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(Supersedes CPG 2-1A5 dated June 1973, which may not be used.)

ATTACK ENVIRONMENT MANUAL

Chapter 5

What the planner needs to know About Initial Nuclear Radiation

FEDERAL EMERGENCY MANAGEMENT AGENCY

LIST OF CHAPTER TITLES

*Chapter 3 will be published at a later date.

FOREWORD

WHAT THE EMERGENCY PLANNER NEEDS TO KNOW ABOUT THE NATURE OF NUCLEAR WAR

No one has gone through nuclear war. This means there isn't any practical experience upon which to build. Nowever, emergency management officials are responsible for preparing for the possibility of nuclear war. Intelligent preparations should be based on a good understanding of what operating conditions may be like in a war that has never occurred. If the planner lacks such understanding, the emergency operations plans produced probably won't make sense if they ever have to be used.

The Attack Environment Manual has been prepared to help the emergency planner understand what such a war could be like. It contains information gathered from over four decades of study of the effects of operational studies and exercises, nuclear test experience, and limited experience in wartime and peacetime disasters that approximate some of the operating situations that may be experienced in a nuclear attack. In short, it summarizes what is known about the nuclear attack environment as it could affect operational readiness at the local level.

The data on the effects of nuclear weapons used in this manual have been taken from the 1977 edition of "The Effects of Nuclear Weapons" (ENW), compiled and edited by S. Glasstone and P. J. Dolan and prepared and published by the United States Department of Defense and the United States Department of Energy. Copies are available for purchase from the U. S. Government Printing Office. The ENW is the most widely available authoritative source of weapon effects and is in many public libraries across the country. For these reasons it was chosen as the source data in this manual.

This Attack Environment Manual supersedes CPG 2-1A1 through 2-1A9.

PREFACE TO CHAPTER 5

This discussion of initial nuclear radiation also introduces the planner and emergency manager to the biological effects of brief exposures to ionizing radiation. It is assumed that the reader is familiar with the material in the preceding chapters. Initial nuclear radiation is most significant for low-yield nuclear detonations. Other effects of detonations from 40 to several hundred kilotons (blast and fire effects) have been included for comparison.

Until the advent of nuclear weapons in 1945, explosives used in conducting wars produced only blast and fire effects. The "atomic bomb" or more correctly the "nuclear weapon" produced a new hazardous effect—nuclear radiation. With the detonation of a nuclear weapon, a portion of the energy appears as nuclear radiation. That which appears during the first minute (the conventional but arbitrary time interval) is called "initial nuclear radiation" (INR). That which continues beyond the first minute and can persist for years is called "residual radiation." Residual radiation can result from fallout or from radioactive materials produced in the vicinity of the detonation by neutron radiation from the weapon. This chapter will discuss the INR, and chapter 6 the fallout radiation. People had, over the years, become familiar with both blast and fire effects. This "new" phenomenon—nuclear radiation—appeared mysterious although it had been known to the scientists since the discovery of X-rays by Roentgen in 1895. It has been stated that more is known about radioactive materials and their effects than about any other hazardous materials. However, as is often the case, much is yet to be learned.

Information is presented in the form of "panels," each consisting of a page of text and an associated sketch, photograph, chart, or other visual image. Each panel covers a topic. This preface is like a panel, with the list of topics in chapter 5 shown opposite. If the graphic portion is converted into slides or vugraphs, the chapter or any part can be used in an illustrated lecture or briefing, if so desired.

The chapter begins with introductory material to acquaint the readers with the phenomenon of nuclear radiation by introducing the neutron and gamma radiation that makes up the initial nuclear radiation from the detonation of a weapon. It then turns to the effects of nuclear radiation on people through the discussion of radiation sickness and the somatic and genetic effects. The next topics are the range of initial nuclear radiation and protection against this radiation. The discussion of initial nuclear radiation from "small" weapons includes reference to the recent studies on reassessing the doses experienced at Hiroshima and Nagasaki. The final topics are the blast and fire effects of the smaller weapons. The chapter concludes with suggested additional reading for those who are interested in further or more detailed information on nuclear radiation.

CONTENTS OF CHAPTER 5

WHAT THE PLANNER NEEDS TO KNOW ABOUT
INITIAL NUCLEAR RADIATION

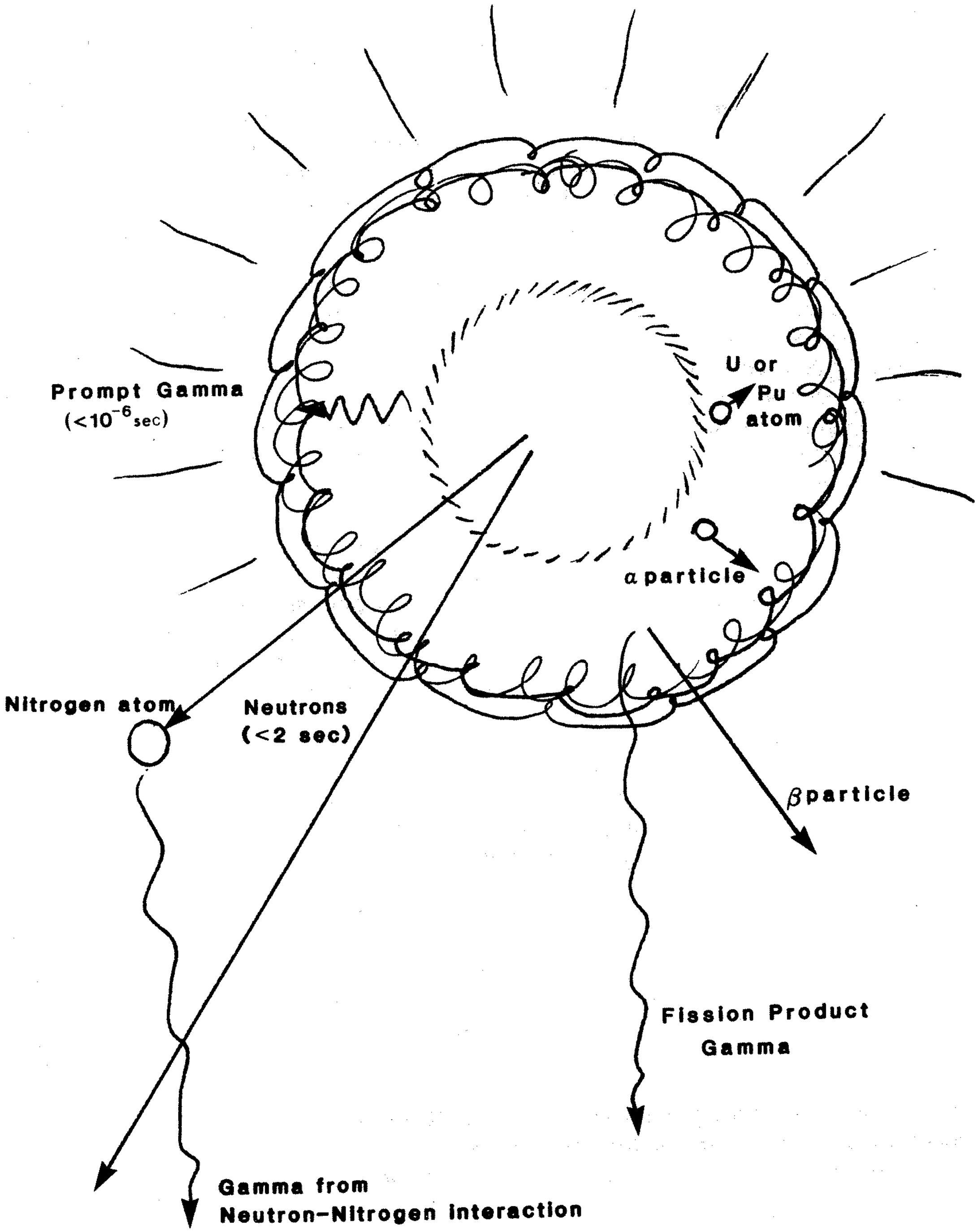
INITIAL NUCLEAR RADIATION

In chapter 3, the effects of the thermal pulse of energy from nuclear detonation were explained. This pulse radiates energy mainly in the visible and infrared band of frequencies of the electromagnetic spectrum. This thermal pulse of radiant energy could cause burns to exposed persons and start fires in light combustible materials. In chapter 4 the effects of the electromagnetic pulse of frequencies below the infrared band were discussed. This “EMP” energy was found to be collected by electrical conductors so that it could cause damage to electronic and electrical equipment. In this chapter we will be concerned with gamma neutron radiation. Gamma radiation is electromagnetic radiation of extremely high frequency, and consequently very short wavelength, as shown in panel 1 of chapter 3. Neutron radiation will be discussed in panel 3 of this chapter.

Initial nuclear radiation (INR) has been somewhat arbitrarily defined as the nuclear radiation emitted during the first minute following the detonation of a nuclear weapon. This time interval was initially chosen on the basis that by 1 minute the rising fireball and nuclear cloud from a surface burst would be too remote from the earth’s surface to cause any significant nuclear radiation effects. Actually, the main exposure to INR occurs in a much shorter time.

When a nuclear weapon explodes, the fission (or fusion) process produces a number of different nuclear radiations. Within a few tenths of a microsecond any fusion neutrons and over 99 percent of the fission produced neutrons are released along with what is called the “prompt” gamma radiation. The prompt gamma radiation is absorbed in the weapon itself before it begins to come apart and thus is not of interest to us here. The neutrons are uncharged particles of high energy. They lose energy by bouncing off atoms of the various material in their path (scattering), eventually being captured in some atom. Both the scattering and capture process can result in the production of gamma radiation.

The uranium (U) or plutonium (Pu) which undergoes the splitting, or fission, process gives rise to the fission products. There are 40 or so ways in which the original atom can split when fission occurs, hence about 80 different initial fission fragments are produced. These are radioactive forms (radioisotopes) of the lighter elements that undergo successive radioactive decay by emitting charged beta particles until the final nucleus is stable. This decay is generally accompanied by gamma radiation. More than 300 different isotopes of 36 elements have been identified among fission products. Since the decay process for some of the fission products begins upon their formation, fission product gamma radiation and beta radiation form part of the initial radiation. Finally, any U or Pu atoms not undergoing fission give rise to alpha particles as they decay, but their contribution, and that of the fission product beta radiation, to the INR may be neglected.



Nuclear Radiation from a Weapon

PANEL 1

GAMMA AND NEUTRON RADIATION

Most people are familiar with the medical uses of X-rays. X-rays are produced when a stream of high-energy electrons is directed against an object. Each element of matter gives off X-rays of characteristic frequencies when bombarded in such fashion. X-rays affect a photographic plate in a way similar to light. The absorption of X-rays in matter depends on the density and composition of the material. Thus, bones absorb more X-rays than the surrounding tissue. This makes it possible to take an X-ray photograph of the bones and organs of a living person. Most people have had such “X-rays” taken at one time or another.

It has been customary to classify electromagnetic radiations by their mode of origin. But the interaction of these radiations with matter is independent of the mode of origin. For practical purposes, gamma rays are like X-rays but they are emitted as the result of changes in the nucleus of the atom. Gamma rays are nuclear radiation whereas X-rays are produced in the outer parts of the atom and could be called "atomic" radiation. The consequences are much the same except that gamma rays are generally more penetrating; and, indeed, photographic film is used to measure quantities of gamma radiation as well as X-radiation.

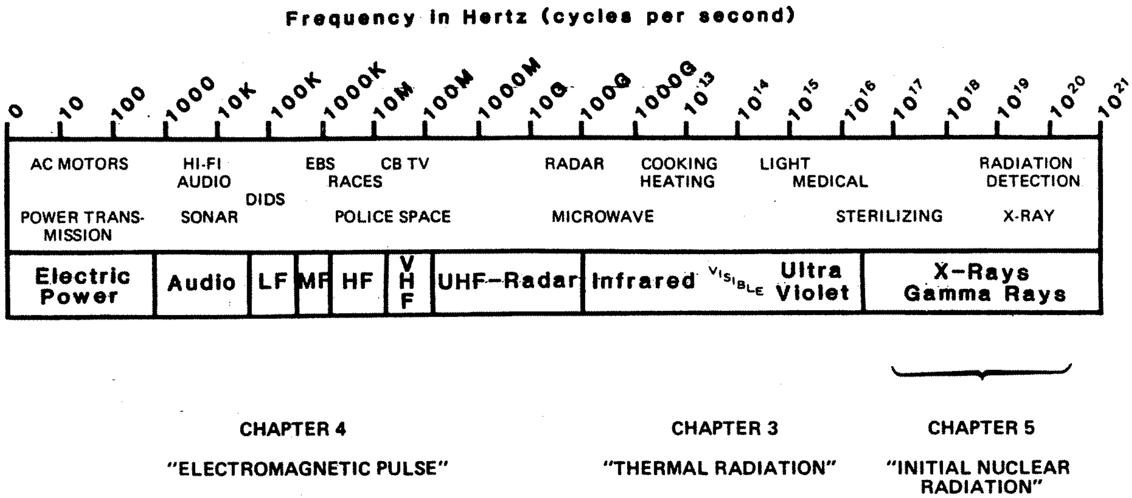
Gamma rays are the main initial nuclear radiation from megaton and large nuclear detonations and are the major component of the INR from smaller yield weapons except at the higher overpressures. We saw in chapter 3 that thermal radiation is largely absorbed in the surface layers of materials and living things. Gamma radiation, on the other hand, is highly penetrating; large masses of earth or concrete are required to protect against it.

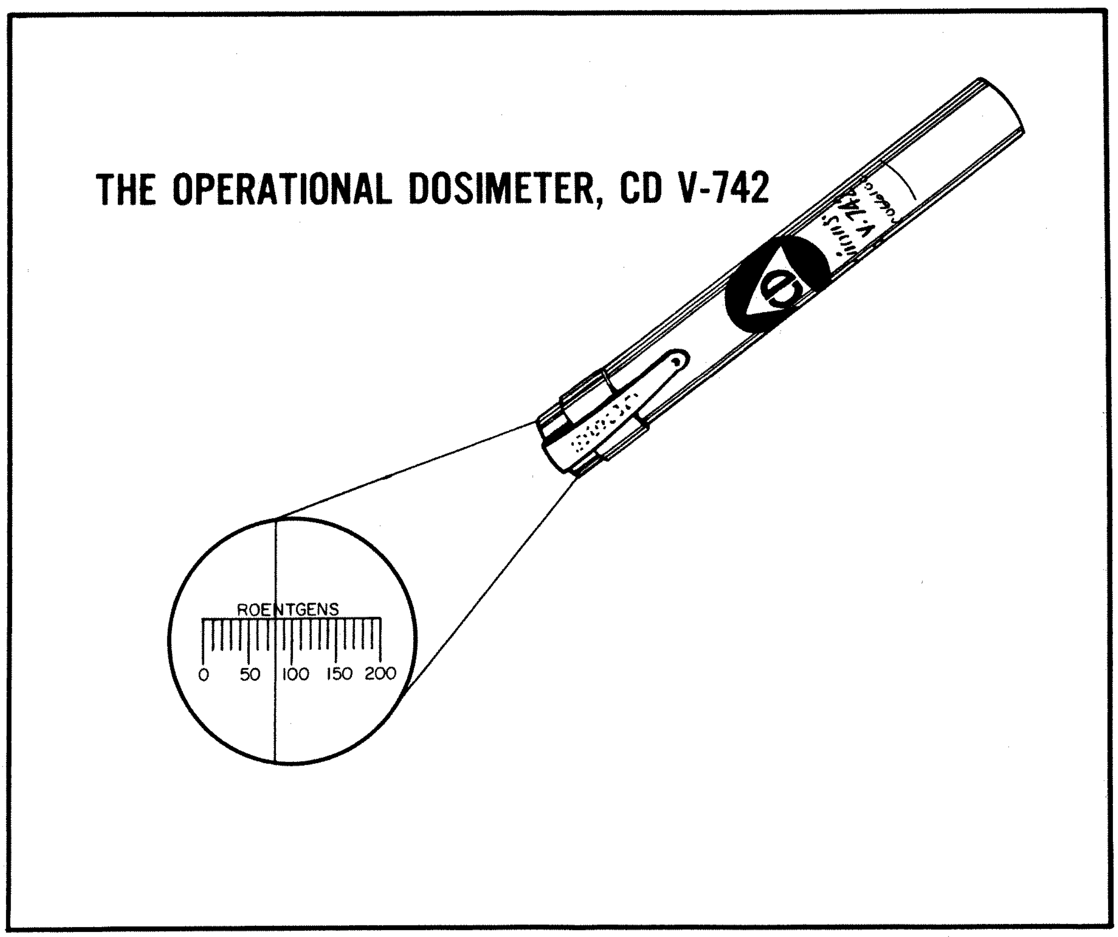
In penetrating materials, including air, gamma rays may be absorbed or changed in direction (scattered) through interaction with the atoms of the material. When gamma rays are absorbed, ions are formed. An ion is an electrically charged atom or group of atoms. Thus, gamma radiation is a form of ionizing radiation.

Exposure to gamma radiation is measured by the amount of ionization produced in air. The unit of exposure used in this manual is the roentgen (R). The device shown here, called a dosimeter, reacts to the ionization produced by gamma radiation and, hence, measures the radiation exposure in roentgens.

Neutrons being neutral particles as described in panel 1 do not produce ions directly but only through interaction of the charged particles and gamma radiation produced by neutron scatter or capture. Neutrons scatter more easily than gamma radiation and thus tend to have a greater angular distribution and to scatter down entranceways, ventilation ducts, etc. The best neutron absorbing materials tend to be those comprised of elements of low atomic mass (water, earth, concrete) and special elements such as boron, cadmium, samarium, europium, gadolinium.

THE ELECTROMAGNETIC RADIATION SPECTRUM





The Operational Dosimeter, CD V-742

RADIATION INJURY

Emergency planners are concerned with gamma radiation because of its capacity to injure people. Injury is caused by the ionization produced in the body by gamma radiation. Broadly speaking, ionizing radiation acts more like cumulative chemical poisons than like physical causes of injury, such as blast, missiles, and thermal radiation. Like chemicals, large single doses can cause severe acute sickness or death, depending on the size of the dose and individual susceptibility. On the other hand, small daily doses can be incurred over extended periods of time without causing illness, although delayed consequences may become apparent later in life, and genetic damage may show up in subsequent generations.

Initial nuclear radiation is a single brief pulse of ionizing radiation. Most of the available information about acute radiation injury is based on experience with single, large exposures. Although much of the information is indirect, more is known about radiation than about most other injurious agents, such as chemical weapons, blast, and the like.

Radiation injury is a collective term used to describe all kinds of biological effects grading in severity from the undetectable to the fatal. The effects of a brief exposure that are known with greatest confidence are shown on this table. Lethal exposures--those that are likely to kill 10 percent, 50 percent, or 100 percent of those exposed--are known with less confidence. A given exposure to radiation will not have the same effect on everyone. Differences in susceptibility among individuals is characteristic of all living creatures. In laboratory studies of the effects of radiation and toxic chemicals on animals, this variation in response makes it useful to determine the exposure or dose that will kill half the animals exposed. This is called the median lethal dose (LD_{50}). The best estimate of the LD_{50} for humans is 450 R*. The dose that causes few deaths (odds of surviving about 10 to 1) is about half the LD_{50}. The 95 percent lethal dose (odds of surviving are 1 in 20) is less than twice the LD_{50}.

It will be noted that the term, “dose,” is used for radiation as it is for toxic chemicals. Another term that the planner may encounter is the “rad,” the standard unit for absorbed radiation. For gamma radiation, the rad is about equal to the roentgen measure of exposure. The emergency planner can regard the units roentgen, rad, and rem as interchangeable for practical purposes. Also, the terms exposure, dose, and dose equivalent may be considered to have the same meaning.

An internal commission, Le Systeme International d’Unites (SI), has established new basic units, including units for measuring radiation. This manual, however, retains the roentgen as the unit for measuring radiation exposure, because it is familiar to the emergency preparedness community and is the unit used by current civil defense radiological instruments

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Some evidence exists that the LD_{50} for INR is about 250 rads to the bone marrow. The figure of 450 R is more appropriate for fallout radiation.

EFFECTS OF A BRIEF GAMMA EXPOSURE

Smallest exposure detectable by statistical study of blood counts of a large group of exposed people	15 R
Smallest exposure detectable in an exposed individual by laboratory means	50 R
Smallest exposure that causes vomiting on day of exposure in about 10 percent of exposed people	75 R
Smallest exposure that causes loss of hair in second week in about 10 percent of exposed people	100 R
Largest exposure that does NOT cause illness severe enough to require medical care in majority of people	200 R

Adapted from Reference 5

PANEL 3

RADIATION SICKNESS

The short-term consequence of overexposure to nuclear radiation has been called radiation sickness. Signs and symptoms associated with the digestive system are those seen earliest and at the lowest exposure levels. This table shows the exposures that will cause about 50 percent incidence of various symptoms of radiation sickness. This prediction is based on clinical data from irradiated hospital patients.

The blood forming organs, mainly the bone marrow, are the most sensitive parts of the body, but observable signs of blood changes develop later and are more evident at higher exposures. These changes result in lowering of the resistance to infection through depression of the body's immune system. This effect does not become significant except at or above exposures comparable to the LD_{50}. When fatalities occur, they are often the result of complicating infection. At progressively higher levels of exposure, the gastrointestinal tract and then the central nervous system are affected.

Radiation sickness is not a communicable disease. It cannot be transmitted to others. In this respect, it is similar to chemical or food poisoning. Indeed, the problem is not protecting others from the radiation victim, but rather protecting the radiation victim from infection from others.

Another point to be noted in the table is that the symptoms that occur earliest and after lowest exposures--particularly nausea and vomiting--are symptoms also of simple anxiety, stress, and fear. Moreover, one or two persons exhibiting these symptoms in a crowded, close environment can induce nausea and vomiting in others. Since radiation injury itself is not painful or otherwise apparent until symptoms of sickness appear, random reactions to the stress of the emergency could be erroneously interpreted as radiation sickness.

ESTIMATED SINGLE RADIATION EXPOSURES THAT
WILL CAUSE 50 PERCENT INCIDENCE OF SYMPTOMS

Signs and Symptoms of Radiation Sickness	Single Exposure (roentgens)	95 Percent Confidence Range (R)
Loss of Appetite	180	150 - 210
Nausea	260	220 - 290
Fatigue	280	230 - 310
Vomiting	320	290 - 360
Diarrhea	360	310 - 410

Adapted from Reference 5

PANEL 4

LEVELS OF SICKNESS

The general course of radiation sickness can be described in understandable terms. It is described here because most people have little knowledge of it, and some familiarity may aid in emergency planning. Grim as some of the description is, it is no more grim than the consequences of massive burns or blast injury.

Unapparent radiation injury occurs when the exposure is less than about 50 R. Level I radiation sickness occurs in the exposure range of 50 R to 200 R. At this level, less than half the persons so exposed will experience nausea and vomit within 24 hours. There are either no subsequent symptoms or, at most, only easy fatigability. Less than 5 percent will require medical care for radiation injury. Others can perform their customary tasks. Deaths that occur are caused by complications such as blast and thermal injuries or infections and debilitating disease.

At Level II, as shown in the Table, more than half of those affected will vomit soon after exposure and will be ill for several days. This will be followed by a period of one to three weeks when there are few or no symptoms. At the end of this latent period, epilation (loss of hair) will be seen in more than half, followed by a moderately severe illness due primarily to the damage to the blood-forming organs. Most of the people in this group require medical care. More than half will survive, with the chances of survival being better for those who received the smaller doses. Note that early and widespread illness does not necessarily make survival unlikely.

The Level III illness is a more serious version of that described for Level II. The initial period of illness is longer, the latent period shorter (one or two weeks), and the ensuing illness is characterized by extensive hemorrhages and complicating infections. Fewer than half will survive in spite of the best medical care, with the chances of survival being poorest for those who receive the largest exposure.

Level IV is an accelerated version of Level III. All in the group will begin to vomit soon after exposure and this will continue for several days or until death, which occurs before the end of the second week, and usually before the appearance of hemorrhages or epilation. Level V is an extremely severe illness in which damage to the brain and nervous system predominates. Symptoms, signs, and rapid prostration come on almost as soon as the dose has been received. Death occurs in a few hours or a few days. Illness of this type has been seen after accidents involving exposure to gamma radiation in excess of several thousand roentgens.

SUMMARY OF RELATIONSHIP BETWEEN EXPOSURE

AND LEVEL OF RADIATION SICKNESS

Exposure Range	Type of Injury	Probable Mortality Rate Within 6 Months of Exposure
0 - 50 R	No observable signs or Symptoms	None
50 - 200 R	Level I Sickness	Less than 5 percent
200 - 450 R	Level II Sickness	Less than 50 percent
450 - 600 R	Level III Sickness	More than 50 percent
More than 600 R	Levels IV & V Sickness	100 percent

Adapted from Reference 5

LATER CONSEQUENCES OF RADIATION EXPOSURE

In addition to acute radiation sickness during the emergency period, other signs of radiation injury can occur months to years after exposure. These late effects are categorized as somatic effects, those occurring in the individual exposed, and genetic effects, those occurring in children of exposed individuals and in subsequent generations. Late somatic effects include those listed here. None of these conditions is caused uniquely by radiation. What the addition of radiation does is to increase the probability of these effects over the standard rate for people of a given age.

Sterility or reduced fertility occurs in many cases of nonfatal radiation sickness, but is temporary in most people. Recovery of fertility may take several years. The risk of developing leukemia is increased by exposure to gamma or neutron radiation. Leukemia has appeared in some of the Japanese who were exposed to initial nuclear radiation, with the majority of excess cases occurring in the first 10 years. The increased incidence appears to be proportional to the dose received. Among the Japanese who survived the largest doses, the incidence was about 50 times the standard rate. For future heavily exposed survivors, this would mean that about 1.5 percent of those 25 to 34, for example, might develop leukemia during a 10-year period instead of 0.03 percent, (the standard 10-year risk rate for leukemia in this age group in the United States).

Among the Japanese survivors, there were about as many cases of cataracts as leukemia--about 100 to 150 cases. Almost all consisted of minor opacity of the lens that did not interfere with vision. Other late effects, such as life-shortening, are not based on human evidence. Results of the continuing study of atomic-bomb survivors have not revealed any consistent evidence of excess mortality (i.e., life-shortening) other than that due to tumor formation for exposures less than approximately 300 R. This same conclusion is also in accord with that of the International Commission on Radiological Protection and the U.N. Scientific Committee on Effects of Atomic Radiation.

Among the somatic effects of radiation other than cancer, developmental effects on the unborn child are of greatest concern. Exposure of the fetus to relatively high doses can cause death (spontaneous abortion), malformation, growth retardation and functional impairment. During the period of organ development in the fetus, doses in excess of about 100 R will cause a high incidence of central nervous system abnormalities. Microcephaly and mental retardation are also associated with acute in utero exposures of more than about 25 to 50 R in the most sensitive time period of 4-13 weeks. Because of genetic and environmental variables encountered in the human population, it is difficult to measure any effects that might be produced by low doses of radiation. At present, it is impossible on the basis of human studies alone to determine, with certainty, a dose below which abnormal growth effects in man are not induced by exposure at sensitive stages in development. Such thresholds do, however, probably exist and they may be higher for protracted exposures than for a single acute exposure.

LATER SOMATIC EFFECTS

Reduced Fertility

Immune System Depression

Leukemia

Cataracts

Other Cancers

Life Shortening

Fetal Injury

Adapted from References 4, 5, 7, and 8

PANEL 6

SOMATIC AND GENETIC EFFECTS

The statements shown here were made in 1967 by Dr. Charles L. Dunham. He was summarizing the views of the professional community at a symposium on the consequences of a nuclear war in which about 3,500 megatons were assumed to be detonated in the United States. As we saw in chapter 1, an attack almost twice as heavy could be delivered today. In the larger war, the number of survivors would be less but the average radiation dose received by the survivors would be much the same as Dr. Dunham's assumption of 200 R. The first quotation refers to the late incidence of new cases of leukemia in the United States is expected to be about 25,600 in 1986 and there will be an estimated 17,400 leukemia deaths. About 130,000 lung cancer deaths (80% due to smoking) are estimated for 1986.

The second quotation refers to the genetic effects--those affecting future generations. Genetic injury does not affect the health of exposed individuals in any way and can be detected only by statistical studies of their descendants. So far, searches for evidence of abnormalities in children conceived after one or both of the parents were irradiated have been unsuccessful. Using pessimistic assumptions, calculations have been made that suggest that major defects in the newborn of succeeding generations might increase to 5 percent from the present rate of 4 percent, assuming that all parents received a dose of 200 to 250 R as a result of an attack.

Both somatic and genetic effects are believed to be directly related to the dose received by the surviving population. Thus, if by effective planning, the protection provided the population could be doubled, the numbers shown here would be cut in half.

PANEL 7

GENERAL PREDICTIONS

“20,000 additional cases per year of leukemia during the first 15 or 20 years postattack followed by an equal number of cases of miscellaneous cancers, added to the normal incidence in the next 30 to 50 years, would constitute the upper limiting case. They would be an unimportant social, economic, and psychological burden on the surviving population.”

"The genetic effects would be lost as at Hiroshima and Nagasaki, in all the other ‘background noise.’”

Dr. Charles L. Dunham
Chairman, Division of Medical Sciences
National Research Council
(1967)

RANGE OF INITIAL NUCLEAR RADIATION

The threat of exposure to injurious amounts of initial nuclear radiation is confined within a radius of about 1 ½ miles from a nuclear detonation. Thus, our hypothetical man standing in the open at 2.2 miles from the ground zero of a 500 KT air burst would be subject to a negligible exposure of less than 1 rad*. Recall that the blast overpressure was about 10 psi, the blast wind about 295 mph. The effect of the thermal pulse would have been fatal. In this table, the radiation exposure in the open is related to blast overpressure for the 200 KT, 500 KT, and 1 MT bursts we have been considering. Significant exposures are limited to the severe blast and thermal damage regions, where the only expected survivors would be in basements or other belowground shelter areas, and are most significant for the lowest-yield weapon.

The amount of initial nuclear radiation at a given location on the earth's surface is related to the slant range from the detonation. If a burst were to occur at higher altitudes as in the case of the air bursts in the table, the initial nuclear radiation would be increased, moreover. Therefore, the surface and near-surface burst presents the most severe initial nuclear radiation threat with respect to concurrent blast effects.

It will be noted in the table that the initial nuclear radiation from surface and air bursts is greatly different. For 500 KT detonations, the exposure in the open approaches lethal levels above 12 psi. In chapter 1, we saw that there were many potential shelter areas, mainly in basements, where people could be expected to survive overpressures of 10 psi or more. Moreover, initial radiation exposures would be additive to subsequent exposure to fallout radiations, which is discussed in chapter 6. Therefore, an understanding of the protection afforded by basements and underground shelter areas against initial nuclear radiation is important.

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*To denote that an exposure is due to a combination of neutron as well as gamma radiation, the unit "rad" is used. For neutrons from nuclear weapons, their effectiveness in causing acute radiation injury is almost the same as for gamma radiation. However, for the production of eye cataracts, leukemia and genetic damage, neutrons are several times more potent than gamma radiation of the same energy.

RELATIONSHIP OF BLAST AND INITIAL RADIATION
(Air and Surface Bursts)

Blast Overpressure (psi)	Initial Nuclear Radiation (rad)		
	200 KT	500 KT	1MT
1	Negligible	Negligible	Negligible
2	Negligible	Negligible	Negligible
5	Negligible (30)	Negligible (5)	Negligible (5)
10	10 (1,200)	Negligible (350)	Negligible (90)
12	25 (2,200)	1 (700)	Negligible (250)
15	80 (6,200)	10 (2,800)	2 (1,200)
20	2,600 (14,000)	65 (8,100)	250 (4,500)

Air bursts are at heights to maximize extent of 10 psi.

Values in parentheses are for surface bursts.

Adapted from Reference 8

PROTECTION AGAINST INITIAL NUCLEAR RADIATION

Here we show again the table of relative blast protection given in chapter 2. A measure of the protection afforded against initial nuclear radiation (INR) has been added in parentheses.

The measure is given in terms of an “INR protection factor (IPF),” which is the ratio of the dose in the open to the dose in the location described, at the same distance from a nuclear detonation. A high protection factor means good radiation protection.

The lower number shown relates to locations near entrances, windows, and other openings where protection is least; the higher number pertains to locations remote from such openings. Since blast protection is also least near such openings, avoiding these areas for the sheltering of people as described in chapter 2, will increase the protection against initial nuclear radiation.

It can be seen that aboveground parts of buildings offer little protection--about a factor of 5 at the most. Most survivors in the region above 10 psi will be in basements, subbasements, and underground areas. Here, the INR protection factor is at least 10 and can be as high as 10,000, except in residential basements where a factor of 10 is the most to be expected. Survivors in residential basements would thus have received a hundred rads or more.

Except in these areas, initial radiation does not appear to be an important threat to life. The emergency planner needs to know the facts about initial nuclear radiation largely because the trend toward the deployment of smaller weapons may continue in the future.

TYPICAL INR PROTECTION FACTOR RANGES
RELATIVE TO BLAST PROTECTION

<u>Description</u>

1. Special facilities (Mine, Cavern, Cave, Tunnel, Subway, etc) (10-10,000).

2. Basement(s) of large structures where the basement overhead floor system is other than wood, flat plate or flat beam. Sub-basements (100-1,000).

3. Basement(s) of wood frame (4-8) and/or brick veneer structures (5-10). Includes residences.

4. First story, second and third story of "strong walled" structures, and no single story has a "side" with 50% or more apertures (2-5). For buildings with three or less stories, the topmost story is automatically eliminated.

5. Basement(s) of structures where the basement overhead floor system is flat plate or slab supported by a flat beam. (10-100).

6. Upper stories of wood frame structures, or structures with weak exterior walls, or excessive apertures (1-4).

Adapted from Reference 2

INITIAL NUCLEAR RADIATION FROM "SMALL" WEAPONS

As we have seen, the initial nuclear radiation is greatly increased relative to blast as the weapon size is decreased, so that survival in ordinary structures may be limited by the lack of initial radiation protection. Since many smaller detonations may cover a sprawling target area complex more efficiently or permit more effective attack against separated industrial facilities, airports, and other key targets, the trend toward deployment of warheads in the kiloton-yield range may continue.

Nuclear weapons in the range of tens to a few hundreds of kilotons also differ from larger megaton-range weapons in the nuclear processes employed in creating an explosive release of energy. About half the energy in large-yield weapons comes from fission of heavy elements like uranium. The remainder comes from fusion of light elements, such as hydrogen. Some small-yield weapons may use only the fission process, as was the case at Hiroshima and Nagasaki. In describing large-yield weapons, we have assumed 50 percent fission yield.

When the explosive power of a nuclear weapon is changed, the extent of blast overpressure varies as the cube root of the change in explosive power. Thus, the extent for a 1 KT detonation is 1/10 of that of a 1 MT detonation (one that has 1,000 times more explosive power) and the extent for a 40 KT detonation is about 1/3 times that of a 1 MT burst. The extent of INR is reduced somewhat but not nearly as much as are the blast overpressures. Consequently, the INR exposure becomes increasingly large at a given overpressure as the weapon yield is reduced, as shown here.

At short range, (where the 5-psi overpressure level occurs at a mile or two from ground zero), neutrons are an important constituent of INR in addition to gamma radiation. As can be seen, at 5 psi the proportion of neutrons increases as the weapon yield decreases.

For 40 KT detonations, INR is significant in the moderate damage region (2 to 5 psi). Further, our imaginary person in the open at 10 psi (about 7/10 mile from Ground zero for a surface burst) is exposed to about 8,000 rem. The protection afforded by a residential basement (5 to 10 IPF) would be insufficient. Only the better parts of large building basements, subbasements, and subways would permit survival.

At higher yields (over 100 KT), INR exposure in the area of severe damage would not be as high but basement protection would be essential and survival possibilities are clearly limited by the INR exposure. For the air burst cases where the height of burst maximizes the ground range of 10 psi, only at overpressures approaching 20 psi or for weapons at 100 KT or less would the INR be a problem in buildings.

RELATIONSHIP OF BLAST AND INITIAL NUCLEAR RADIATION

SURFACE BURSTS

Blast Overpressures (psi)	Nuclear Radiation (rad)				
	40KT	100KT	200KT	500KT	1MT
1	Neg	Neg	Neg	Neg	Neg
2	5 (1)	12 (1)	Neg	Neg	Neg
5	660 (15)	120 (12)	30 (3)	5 (1)	5 (Neg)
10	7800 (28)	2400 (22)	1200 (10)	350 (3)	90 (Neg)
15	27000 (40)	9600 (28)	6200 (16)	2800 (5)	1200 (2)
20	52000 (45)	21000 (34)	14000 (20)	8100 (7)	4500 (2)

AIR BURSTS
(Height of bursts to maximize extent of 10 psi)

Blast Overpressures (psi)	Nuclear Radiation (rad)				
	40KT	100KT	200KT	500KT	1MT
1	Neg	Neg	Neg	Neg	Neg
2	Neg	Neg	Neg	Neg	Neg
5	24 (8)	Neg	Neg	Neg	Neg
10	440 (19)	60 (16)	10 (1)	1 (Neg)	Neg
15	1600 (29)	300 (23)	80 (11)	10 (1)	2 (Neg)
20	20000 (45)	5900 (38)	2600 (26)	650 (10)	250 (2)

Parentheses show percent of neutrons.

Adapted from Reference 8

PANEL 10

WHAT HAPPENED AT HIROSHIMA

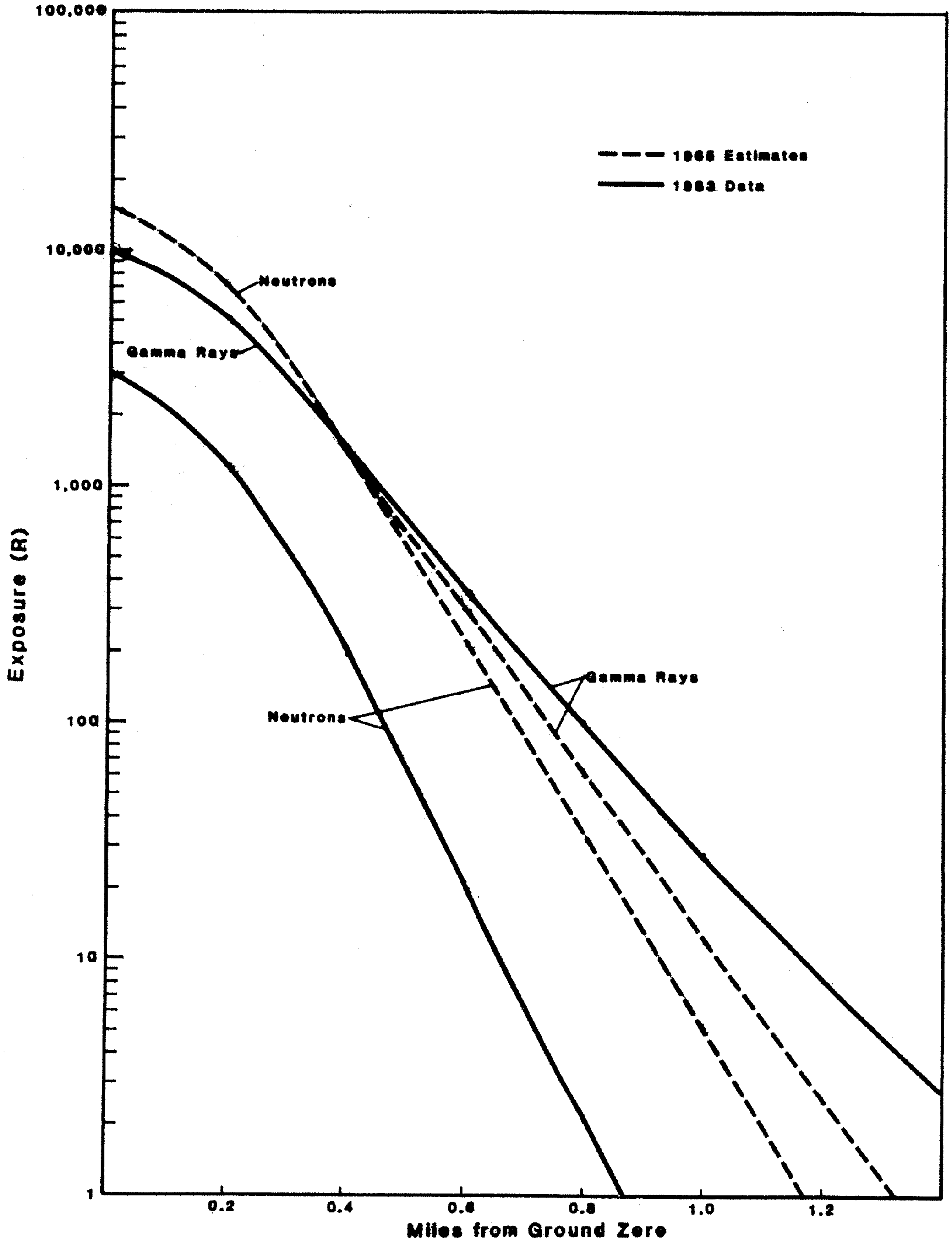
At Hiroshima, casualties were the result of a combination of the three major "direct" effects but blast and thermal radiation seemed to be the dominant causes. The weapon was relatively small (about 15KT) and exploded at about 1,900 feet. It was a clear morning with a large number of people in the streets at the time. The maximum blast overpressure was about 30 psi on the ground directly under the bomb, and the initial radiation dose there was about 13,000 rad. However, as shown on the previous panel, the initial nuclear radiation exposure reduces rapidly with increased distance from the weapon.

At 8 psi blast overpressure, where more than half the people in the Japanese houses were killed, the INR exposure was about 200 rad, too low to cause death. If the weapon had been detonated within a few hundred feet of the ground, initial nuclear radiation would have been the most important cause of death. For example, at 8 psi, the INR exposure would have been nearer 7,000 rad and the shielding provided by the houses would not have prevented almost 100 percent fatalities from the INR. In discussing the threat of initial nuclear radiation, we have assumed that air bursts would occur. If this is not the case, the threat from INR would be greatly increased.

Radiation doses received by the survivors of the Japanese bombings were estimated in increasingly sophisticated studies between 1950 and 1965. The latest of these, designated as TD65, were used in risk assessment studies throughout the 1970's. More recently, these TD65 values have been subjected to critical review as a result of concern over radiation protection standards. A 1978 controversial stuffy of leukemia risks indicated a large relative effectiveness for neutrons at low doses in Hiroshima. At the time, it was believed that the effects observed among the Hiroshima population were primarily due to neutron radiation while those at Nagasaki resulted from gamma radiation. In the 1980's, numerous programs for reassessment of the A-bomb radiation dosimetry have been instituted at national laboratories, universities, and private firms both in the U.S. and Japan. Review and oversight of the reassessment are being provided by committees appointed by the U.S. National Academy of Sciences and the Japanese Ministry of Health and Welfare. Their role is to ensure that the programs have a fire scientific basis and that the final results are formulated for specific application to the epidemiological studies on the A-bomb survivors by the joint U.S.-Japan institution known as the Radiation Effects Research Foundation (RERF). The data from the RERF studies form the largest resource of information on human radiation responses, particularly leukemia, cancer, and genetic effects. The value of the data is dependent, however, upon the accuracy of the radiation dose estimates for each individual in the affected populations of the two cities.

Certain of the modern studies using newer calculational techniques have indicated that the neutron radiation in Hiroshima was overestimated and that the effectiveness of neutrons cannot be obtained from the health effects among the A-bomb survivors. The facing panel reflects the results of one study.

COMPARISON OF VALUES AND STATE-OF-THE-ART CALCULATIONS FOR INITIAL NUCLEAR RADIATION IN HIROSHIMA



Adapted from Reference 13

PANEL 11

BLAST EFFECTS OF "SMALL" WEAPONS

Although the employment of multiple warheads consisting of many nuclear weapons by the Soviet Union is a possibility we hope will not materialize, the emergency planner should keep in mind the ways in which the other direct effects of small weapons differ from those in the yield ranges that have been emphasized so far. In addition to initial nuclear radiation, there will be changes in the blast and thermal effects. These changes will be most apparent in the 40 to 100 kiloton range.

Shown here is the general picture of the blast protection afforded by ordinary buildings. The median lethal overpressure values given in chapter 2 for 200 KT to 1 MT yield weapons is shown in parentheses. One can see that, in general, people could survive at higher overpressures for low-yield explosions. For a 40 KT detonation, the blast wind persists for about one second. Debris is not blown as violently as in megaton detonations. Since people are injured mainly by blast wind effects, casualties are significantly reduced at corresponding overpressures.

It should be kept in mind, of course, that a table such as this is approximate. The variations due to strong or weak walls and to the design of ground floors over basements would still influence the blast protection afforded by specific buildings. However, the hazard of being blown out of upper stories would be greatly reduced, as would the effects of air blast penetrating into basement rooms. Debris, of course, would tend to remain on site, with less interference with movement but more problems in search and rescue of trapped survivors.

And because of the generally increased survivability at given overpressures, the potential threat from initial nuclear radiation would be increased.

BLAST PROTECTION IN CONVENTIONAL BUILDINGS

From Low-Yield Weapons

	Median Lethal Overpressures (MLOP)	
Location	Residences	National Facility Survey Buildings
Aboveground	7 psi (5) *	9 psi (5-8)
Belowground	12 psi (10)	14 psi (10)

*MLOP for 200 KT to 1 MT weapons.

FIRE EFFECTS OF "SMALL" WEAPONS

The extent of thermal radiation from lower kiloton-yield weapons is less at corresponding blast overpressures than for higher yield weapons, as shown in the upper table. On the other hand, the thermal energy is delivered in a much shorter time period. Hence, the critical ignition energies are lower. The result is that the limit of significant ignitions remains about the same--approximately the range of 2 psi blast overpressure.

Visibility conditions affect low-yield weapons less than large-yield weapons because of the short ranges involved. Air bursts of low-yield weapons extend the range of low overpressures more than the thermal effect. The experimental evidence on the extinguishment of ignitions by the blast wave applies to low-yield weapons as well as high-yield weapons.

RELATIONSHIP OF BLAST AND HEAT
(Surface Burst on a Clear Day)

Blast Overpressure (psi)	Heat Radiation (cal/sq. cm) 40KT	100KT	500 KT
1	3	4	4
2	8	10	11
5	25	33	38
10	55	74	92
20	118	157	200

IGNITION ENERGIES FOR KINDLING FUELS
(cal/sq. cm.)

	Weapon Yield 40KT	100KT	500 KT
GROUP I			
Crumpled newspaper, dark picture	5	6	6
Black lightweight cotton curtains	3	4	5
Dry rotted wood and dry leaves	4	5	5
GROUP II			
Beige lightweight cotton curtains	10	15	23
Kraft corrugated paper cartons	16	18	18
White typing paper	24	26	30
Heavy dark cotton drapes	15	15	16
GROUP III			
Upholstered furniture	12	16	25
Beds	8	11	20
Wood shingles	90	100	125

Adapted from Reference 8

SUMMARY

We can summarize what the planner needs to know about initial nuclear radiation by noting the following facts:

(1) Given the weapons in the range of yields that the Soviets have at present, initial nuclear radiation is mainly of interest to the designers of blast-resistant structures and in the survey of best available shelter from direct weapons effects.

(2) If multiple-warhead weapons of lower yields, say 100 KT or less, should be employed by the Soviets, many areas that would otherwise offer good blast protection may not offer sufficient protection against initial nuclear radiation. In effect, there would be less "all-effects" protected space in existing buildings.

(3) As will be seen in the next chapter, radiation exposures from initial nuclear radiation and fallout are additive. Thus, less than lethal exposures to initial nuclear radiation can make subsequent exposure to fallout radiation a very serious matter under current fallout protection standards. This could be of significance for survivors inside the 12-15 psi region from the many 500 KT to 1 MT weapons that are part of the Soviet threat.

INITIAL NUCLEAR RADIATION
IS IMPORTANT:

(1) To designers of blast resistant structures and in all-effects surveys.

(2) If and when low-yield multiple warheads became a threat.

(3) Because any initial radiation exposure will reduce the amount of subsequent fallout radiation exposure that can be accepted.

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