas, can undergo either of two kinds of damage. First, there can be actual physical damage to an electrical component such as shorting of a capacitor or burnout of a transistor, which would require replacement or repair before the equipment can again be used. Second, at a lesser level, there can be a temporary operational upset, frequently requiring some effort to restore operation. For example, instabilities induced in power grids can cause the entire system to shut itself down, upsetting computers that must be started again. Base radio stations are vulnerable not only from the loss of commercial power but from direct damage to electronic components connected to the antenna. In general, portable radio transmitter/receivers with relatively short antennas are not susceptible to EMP. The vulnerability of the telephone system to EMP could not be determined.

#### Fallout

While any nuclear explosion in the atmosphere produces some fallout, the fallout is far greater if the burst is on the surface, or at least low enough for the fireball to touch the ground. As chapter V shows in some detail, the fallout from air bursts alone poses long-term health hazards, but they are trivial compared to the other consequences of a nuclear attack. The significant hazards come from particles scooped up from the ground and irradiated by the nuclear explosion.

The radioactive particles that rise only a short distance (those in the "stem" of the familiar mushroom cloud) will fall back to earth within a matter of minutes, landing close to the center of the explosion. Such particles are unlikely to cause many deaths, because they will fall in areas where most people have already been killed. However, the radioactivity will complicate efforts at rescue or eventual reconstruct ion.

The radioactive particles that rise higher will be carried some distance by the wind before returning to Earth, and hence the area and intensity of the fallout is strongly influenced by local weather conditions. Much of the material is simply blown downwind in a long plume, The map shown in figure 2 illustrates the plume expected from a 1-Mt surface burst in Detroit if winds were blowing toward Canada. The illustrated plume assumed that the winds were blowing at a uniform speed of 15 mph [24 km] over the entire region, The plume would be longer and thinner if the winds were more intense and shorter and somewhat more broad if the winds were slower. If the winds were from a different direction, the plume would cover a different area. For example, a wind from the northwest would deposit enough fallout on Cleveland to inflict acute radiation sickness on those who did not evacuate or use effective fallout shelters (figure 3). Thus wind direction can make an enormous difference. Rainfal I can also have a significant influence on the ways in which radiation from smaller weapons is deposited, since rain will carry contaminated particles to the ground. The areas receiving such contaminated rainfall would become "hot spots, " with greater radiation intensity than their surroundings, When the radiation intensity from fallout is great enough to pose an immediate threat to health, fallout will generally be visible as a thin layer of dust.

The amount of radiation produced by fallout materials will decrease with time as the radioactive materials "decay." Each material decays at a different rate, Materials that decay rapidly give off intense radiation for a short period of time while long-lived materials radiate less intensely but for longer periods, Immediately after the fallout is deposited in regions surrounding the blast site, radiation intensities will be very high as the short-lived materials decay. These intense radiations will decrease relatively quickly. The intensity will have fallen by a factor of 10 after 7 hours, a factor of 100 after 49 hours and a factor of 1,000 after 2 weeks. The areas in the plume illustrated in figures 2 and 3 would become "safe" (by peacetime standards) in 2 to 3 years for the outer ellipse, and in 10 years or so for the inner ellipse.

Some radioactive particles will be thrust into the stratosphere, and may not return to Earth for some years. In this case only the particularly long-lived particles pose a threat, and they are dispersed around the world over a range of latitudes, Some fallout from U.S. and Soviet weapons tests in the 1950's and early 1960's can still be detected. There are also some particles in the immediate fallout (notably Strontium 90 and Cesium 137) that remain radioactive for years. Chapter V discusses the likely hazards from these long-lived particles.

The biological effects of fallout radiation are substantially the same as those from direct radiation, discussed above, People exposed to enough fallout radiation will die, and those exposed to lesser amounts may become ill. Chapter 11 I discusses the theory of fallout sheltering, and chapter IV some of the practical difficulties of escaping fallout from a large counterforce attack.

There is some public interest in the question of the consequences if a nuclear weapon destroyed a nuclear powerplant. The core of a power reactor contains large quantities of radioactive material, which tends to decay more slowly (and hence less intensely) than the fallout particles from a nuclear weapon explosion, Consequently, fallout from a destroyed nuclear reactor (whose destruction would, incidently, require a high-accuracy surface burst) would not be much more intense (during the first day) or widespread than "ordinary" fallout, but would stay radioactive for a considerably longer time. Areas receiving such fallout would have to be evacuated or decontaminated; otherwise survivors would have to stay in shelters for months,

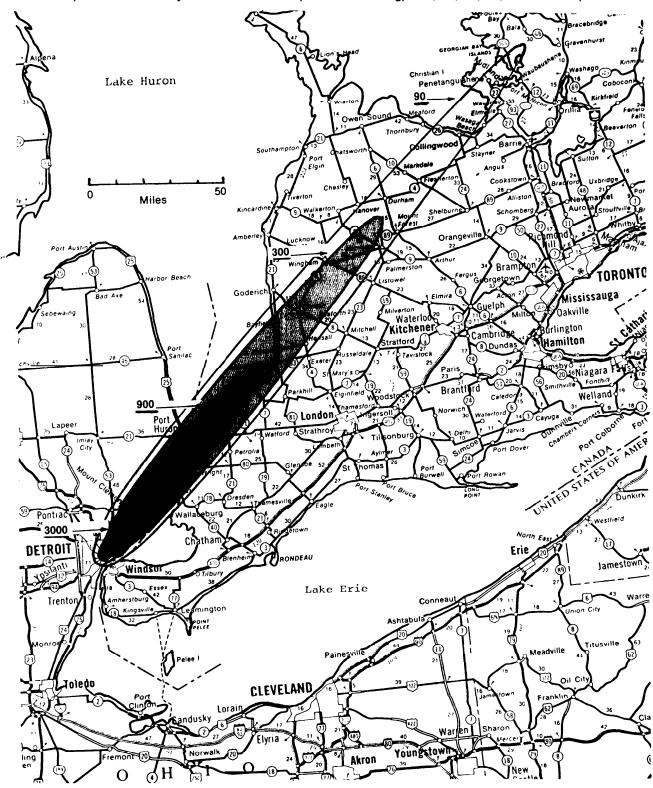


Figure 2.— Main Fallout Pattern —Uniform 15 mph Southwest Wind (1-Mt Surface Burst in Detroit). (Contours for 7-Day Accumulated Dose (Without Shielding) of 3,000,900,300, and 90 Rem.)

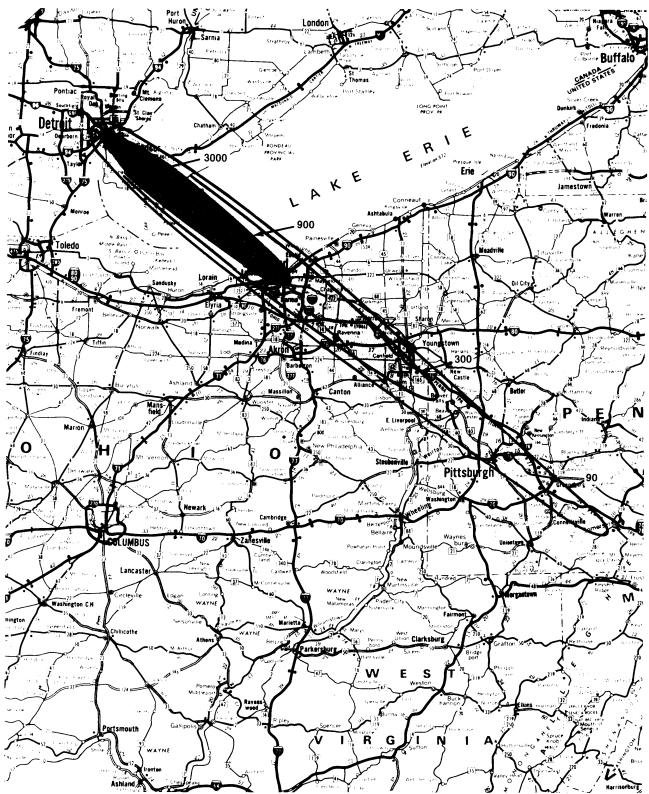


Figure 3.—Main Fallout Pattern —IJniforrn 15 mph Northwest Wind (1-Mt Surface Burst in Detroit). (Contours for 7-Day Accumulated Dose (Without Shielding) of 3,000,900,300, and 90 Rem.)

45-407 O = 79 = 3

#### **Combined Injuries (Synergism)**

So far the discussion of each major effect (blast, nuclear radiation, and thermal radiation) has explained how this effect in isolation causes deaths and injuries to humans. It is customary to calculate the casualties accompanying hypothetical nuclear explosion as follows: for any given range, the effect most likely to kill people is selected and its consequences calculated, while the other effects are ignored. it is obvious that combined injuries are possible, but there are no generally accepted ways of calculating their probability. What data do exist seem to suggest that calculations of single effects are not too inaccurate for immediate deaths, but that deaths occurring some time after the explosion may well be due to combined causes, and hence are omitted from most calculations. Some of the obvious possibilities are:

- Nuclear Radiation Combined With Thermal Radiation.- Severe burns place considerable stress on the blood system, and often cause anemia. It is clear from experiments with laboratory animals that exposure of a burn victim to more than 100 reins of radiation will impair the blood's ability to support recovery from the thermal burns. Hence a sublethal radiation dose could make it impossible to recover from a burn that, without the radiation, would not cause death.
- Nuclear Radiation Combined With Mechanical Injuries. –Mechanical injuries, the indirect results of blast, take many forms. Flying glass and wood will cause puncture wounds. Winds may blow people into obstructions, causing broken bones, concussions, and internal injuries. Persons caught in a collapsing building can suffer many similar mechanical injuries. There is evidence that all of these types of injuries are more serious if the person has been ex-

posed to 300 reins, particularly if treatment is delayed. Blood damage will clearly make a victim more susceptible to blood loss and infection. This has been confirmed in laboratory animals in which a borderline lethal radiation dose was followed a week later by a blast overpressure that alone would have produced a low level of prompt lethality. The number of prompt and delayed (from radiation) deaths both increased over what would be expected from the single effect alone.

Thermal Radiation and Mechanical Iniuries. — There is no information available about the effects of this combination, beyond the common sense observation that since each can place a great stress on a healthy body, the combination of injuries that are individually tolerable may subject the body to a total stress that it Mechanical tolerate. injuries cannot should be prevalent at about the distance from a nuclear explosion that produces sublethal burns, so this synergism could be an important one.

In general, synergistic effects are most likely to produce death when each of the injuries alone is quite severe. Because the uncertainties of nuclear effects are compounded when one tries to estimate the likelihood of two or more serious but (individually) nonfatal injuries, there really is no way to estimate the number of victims.

A further dimension of the problem is the possible synergy between injuries and environmental damage. To take one obvious example, poor sanitation (due to the loss of electrical power and water pressure) can clearly compound the effects of any kind of serious injury. Another possibility is that an injury would so immobilize the victim that he would be unable to escape from a fire.

# DETROIT AND LENINGRAD

Detroit and Leningrad are representative industrial cities large enough to warrant the use of very large weapons. Both have metropolitan populations of about 4.3 million, and both are major transportation and industrial centers.

In assessing and describing the damage, several assumptions were made that may not be realistic, but which assisted in making a clear presentation of the range of possible effects:

- . There is no warning. The populations have not evacuated or sought shelter, both of which measures could reduce casualties.
- The detonations take place at night when most people are at their residences. This corresponds to the available census data about where people are, and indeed people are near their residences more than half the time.
- There is clear weather, with visibility of 10 miles [16 km].
- The air bursts are at an altitude that maximizes the area of 30 psi or more overpressure. A higher height of burst would have increased the range of 5-psi overpressure (i.e. destruction of all residences) by up to 10 percent, at the cost of less damage to very hard structures near the center of the explosion.
- No other cities are attacked, an assumption that allows for analyzing the extent of outside help that would be required, if it were available.

#### 1 Mt on the Surface in Detroit

#### Physical Damage

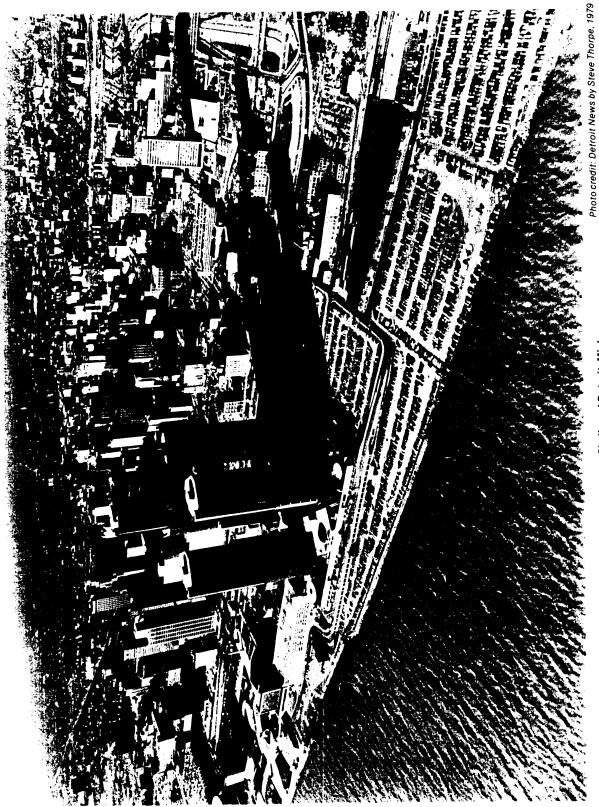
Figure 4 shows the metropolitan area of Detroit, with Windsor, Canada, across the river to the southeast and Lake St. Clair directly east. The detonation point selected is the intersection of 1-75 and 1-94, approximately at the civic center and about 3 miles [5 km] from the Detroit-Windsor tunnel entrance. Circles are drawn at the 12-, 5-, 2-, and 1-psi limits.

The I-Mt explosion on the surface leaves a crater about 1,000 feet [300 m] in diameter and 200 feet [61 m] deep, surrounded by a rim of highly radioactive soil about twice this diameter thrown out of the crater. Out to a distance of 0.6 miles [1 km] from the center there will be nothing recognizable remaining, with the exception of some massive concrete bridge abutments and building foundations. At 0.6 miles some heavily damaged highway bridge sections will remain, but little else until 1.3 miles [2. I km], where a few very strongly constructed buildings with poured reinforced concrete walls will survive, but with the interiors totally destroyed by blast entering the window openings. A distance of 1.7 miles [2.7 km] (1 2-psi ring) is the closest range where any significant structure will remain standing.

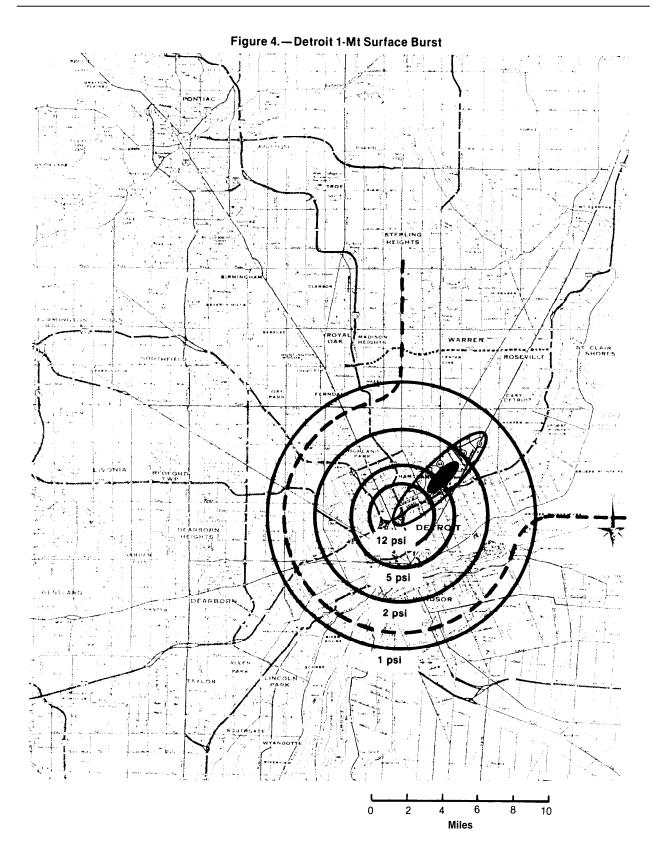
Of the 70,000 people in this area during nonworking hours, there will be virtually no survivors. (See table 4.) Fatalities during working hours in this business district would undoubtedly be much higher. The estimated daytime population of the "downtown" area is something over 200,000 in contrast to the census data of about 15,000. If the attack occurred during this time, the fatalities would be increased by 130,000 and injuries by 45,000 over the estimates in table 4. Obviously there would be some reduction in casualties in outlying residential areas where the daytime population would be lower.

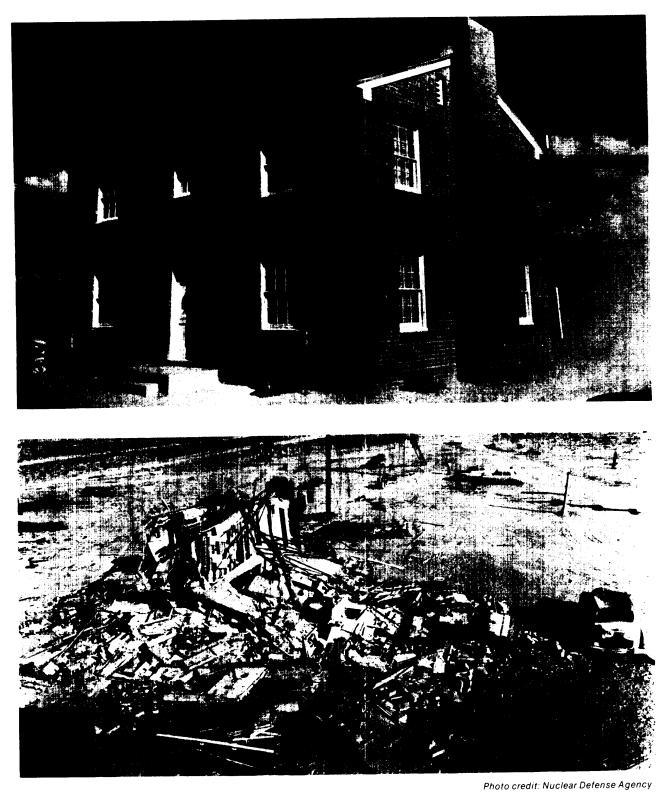
In the band between the 1.7- and the 2.7-mile (5 psi) circles, typical commercial and residential multistory buildings will have the walls completely blown out, but increasingly at the greater distances the skeletal structure will remain standing.

Individual residences in this region will be totally destroyed, with only foundations and basements remaining, and the debris quite uniformly distributed over the area. Heavy industrial plants will be destroyed in the inner part of the ring, but some industry will remain functional towards the outer edge. The debris depth that will clutter the streets will naturally









Damage to unreinforced brick house (5-psi overpressure)

Region (mi)	Area (mi²)	Population	Fatalities	Injuries	Uninjured
0-1 7	91	70	70	0	0
1 7-27	13.8	250	130	100	20
27-47	465	400	20	180	200
47-74	1026	600	0	150	450

# Table 4.—Casualty Estimates (in thousands)

depend on both the building heights and how close together they are spaced. Typical depths might range from tens of feet in the downtown area where buildings are 10 to **20** stories high, down to several inches where buildings are lower and streets broader in the sector to the west and north, In this band, blast damage alone will destroy all automobiles, while some heavier commercial vehicles (firetrucks and repair vehicles) will survive near the outer edges. However, few vehicles will have been sufficiently protected from debris to remain useful. The parking lots of both Cobb Field and Tiger Stadium will contain nothing driveable.

I n this same ring, which contains a nighttime population of about 250,000, about half will be fatalities, with most of the remainder being injured. Most deaths will occur from collapsing buildings. Although many fires will be started, only a small percentage of the buildings are likely to continue to burn after the blast wave passes. The mechanics of fire spread in a heavily damaged and debris strewn area are not well understood. However, it is probable that fire spread would be slow and there would be no firestorm. For unprotected people, the initial nuclear radiation would be lethal out to 1.7 miles [2.7 km], but be insignificant in its prompt effects (50 reins) at 2.0 miles [3.2 km]. Since few people inside a 2-mile ring will survive the blast, and they are very likely to be in strong buildings that typically have a 2- to 5protection factor, the additional fatalities and injuries from initial radiation should be small compared to other uncertainties.

The number of casualties from thermal burns depends on the time of day, season, and atmospheric visibility. Modest variations in these factors produce huge changes in vulnerability to burns. For example, on a winter night less than 1 percent of the population might be exposed to direct thermal radiation, while on a clear summer weekend afternoon more than 25 percent might be exposed (that is, have no structure between the fireball and the person). When visibility is 10 miles [16 km], a I-Mt explosion produces second-degree burns at a distance of 6 miles [10 km], while under circumstances when visibility is 2 miles [3 km], the range of second-degree burns is only 2.7 miles [4.3 km]. Table 5 shows how this variation could cause deaths from thermal radiation to vary between 1,000 and 190,000, and injuries to vary between 500 and 75,000.

In the band from 2.7 to 4.7 miles [4.4 to 7.6 km] (2 psi), large buildings will have lost windows and frames, interior partitions, and, for those with light-walled construction, most of the contents of upper floors will have been blown out into the streets. Load-bearing wall buildings at the University of Detroit will be severely cracked. Low residential buildings will be totally destroyed or severely damaged. Casualties are estimated to be about 50 percent in this region, with the majority of these injured. There will still be substantial debris in the streets, but a very significant number of cars and trucks will remain operable. In this zone, damage to heavy industrial plants, such as the Cadillac plant, will be severe, and most planes and hangars at the Detroit City Airport will be destroyed.

In this ring only 5 percent of the population of about 400,000 will be killed, but nearly half will be injured (table 4). This is the region of the most severe fire hazard, since fire ignition and spread is more likely in partly damaged buildings than in completely flattened areas. Perhaps 5 percent of the buildings would be initially ignited, with fire spread to adjoining buildings highly likely if their separation is less than 50 feet [15 m]. Fires will continue to spread for 24 hours at least, ultimately destroying about half the buildings. However, these estimates are extremely uncertain, as they are based on poor data and unknown weather conditions. They are also made on the assumption that no effective effort is made by the uninjured half of the population in this region to prevent the ignition or spread of fires.

As table 5 shows, there would be between 4,000 and 95,000 additional deaths from thermal radiation in this band, assuming a visibility of 10 miles [16 km]. A 2-mile [3 km] visibility would produce instead between 1,000 and 11,000 severe injuries, and many of these would subsequently die because adequate medical treatment would not be available.

In the outermost band (4.7 to 7.4 miles [7.6 to 11.9 km]) there will be only light damage to commercial structures and moderate damage to residences. Casualties are estimated at 25 percent injured and only an insignificant number killed (table 4). Under the range of conditions displayed in table 5, there will be an additional 3,000 to 75,000 burn injuries requiring specialized medical care. Fire ignitions should be comparatively rare (limited to such kindling material as newspaper and dry leaves) and easily control led by the survivors.

Whether fallout comes from the stem or the cap of the mushroom is a major concern in the general vicinity of the detonation because of the time element and its effect on general emergency operations. Fallout from the stem starts building after about 10 minutes, so during the first hour after detonation it represents the prime radiation threat to emergency crews. The affected area would have a radius of about 6.5 miles [10.5 km] (as indicated by the dashed circle on figure 4) with a hot-spot a distance downwind that depends on the wind velocity. If a 15-mph wind from the southwest is assumed, an area of about 1 mi<sup>2</sup>[260 hectares]-the solid ellipse shown --would cause an average exposure of 300 reins in the first hour to people with no fallout protection at all. The larger toned ellipse shows the area of 150 reins in the first hour. But the important feature of short-term (up to 1 hour) fallout is the relatively small area covered by lifethreatening radiation levels compared to the area covered by blast damage.

Starting in about an hour, the main fallout from the cloud itself will start to arrive, with some of it adding to the already-deposited local stem fallout, but the bulk being distributed in an elongated downwind ellipse. Figures 2 and 3 show two fallout patterns, differing only in the direction of the wind. The

Distance from	Survivors of	Fatalities (eventual)		Injuries				
blast (mi)	blast effects	2-mile visibility	10-mile visibility	2-mile visibility	10-mile visibility			
(1 percent of population exposed to line of sight from fireball)								
0 - 1 . 7 1 7 - 2 7 2 7 - 4 . 7 . 47 - 7 4 .	0 120,000 380,000 600,000	1,200 <b>0</b>	1, 200 <sup>0</sup> 3,800 2,600	500 0 0	0 0 3,000			
Total (rounded		1,000	8,000	500	3,000			
	(25 percent	of population expos	sed to line of sight fi	rom fireball)				
0 - 1 7 . 1 7 - 2 7 , 2 . 7 - 4 7 4 , 7 - 7 4 .	0 120,000 380.000 600,000	30,000 O 0	0 30,000 95,000 66,000	0 0 11,000 0	0 0 75,000			
Total (rounded)		30,000	190.000	11.000	75,000			

#### Table 5.–Burn Casualty Estimates (1 Mt on Detroit)

These calculations arbitrarily assume that exposure to more than 6-7 cal/cm<sup>2</sup> produces eventual death, and exposure to more than 3-4 cal/cm<sup>2</sup> produces a significant injury, requiring specialized medical treatment.

contours marked are the number of reins received in the week following the arrival of the cloud fat lout, again assuming no fallout protection whatever. Realistic patterns, which will reflect wind shear, 2 wider crosswind distribution, and other atmospheric vari ~bilities, will be much more complex than this i lustration.

#### Infrastructure Status

As a complement to the prece ~ing description of physical destruction, the status of the various infrastructure elements of the Detroit metropolitan area, and the potential for their recovery, can be addressed. The reader should understand that this tutorial considers Detroit to be the only damaged area in the United States, that there is no other threat that would prevent survivors and those in surrounding areas from giving all possible aid, and that Federal and State governments will actively organize outside assistance.

The near half-million injured present a medical task of incredible magnitude. Those parts of Wayne, Macomb, and Oakland counties shown on the map have 63 hospitals containing about 18,000 beds. However, 55 percent of these beds are inside the 5-psi ring and thus totally destroyed. Another 15 percent in the 2to 5-psi band will be severely damaged, leaving 5,000 beds remaining outside the region of significant damage. Since this is only 1 percent of the number of injured, these beds are incapable of providing significant medical assistance. In the first few days, transport of injured out of the damaged area will be severely hampered by debris clogging the streets. In general, only the nonprofessional assistance of nearby survivors can hope to hold down the large number of subsequent deaths that would otherwise occur. Even as transportation for the injured out of the area becomes available in subsequent days, the total medical facilities of the United States will be severely overburdened, since in 1977 there were only 1,407,000 hospital beds in the whole United States. Burn victims will number in the tens of thousands; yet in 1977 there were only 85 specialized burn

centers, with probably 1,000 to 2,000 beds, in the entire United States.

The total loss of all utilities in areas where there has been significant physical damage to the basic structure of buildings is inevitable. The electric power grid will show both the inherent strength and weakness of its complex network. The CO I lapse of buildings and the toppling of trees and utility poles, along with the injection of tens of thousands of volts of EMP into wires, will cause the immediate loss of power in a major sector of the total U.S. power grid. Main electrical powerplants (near Grosse Point Park to the east, and Zug Island to the south) are both in the I-psi ring and should suffer only superficial damage. Within a day the major area grid should be restored, bringing power back to facilities located as close to the blast as the I-psi ring. Large numbers of powerline workers and their equipment brought in from the surrounding States will be able to gradually restore service to surviving structures in the 1- to 2-psi ring over a period of days.

The water distribution system will remain mostly intact since, with the exception of one booster pumping station at 2 psi (which will suffer only minor damage), its facilities are outside the damaged area. However, the loss of electric power to the pumps and the breaking of many service connections to destroyed buildings will immediately cause the loss of all water pressure. Service to the whole area will be restored only when the regional power grid is restored, and to the areas of light and intermediate damage only as valves to broken pipes can be located and shut off over a period of days. There will be only sporadic damage to buried mains in the 2- to 5-psi region, but with increasing frequency in the 5- to 12-psi region. Damaged sections near the explosion center will have to be closed off.

The gas distribution system will receive similar damage: loss of pressure from numerous broken service connections, some broken mains, particularly in the 5- to 12-psi ring, and numerous resulting fires. Service will be slowly restored only as utility repairmen and service equipment are brought in from surrounding areas.

Rescue and recovery operations will depend heavily on the reestablishment of transportation, which in Detroit relies on private cars, buses, and commercial trucks, using a radial interstate system and a conventional urban grid. Since bridges and overpasses are surprisingly immune to blast effects, those interstate highways and broad urban streets without significant structures nearby will survive as far in as the 12-psi ring and can be quickly restored to use on clearing away minor amounts of debris. However, the majority of urban streets will be cluttered with varying quantities of debris, starting with tree limbs and other minor obstacles at 1 psi, and increasing in density up to the 12-psi ring, where all buildings, trees, and cars will be smashed and quite uniformly redistributed over the area. It could take weeks or months to remove the debris and restore road transportation in the area.

The Detroit city airport, located in the middle of the 2- to 5-psi ring, will have essentially all of its aircraft and facilities destroyed. Usually runways can be quickly restored to use following minor debris removal but, in this particular example with the southwest wind, the airport is the center of the fallout hot spot from the dust column as well as of the intensive fallout from the cloud. Thus, cleanup efforts to restore flight operations could not commence for 2 weeks at the earliest, with the workers involved in the cleanup receiving 100 reins accumulated during the third week. The Detroit Metropolitan Wayne County Airport and the Willow Run Airport are far outside the blast effects area and would be available as soon as the regional power grid electric service was restored.

The main train station, near the Detroit-Windsor highway tunnel, would have suffered major damage (5 psi), but since few people commute to the downtown area by train, its loss would not be a major factor in the overall paralysis of transportation. The surrounding industry depends heavily on rail transportation, but rail equipment and lines will usually survive wherever the facilities they support survive.

Most gasoline fuel oil tanks are located out beyond Dearborn and Lincoln Park and, at 16 miles from the detonation, will have suffered no damage. Arrival of fuel should not be impeded, but its distribution will be totally dependent on cleanup of streets and highways.

The civil defense control center, located just beyond the Highland Park area in the 1- to 2psi ring, should be able to function without impairment. Commercial communications systems (television and base radio transmitters) will be inoperable both from the loss of commercial power in the area and, for those facilities in the blast area, from EMP. Those not blast damaged should be restored in several days. In the meantime, mobile radio systems will provide the primary means of communicating into the heavily damaged areas. The telephone system will probably remain largely functional in those areas where the lines have survived structural damage in collapsing buildings, or street damage in areas where they are not buried.

#### Radioactive Fallout

The extent and location of radioactive fallout will depend on weather conditions, especially the speed and direction of the wind. Figures 2 and 3 show how a uniform wind velocity of 15 mph could distribute fallout either over sparsely populated farming areas in Canada if the wind is from the southwest, or over Cleveland and Youngstown, Ohio, and Pittsburgh, Pa., if the wind is from the northwest. It should not be forgotten that these fallout patterns are idealized—such neat elipses would occur in reality only with an absolutely constant wind and no rain.

No effort was made to calculate the deaths, injuries, or economic losses that might result from such fallout patterns. However, the possibilities are instructive:

. The onset of fallout would depend on wind velocity and distance from the ex-

plosion and it would be most dangerous during the first few days. In the case of an attack on a single city (using a surface burst, as our example does), people living downwind would probably evacuate. Those who neither evacuated nor found adequate fallout shelters would be subjected to dangerous levels of radiation: people in the inner contour would receive a fatal dose within the first week; people in the next contour out would contract very severe radiation sickness if they stayed indoors and would probably receive a fatal dose if they spent much time outdoors; people in the next contour out would contract generally nonfatal radiation sickness, with increased hazards of deaths from other diseases. People in the outer contour (90 roentgens in the first week) would suffer few visible effects, but their life expectancy would drop as a result of an increased risk of eventual cancer.

- As time passes, the continuing decay of fallout radiation could be accelerated by decontamination. Some decontamination takes place naturally, as rain washes radioactive particles away, and as they are leached into the soil which attenuates the radiation. It is also possible to take specific measures to speed decontamination. Presumably evacuees would not move back into a contaminated area until the effects of time and decontamination had made it safe.
- A limiting case is one in which no significant decontamination takes place, and areas receiving fallout become safe only when the radioactive particles have decayed to safe levels. Decay to a level of 500 millirems per year would require 8 to 10 years for the inner contour (3,000 roentgens in the first week); 6 years or so for the next contour (900 roentgens in the first week); 3 to 4 years for the next contour (300 roentgens in the first week); and about 3 years for the outer contour (90 roentgens in the first week).
- Natural processes could concentrate some radioactive particles, and those that

entered the food chain could pose an additional hazard.

#### Summary

It should be emphasized that there are many uncertainties in the assumptions underlying the description of the results of a I-Mt surface burst in Detroit. Nevertheless, several salient features stand out:

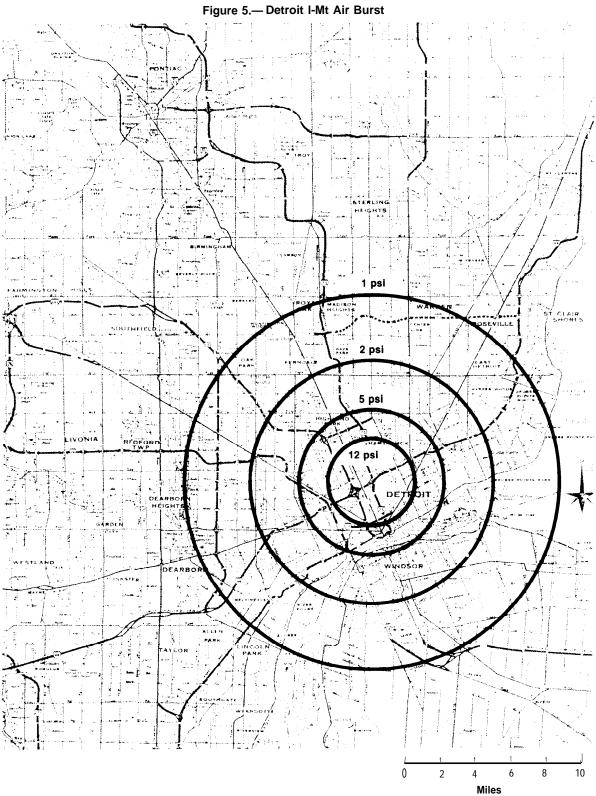
- seventy square miles of property destruction (2 psi),
- a quarter-of -a-roil I ion fatalities, plus half a million injuries,
- additional damage from widespread fires,
- casualties could have been greatly re duced by an alert and informed population, and
- rescue and recovery operations must be organized and heavily supported from outside the area (food, medical, utility restoration, and cleanup).

#### I-Mt Air Burst on Detroit

For comparison, the same I-Mt nuclear weapon was assumed to have been air burst at an altitude of 6,000 feet [1.8 km] over the same interstate intersection as used in the preceding ground burst discussion. This altitude will maximize the size of the 30-psi circle, but the radius of the 5-psi circle that results will be only 10 percent smaller than what would have resulted from a height of burst raised to the 5psi optimized value. There will be several significant differences in this case.

- The sizes of the rings of pressure damage will be larger.
- The range of thermal burns and fire starts will also increase.
- There will be no significant fallout.
- There will be no crater.
- The strongest structures may partly survive even directly under the blast.

Figure 5 shows the corresponding pressure circles and figure 6 (second column) illustrates that the number of fatalities nearly doubled, and the number of injured have greatly increased. At the same time, damage to major in-



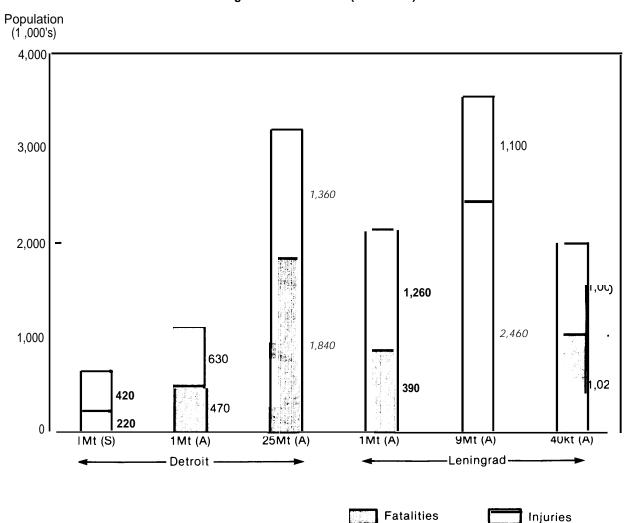


Figure 6.—Casualties (thousands)

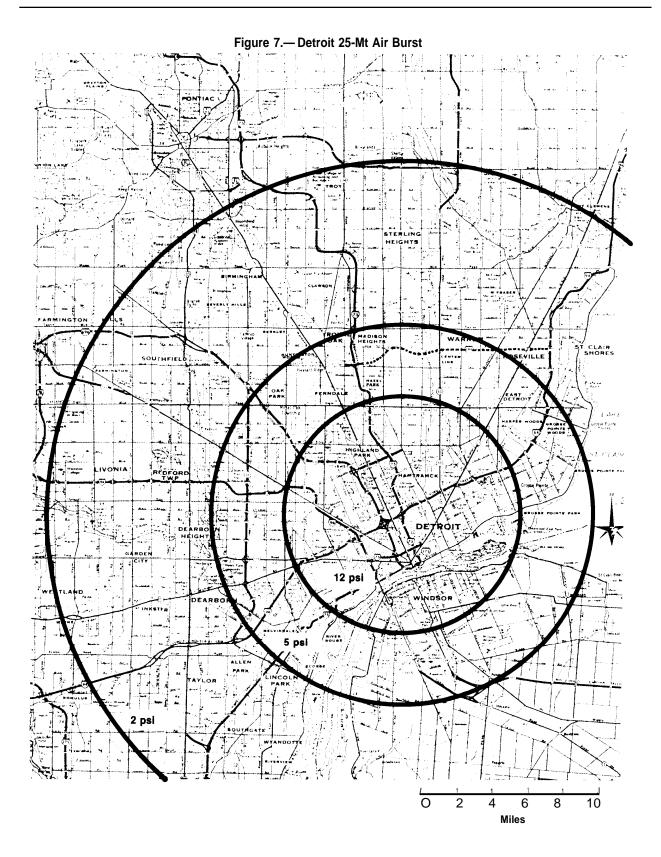
dustrial facilities is becoming significant, with the Chrysler plant in the middle of the 2- to 5psi band, and the Ford River Rouge plant in the 1- to 2-psi band.

#### 25-Mt Air Burst on Detroit

For 25 Mt, we assumed a burst altitude of 17,500 feet [5.3 km], over the same detonation point. Figure 7 shows the 12-, 5-, and 2-psi rings, but the 1-psi ring at 30.4 miles [48.9 km] is completely off the map. It is obvious that damage and casualties would be increased even further had the detonation point been moved about 5

miles [8 km] to the northwest. But even without this shift, it is clear that the whole metropolitan area has been heavily damaged by the explosive power of this huge weapon. The casualties are again shown on figure 6 (column 3). The contrasts to the I-Mt surface burst are stark:

There will be very few survivors (1.1 million available to assist the much more numerous casualtie
1-Mt surface burst in which
3.7 million survivors were potentially avail able to assist the 640,000 casualties.



- There will be virtually no habitable housing in the area.
- Essentially all heavy industry will be totally destroyed.

As a result, rescue operations will have to be totally supported from outside the area, with evacuation of the 1.2 mi II ion survivors the only feasible course. Recovery and rebuilding will be a very long-term, problematical issue.

#### Leningrad

Leningrad is a major industrial and transportation center built on the low-lying delta where the Neva River enters the Gulf of Finland. The older part of the city is built on the delta itself, with the newer residential sections leapfrogging industrial sections, primarily to the south and southwest (figure 8). The residential and commercial (but not industrial) areas are shown on the map.

The major difference between housing in Leningrad and that in Detroit is that Leningrad suburbs contain very few single-family residences. In the older part of Leningrad, the buildings have masonry load-bearing walls and wooden interior construction and are typically six to eight stories, reflecting the early code that only church spires could be higher than the Tsar's Winter Palace. The post-World War I I housing construction is 10- to 12-story apartments having steel frames and precast concrete walls, with the buildings comfortably spaced on wide thoroughfares in open parklike settings.

Since actual population density data for Leningrad was unavailable, simplifying demographic assumptions are used. The assumed populated areas are shown in figure 9, broken down into I-km [0.6 mile] squares. The stated area of Leningrad is 500 km<sup>2</sup>[193 mi<sup>2</sup>]. Since the shaded squares cover 427 km<sup>2</sup>[165 mi<sup>2</sup>], it is assumed that the remaining areas are relatively uninhabited at night. It has also been assumed that in these inhabited areas the population density is uniform at 10,000 per km', because although the building density is lower in the newer apartment areas, the buildings themselves are generally higher. Thus, the population density does not drop off as it does in the U.S. suburbs of predominately single-family houses.

#### I-Mt and 9-Mt Air Bursts on Leningrad

The Leningrad apartments described are likely to have their walls blown out, and the people swept out, at about 5 psi, even though the remaining steel skeleton will withstand much higher pressures. Thus, although the type of construction is totally different from Detroit, the damage levels are so similar that the same relationship between overpressure and casualties is assumed (figure 1, p. 19).

The I-Mt and 9-Mt air burst pressure rings are shown in figures 10 and 11. Note that for the 9-Mt case the I-psi ring falls completely off the map, as was the case for 25 Mt on Detroit. The calculated casualties are illustrated on figure 6 (columns 4 and 5), and are about double those for Detroit for the comparable I-Mt case. This results directly from the higher average population density. Other contrasts between the cities can be noted; in Leningrad:

- People live close to where they work. In general, there is no daily cross-city movement.
- Buildings (except in the old part of the city) are unlikely to burn.
- Apartment building spacing is so great as to make fire spread unlikely, even though a few buildings would burn down.
- There will be much less debris preventing access to damaged areas.
- Transportation is by rail to the outlying areas, and by an excellent metro system within the city.
- There is only one television station— in the middle of the city— so mass communications would be interrupted until other broadcasting equipment was brought in and set up.

#### Ten 40-kt Air Bursts on Leningrad

Figure 12 shows one possible selection of burst points, set to have the 5-psi circles

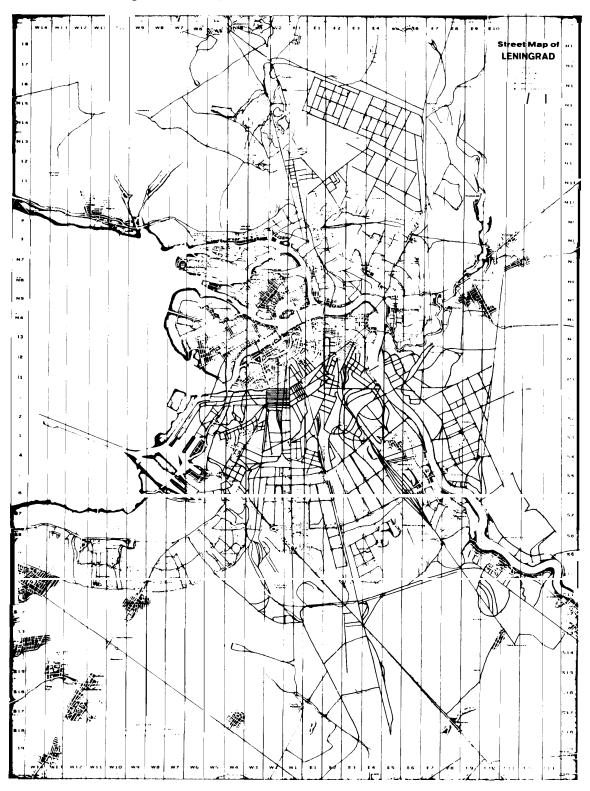


Figure 8.— Leningrad—Commercial and Residential Sections

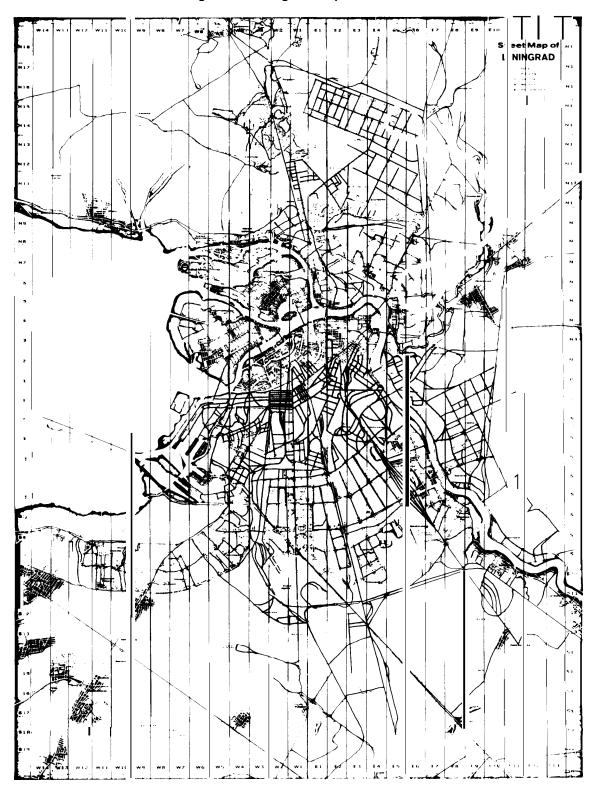


Figure 9.—Leningrad—Populated Area

45-407 O = 79 = 4

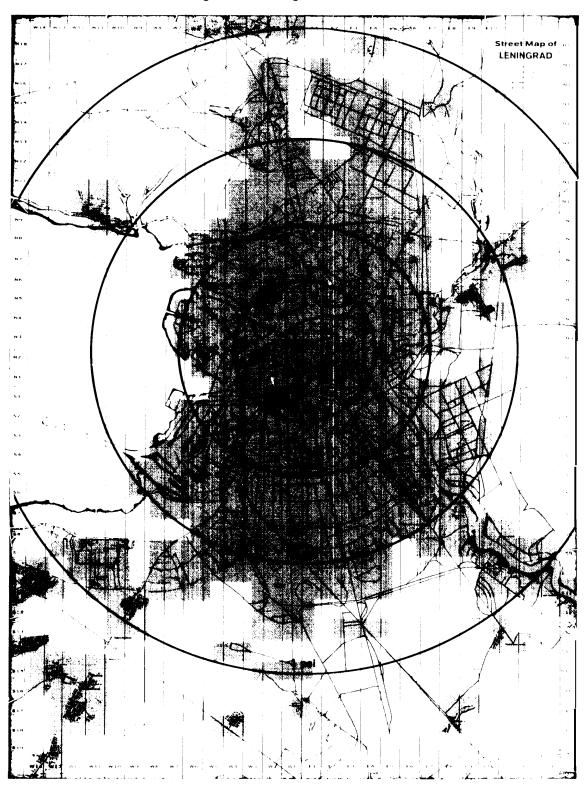


Figure 10.— Leningrad 1"Mt Air Burst

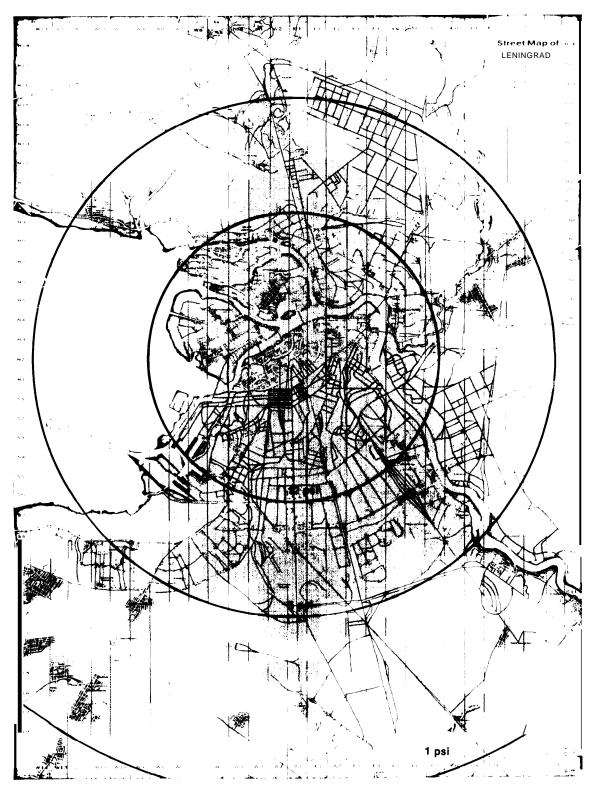


Figure 11 .-- Leningrad 9-Mt Air Burst

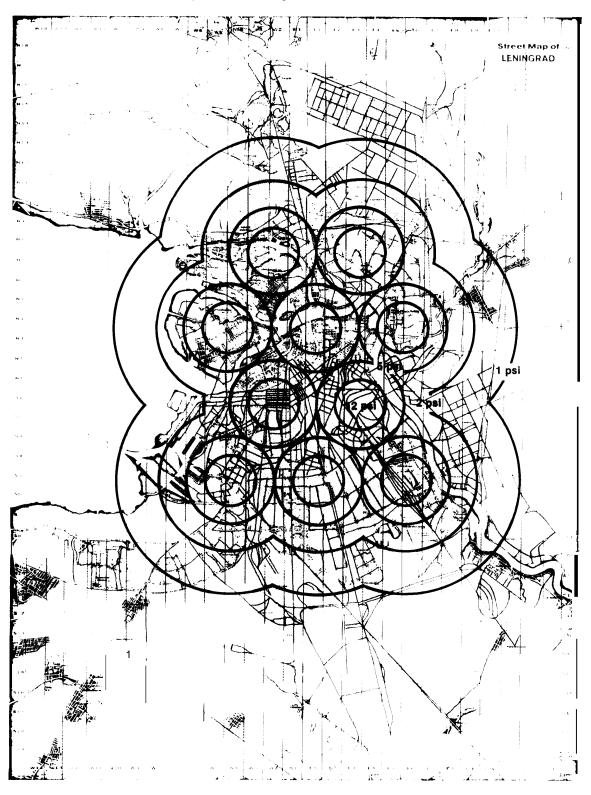


Figure 12.—Leningrad Ten 40-kt Air Burst

touching, and with only the envelope of the 2and I-psi rings shown, Since this is an effects discussion only, it is assumed that this precise pattern can be achieved. The errors arising from neglecting the overlap of the 2- to 5-psi bands will be negligible compared to uncertainties in population distribution and structural design. Casualty estimates are shown in the right hand column of figure 6 (p. 37). Note

that fatalities are only slightly greater than for the I-Mt case, which corresponds well to the equivalent megatonage (1.17 Mt) of the ten 40kiloton (kt) weapons. However, the number of injured are considerably smaller because they primarily occur in the 2- to 5-psi band, which is much smaller for the 40-kt pattern than for the single 1-Mt case.

### 1-KT TERRORIST WEAPON AT GROUND LEVEL

To this point this chapter has addressed nuclear effects from current strategic weapon systems. Another nuclear weapon of concern is one constructed by terrorists and detonated in a major city, \* A terrorist group using stolen or diverted fission material, having general technical competence but lacking direct weapon design experience, could probably build a weapon up to several kilotons. This weapon would be large and heavy, certainly not the often-discussed "suitcase bomb, " so is likely to be transported in a van or small truck, with threatened detonation either in the street or the parking garage of a building.

Because of the locations and yield of this weapon, its effects will be much less devasting than those of high-yield, strategic weapons. The range and magnitude of all the nuclear effects will be greatly reduced by the low yields; in addition, the relative range of lethal effects will be changed. At high yields, blast and thermal burn reach out to greater distances than does the initial nuclear radiation. At 1 kt the reverse is true; for example, 5-psi overpressure occurs at 1,450 feet [442 m], while 600 reins of initial radiation reaches out to 2,650 feet [808 m], For the 1-Mt surface burst, 5 psi occurred at 2.7 miles and 600 reins at 1.7 miles.

In addition to these changes in range, the highly built-up urban structure in which the weapon is placed will significantly modify the resulting nuclear environment. This occurs

when the lethal range of effects shrink to such an extent that they are comparable to the size of urban structures. It is indeed reasonable to expect that the blast effects of a small weapon (5 psi at a range of only 1,450 feet) will be severely influenced by nearby structures having comparable dimensions. Preliminary calculations have confirmed this. For example, suppose a device is detonated in a van parked alongside a 1,000-foot high building in the middle of the block of an urban complex of rather closely spaced streets in one direction and more broadly spaced avenues in the other direction. Whereas the 2.5-psi ring would have a radius of 2,100 feet [640 m] detonated on a smooth surface, it is found that this blast wave extends to 2,800 feet [850 m] directly down the street, but to only 1,500 feet [460 m] in a random direction angling through the built-up blocks. These calculations have been made by many approximating factors which, if more accurately represented, would probably lead to an even greater reduction in range.

Other weapons effects will be similarly modified from those predicted on the basis of a relatively open target area. In the case of initial nuclear radiation, a lethal 600 rem would be expected to extend to **2,650** feet **[808** m] from 1 kt. Because of the great absorption of this radiation as it passes through the multiple walls of the several buildings in a block, it is expected that 600 reins will reach out no further than 800 feet [245 m], thus covering an area only one-tenth as great. The thermal radiation will affect only those directly exposed up

<sup>\*</sup>OTA report on "Nuclear Proliferation and Safeguards, "US Government Printing Office, June 1977, pp 111-12.2

and down the street, while the majority of people will be protected by buildings. For the same reason directly initiated fires will be insignificant, but the problem of secondary fires starting from building damage will remain. The local fallout pattern also will be highly distorted by the presence of the buildings. The fireball, confined between the buildings, will be blown up to a higher altitude than otherwise expected, leading to reduced local fallout but causing broadly distributed long-term fallout. In summary, the ranges of nuclear effects from a low-yield explosion in the confined space of an urban environment will differ significantly from large yield effects, but in ways that are very difficult to estimate. Thus the numbers of people and areas of buildings affected are very uncertain. However, it appears that, with the exception of streets directly exposed to the weapon, lethal ranges to people will be smaller than anticipated and dominated by the blast-induced CO I lapse of nearby buildings.