Introduction

U.S. Position

The U.S. position is that there is no conventional or customary rule of law specifically prohibiting the use of nuclear weapons and hence that the use of such weapons is presumptively lawful. The United States recognizes, however, that the law of armed conflict, including the established rules of necessity, proportionality, discrimination, civilian immunity, neutrality, moderation, and humanity, apply to the use of any weapon, including any nuclear weapon—and acknowledges that the use of a nuclear weapon would be unlawful if, in the circumstances, it would violate any of these rules.

The United States asserts that nuclear weapons, for this purpose, are indistinguishable from conventional weapons: The legality of their use must be determined on a case-by-case basis based on the particular circumstances of each possible use.

In taking this position, the United States recognizes that, under these rules, the lawfulness of the use of nuclear weapons turns largely on the likely effects of such use. The U.S. defense before the International Court of Justice (ICJ) of the potential lawfulness of use of nuclear weapons was premised in major part on the United States' asserted ability to use certain such weapons (ostensibly, precision low-yield tactical ones) in such a way and in such circumstances as to limit and control their effects, including their radiation and, ostensibly, their escalation effects.

The United States recognizes that the use of nuclear weapons would be unlawful under the rules of necessity, proportionality and discrimination if the effects of the use would not be controllable and actually controlled during the strike.

The United States further recognizes that the strike would be unlawful under the rule of necessity if it was not actually necessary to use the nuclear weapon to achieve the particular mission, *i.e.,* if conventional weapons would suffice.

The United States similarly recognizes that the strike would be unlawful under the rule of proportionality if its effects on protected persons would likely be disproportionate to the concrete and direct military benefits of the strike.

Likewise it recognizes that the strike would be unlawful under the rule of discrimination if its effects could not discriminate military from non-military targets so as to avoid disproportionate collateral injury to protected persons.

The United States' defense of the lawfulness of these weapons before the ICJ was thus specifically based on its contention that it is able to deliver nuclear weapons (ostensibly, a small number of precision low-yield tactical devices) accurately and directly against discrete military targets in remote areas, and of doing so in such a way as to control and limit resultant nuclear radiation and not endanger substantial numbers of noncombatants. The United States further told the Court that the potential effects of using nuclear weapons are not materially different from using modern conventional weapons and disputed that the limited use of low-yield nuclear weapons would necessarily escalate into a strategic nuclear exchange.

The Existence of Binding Legal Standards

The striking point is that, notwithstanding the obvious political and national security issues that are present, there is law in this area, and that the United States recognizes such law,[1] and indeed, as we shall see, has integrated it into its military training and contingency planning. Perhaps even more striking is that the proponents and opponents alike of the nuclear weapons regime generally agree on the substance of such governing rules of law.

The ICJ's Nuclear Weapons Advisory Opinion

The ICJ, in its 1996 advisory opinion as to nuclear weapons, mirrored the United States' non-defense of the lawfulness of the use of large scale nuclear weapons, but found itself unable to decide whether a more limited use of nuclear weapons could ever be lawful.

Specifically, the Court determined that, because of the potential of nuclear weapons to destroy civilization and the entire ecosystem of the planet, the use of nuclear weapons would generally be unlawful, but that it was not in possession of sufficient facts to evaluate whether use of nuclear weapons (ostensibly, precision low-yield tactical ones) could be lawful in extreme circumstances of self-defense when a State's survival was at stake.

The Court stated that it did not have sufficient facts to determine the validity of the argument of the United States and other nuclear weapons States to the effect that highly accurate low-yield tactical nuclear

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[1] There are additional points of international law that are, in fact, in contention.

weapons could be used in such a way as to limit and control their effects.

Approach

The U.S. position and the ICJ decision constitute the starting point of my analysis: The Court may not have had the facts, or even fully recognized the scope of the potentially relevant facts, but the facts exist, and are generally unclassified and openly available. We need to identify them, put them on the table and examine them in the light of the applicable law.

My analysis proceeds on two levels. First, I develop the applicable law as articulated by the United States and apply it to widely recognized and ostensibly incontrovertible facts as to nuclear weapons. Secondly, I develop certain additional principles of law which appear to be so widely recognized as to constitute binding principles of international law, and similarly apply them to the facts as to nuclear weapons.

The U.S. position and the ICJ decision are covered in Part I (Chapters 1–3); additional principles of law are covered in Parts II and III (Chapters 4–14); and the facts are covered in Part IV (Chapters 15–28). My conclusions are set forth in Part V (Chapters 29–30).

Analysis Based on U.S. Statements of the Law

Under this approach, I base the analysis upon the United States' own statements of the applicable law and upon statements of the facts so widely recognized as to be essentially incontrovertible.

The law of armed conflict is communicated to the U.S. military through military manuals setting forth such law for training and planning purposes and directing the military as to the legal restrains within which they operate. In Chapter 1, I review descriptions from U.S. military manuals of the rules of armed conflict applicable to the lawfulness or unlawfulness of the use of any weapon.

In Chapter 2, I review statements from the military manuals and from arguments of the United States before the ICJ setting forth the United States' position as to the application of such rules of law to the use of nuclear weapons. Here, we see some retrenchment from the generic statements of the applicable rules, as described in Chapter 1, but the United States' defense of these weapons is still largely on a factual level: that it can use the weapons in such a way as to keep their effects within legal limits.

Applicable Factual and Legal Questions

The U.S. focus, in its defense of nuclear weapons before the ICJ, on the asserted lawfulness of the surgical use of precision low-yield nuclear weapons against remote targets staked out not only a factual position as to the characteristics and effects of nuclear weapons and their delivery systems, but also an implicit legal position as to the scope of the facts relevant to the analysis.

Specifically, the U.S. position implies that, in evaluating the lawfulness of the limited use of precision low-yield tactical nuclear weapons, one should look at the matter in the abstract, in a hypothetical test tube type fashion, without reference to the risk factors that will inevitably be present, even with the most limited of uses, including such risks as those of hitting the wrong target or of precipitating a nuclear, chemical or biological weapons response and resultant escalation to more widespread use of such weapons.

The extent of such risk factors is only heightened by the fact that the circumstances in which the United States might actually consider the use of nuclear weapons would by definition be ones of extreme military challenge and hence of volatility, with considerable pressures of all kinds upon people and equipment.

Need for Evaluation Based on Probabilities

If it were possible to wait and see what happened, with at least the theoretical prospect of a war crimes prosecution if the strike turned out to exceed permissible limits, the integrity of the legal safeguards (and deterrent) could be preserved. But with nuclear weapons, of course, there may be no such luxury of hindsight. If the law is to be applied at all, it must be in advance, when only estimates of probabilities can be known (Chapters 1, 15, 29, 30). That limitation is inescapable, yet our thinking, as manifest by the treatment of the matter before the ICJ (Chapters 2, 3), has yet to come to grips with this aspect of the matter.

The issues as to the scope of the relevant facts and the appropriate treatment of probabilities were not focused on by the United States in its arguments to the ICJ or addressed in any depth by the ICJ in its decision, and appear not to have been much focused on at all in the literature on this subject (Chapters 2, 3). Yet they seem to be the heart of the matter.

Nor are they beyond the ability of legal systems to address. The imposition of civil and criminal liability based upon unjustifiable risk creation is a central function of law throughout the world.

The applicable rules of law, as described by the United States (Chapters 1 and 2) and as reviewed by the ICJ in its decision (Chapter 3), provide guidance as to the scope of relevant facts, and, hence, as to the consideration that must be given to probabilities in conducting the legal analysis: The rules of necessity, proportionality, and discrimination, and even those of civilian immunity and neutrality, are rules of reason (Chapter 1). Compliance is to be evaluated in light of all of the reasonably available facts, including particularly those bearing on the likely effects of the use of nuclear weapons.

Range of Factual Issues

This brings into the analysis a far wide range of facts, including such matters as the following:

- The characteristics, capabilities, and effects of nuclear weapons and their delivery systems (Chapter 15);
- U.S. declaratory and operational policy as to the circumstances in which it might use nuclear weapons and its assumptions as to how other States might act (Chapters 16-18);
- the U.S. nuclear force structure, consisting of the nuclear weapons available for use and whose potential use is the subject of U.S. military training and contingency planning (Chapter 19);
- the practical experience as to the times the United States has threatened or considered the use of nuclear weapons, reflecting the types of nuclear risks the United States has been willing to take and hence potential risk factors in the event of major confrontation in the future (Chapter 20);
- probabilities of as to the accuracy with which the United States could likely deliver nuclear weapons to designated targets (Chapter 21);
- risks inherent in the nuclear weapons regime, including the risks of inadvertent use and of precipitating undesired intentional use (Chapter 22);
- the nuclear arsenals of other States, reflecting the scope of volatility as to weapons that might be brought into play in the event of a major international confrontation (Chapter 23);
- the risks of escalation and other excessive effects (Chapters 24–26);

- the risks that even a limited use of nuclear weapons would precipitate use of chemical or biological weapons, and *vice versa* (Chapter 27); and
- the potential of today's high tech conventional weapons to accomplish missions for which nuclear weapons might previously have been considered (Chapter 28).

Potential *Per Se* Unlawfulness Based on Overall Facts

The question is whether such risk factors are so inherent in the use of nuclear weapons, in the types of circumstances in which such weapons might be used, and so serious, as to render even the most limited use of nuclear weapons unlawful. This is the central theme of the fact chapters (Chapters 15–28), and I attempt to pull it all together in Chapters 29 and 30.

Application of Established Principles of Law

The United States further argued to the ICJ there can be no *per se* rule prohibiting the use of nuclear weapons unless the United States has specifically agreed to such a rule. This raises legal issues as to the nature and sources of international law, and specifically as to the role of general principles of the law of armed conflict, such as those referred to above: Are such principles binding no matter how they cut, or is their application subject to the consent of the individual State against which they are being applied. I address this issue in Chapters 1 and 29.

Requisite Mental State for War Crimes Liability

One way of approaching the question of potential culpability for risk creation is through the required mental state for the violation in question. Is it required, for example, as the United States has at times ostensibly contended, that, to be unlawful, a particular use of nuclear weapons would have to necessarily involve the deliberate causing of impermissible effects, or are recklessness, wantonness, gross negligence or even simple negligence sufficient? I address the U.S. position on the issue in Chapters 1, 2 and 29, and analyze the issue more broadly in Chapters 6–9, and 30.

Interpretation of Law in Light of Its Purpose

As addressed in Chapter 5, it is a fundamental principle of construction that international law, like law generally, is to be interpreted and applied in light of its purposes. In Chapter 1, I address

U.S. statements as to the purposes of the law of armed conflict, and in Chapter 29 I examine the implications of such purposes.

Analysis Based on Generally Recognized Principles of Law

Where my first approach is based on U.S. statements of the applicable law, this second approach arguably involves an extension of the law, or at least a new focus, namely the recognition that certain rules of law as to the prerequisites for a *per se* rule and as to civil and criminal liability for risk creation are so widely recognized as to constitute binding principles of international law.

Prerequisites for a *Per Se* Rule

For a *per se* rule to arise, is it necessary that every single imaginable use be unlawful, or is it sufficient if most, but not necessarily all, such uses would be unlawful, or if the vast majority of the likely uses, in the circumstances in which such uses would likely take place, would be unlawful. I address this issue in Chapters 1, 2, 4 and 30.

Weighing of Probabilities

A further issue is that of the level of risk of impermissible effects that must be present for unlawfulness to incept. How are risks to be weighted, including particularly small risks of extremely severe, even apocalyptic effects? Such matters can be conceptualized as presenting *mens rea* issues as to the mental state necessary for war crimes liability or substantive issues as to limits on permissible risk creation. I address such matters in Chapters 6–8, and then, in Chapter 9, propose various formulaic approaches for evaluating probabilities as to nuclear weapons risks. I present my overall analysis in Chapter 30.

The “So What” Question

What difference would unlawfulness make, since the weapons cannot be uninvented? This is the inevitable question—the one I have been most asked from all types of audience, as I have been working on this book. The matter must be addressed if we are to substantiate the practicality of concerning ourselves with this issue.

Effects of the U.S. Position of Presumptive Lawfulness

The United States’ position as to the lawfulness of the use of nuclear weapons has significant effects. It means that military training and planning—the whole military mindset—proceed on the assumption that nuclear weapons can be used (Chapters 2, 16–18). Nuclear weapons are a working part of the national arsenal and the military are charged with being prepared to use them, and in fact maintain detailed contingency plans to do so (Chapters 2, 16–19, 26).

In the extreme circumstances in which the President or the military might turn to these weapons, there would likely be little inclination or opportunity to focus on the requirements of international law. Advance planning might have covered some of the ground, but a decision would need be made, probably quickly (as we shall see, likely within minutes or even seconds) and not very clearheadedly, from a mindset of presumptive lawfulness (Chapters 2, 25–26).

The upshot is a substantial likelihood that a possible launch would not be subjected to serious consideration as to the legalities. As reflected in one of the more recent U.S. joint military manuals (applicable to all the services), the U.S. position is functionally equivalent to one of unqualified lawfulness; presumptive lawfulness becomes *per se* lawfulness as far as the constraints of the law are concerned (Chapter 2).

This serves various purposes. Some of the U.S. political and military leadership might contemplate the actual use of these weapons in extreme circumstances, notwithstanding the widescale recognition by the U.S. leadership throughout the nuclear era that nuclear weapons are so destructive and provocative as to make their actual use extremely dangerous (Chapters 24–25).

Most centrally, presumptive lawfulness serves the purpose of legitimizing nuclear deterrence, a policy which, in the contemporary strategic environment, with the end of the Cold War and demise of the Soviet Union, is substantially outmoded, to the extent that, paradoxically, the United States has formally recognized that its greatest security threat is not any enemy needing to be deterred but rather nuclear weapons themselves (Chapters 18, 23, 22, 30).

Significance of Presumed Lawfulness to Deterrence

Military response by the United States in a particular situation will likely be the product not of what the civilian or military decision-makers independently decide to do in the throes of battle, but rather of years of the United States' training of its armed forces, conceptualization and implementation of its force structure, development of contingency and target planning, and the like (Chapters 15–19, 26).

The United States acknowledged as much before the ICJ, in arguing that the credibility of nuclear deterrence depends upon the legality of the use of such weapons. If the use of nuclear weapons were determined to be unlawful, the United States would be required to revise its training, planning, equipment procurement and force structures.

One of the lead U.S. lawyers argued to the ICJ:

> [E]ach of the Permanent Members of the Security Council has made an immense commitment of human and material resources to acquire and maintain stocks of nuclear weapons and their delivery systems, and many other States have decided to rely for their security on these nuclear capabilities. If these weapons could not lawfully be used in individual or collective self-defense under any circumstances, there would be no credible threat of such use in response to aggression and deterrent policies would be futile and meaningless. In this sense, it is impossible to separate the policy of deterrence from the legality of the use of the means of deterrence. Accordingly, any affirmation of a general prohibition on the use of nuclear weapons would be directly contrary to one of the fundamental premises of the national security policy of each of these many States.

The United States further stated in its memorandum to the ICJ:

> It is well known that the Permanent Members of the Security Council possess nuclear weapons and have developed and deployed systems for their use in armed conflict. These States would not have borne the expense and effort of acquiring and maintaining these weapons and delivery systems if they believed that the use of nuclear weapons was generally prohibited.

Perspective of the United States

I have written this book from the perspective of the United States to highlight the extent to which the unlawfulness of the use of nuclear weapons is evident from statements of the applicable law by the United States and essentially incontrovertible facts. Yet the U.S. statements of the law are not gratuitous; they accurately describe rules of law equally binding on other States.

Time of Opportunity

The Cold War developed so quickly upon the heels of the invention of these weapons and the weapons at first appeared to be such a military panacea that there was limited political opportunity or inclination to develop a legal regime limiting their development and potential use. The U.S. position as to the lawfulness of the use of nuclear weapons has its roots in outmoded realities: (1) the existence of a limited nuclear club of which the United States was the charter member; (2) the sense, at least in the beginning, that these are just another weapon; (3) feelings of vulnerability and ideological fervor fueled by the perceived threat from the Soviet Union; and (4) the reigning strategic regime of deterrence.

The current environment presents a realistic opportunity, perhaps the first since the dawn of the nuclear age, to come to grips with the reality that nuclear weapons are so destructive, their effects so unpredictable and potentially apocalyptic (Chapter 15), the likelihood of escalation to a broader nuclear exchange from even a "low-level" launch so great (Chapters 25–26), that denuclearization is a practical and legal as well as moral imperative.

The Cold War taught us that these weapons could end up being used; they were seriously threatened on numerous occasions (Chapter 20). The nuclear club has expanded, as has the potential over time for break-out by other States (Chapter 23). While nuclear weapons previously represented, at least ostensibly, an economic way to deter the Soviet Union from exploiting its conventional weapons superiority (Chapters 18, 22), now it is the United States that has a conventional weapons superiority threatened by the actual or potential nuclear capability of other nations and terrorist forces (Chapters 18, 22).

The recognition of the unlawfulness of the use of nuclear weapons would not necessarily bar possession, and obviously, on some level, at least pending some idealized denuclearized future, deterrence would be implicit and ever present, but, as acknowledged by the United States before the ICJ, the whole mindset as to planning, training, and even thinking, would be radically altered.

Contemporary Role of Nuclear Weapons

The Nuclear Posture Review, a widescale evaluation of U.S. nuclear policy conducted at the highest levels of the civilian and military leadership and adopted by the Clinton Administration, has resulted in a substantial withdrawal from reliance on nuclear weapons, and particularly from tactical nuclear weapons. Nuclear stockpiles have been substantially cut; entire weapons systems, eliminated. MIRVing is in the process of being discontinued; nuclear testing has been stopped; and nuclear weapons budgets have been truncated. Tactical nuclear weapons are no longer placed in the hands of any U.S. ground or naval surface forces. The Army and the Marines have been de-nuclearized; the Navy no longer deploys non-strategic nuclear weapons, and the Air Force has dramatically cut its tactical nuclear stockpile. (Chapter 18).

Even as tactical nuclear weapons have been withdrawn from service and nuclear weapons generally de-emphasized, the mission, for planning purposes, of such weapons has been expanded to include widescale chemical and biological weapons targets (Chapter 27), notwithstanding pledges by the United States at the highest level of government that it would not use nuclear weapons against a non-nuclear State (Chapters 3, 30).

In addition, in the post Cold War era, the U.S. military has emphasized its continued commitment to the integration of such weapons into its active operational planning, as reflected in military manuals, such as the Chairman of the Joint Chiefs of Staff's *Joint Pub 3-12, Doctrine for Joint Nuclear Operations* (Dec. 15, 1995) and *Joint Pub 3-12.1 Doctrine for Joint Theater Nuclear Operations* (Feb. 9, 1996) (Chapters 2, 25-26, 30).

The one area the Nuclear Posture Review notably did not encompass was the legal area. This book represents an effort to foster the United States' coming to grips with this remaining area.

The Uncertain Continuation of the Luck of the Cold War

The stakes are high. On one level, deterrence may have worked, and indeed may have contributed to the demise of the Soviet venture. With its military force checked and the potential for economic and social transformation circumscribed by its inherent limitations and the costs of maintaining the military balance, the Soviet system was unable to survive. On the other hand, human life is long and empire, however brutal and entrenched, short.

However one comes out on the question of whether deterrence worked, we were lucky during the Cold War. Nuclear weapons had just been invented, and this was the first test of our civilization's ability to handle them. Risks were taken that threatened everything. But such luck cannot be counted on; human experience is to the contrary.

Thesis

We are essentially talking about Phase II—in effect, the second historical period—in the effort by our civilization and international legal system to address the challenge of nuclear weapons. My thesis is that the existing rules of law, as recognized by the United States, are adequate to the task, if we face up to the application of these rules to the full panoply of essentially indisputable facts (Chapters 29, 30).

with their bombs and air launched missiles; and long-range cruise missiles.[1232]

While the terminology used to describe non-strategic nuclear weapons varies, such weapons generally include "tactical" or "battlefield" nuclear weapons, with an additional category of "theater" nuclear weapons sometimes being used. Tactical nuclear weapons are short-range or battlefield weapons designed for local use in a particular battle and include nuclear bombs, short range missiles, nuclear artillery and atomic demolition munitions.[1233] Theater nuclear weapons are generally those designed for use in an intermediate range, generally from about 1,500 to 3,000 nautical miles, and designated for use in regional confrontations, generally against targets such as bases and support facilities for the enemy military effort.[1234] Typically, strategic nuclear weapons have been more destructive than the tactical or theater nuclear weapons.[1235]

Radiation Effects of Nuclear Weapons

This, of course, goes to the heart of the issue. What are the likely effects of the use of a particular nuclear weapon, by itself and in the context of likely accompanying and escalatory nuclear strikes?

Radiation

Radiation, the release of energy in the form of alpha, beta, or gamma particles, ionizes atoms in cells through which it passes, stripping neutral atoms of an electron, leaving the atoms positively charged (ionized) and chemically unstable.[1236] Molecules containing such unstable ions then react with other molecules to form new compounds, while the newly freed electrons similarly affect other

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[1232] *See* UNITED NATIONS DEPARTMENT, *supra* note 2, at 11–12. *See also* NUCLEAR WEAPONS DATABOOK, *supra* note 1, at 100–106.

[1233] *See* UNITED NATIONS DEPARTMENT, *supra* note 2, at 11–12.

[1234] *See id.* at 12.

[1235] *See id*. The larger strategic warheads also cause greater collateral loss of life than the tactical warheads. *See* The Effects of Nuclear War, *supra* note 7, at 6.

[1236] *See* JACOB SHAPIRO, RADIATION PROTECTION: A GUIDE FOR SCIENTISTS AND PHYSICIANS 10 (1972). *See also* JOHN W. GOFMAN, RADIATION AND HUMAN HEALTH 62 (1983) (stating that the release of electrons by ionizing radiation causes cellular and chromosomal injuries); BIER V, HEALTH EFFECTS TO EXPOSURE TO LOW LEVELS OF IONIZING RADIATION 9 (1990).

atoms.[1237] These molecular disruptions cause cellular and chromosomal injuries to human cells.[1238] "[W]hen the molecules affected are essential for the normal functioning of a cell, the cell in turn suffers injury or dies."[1239]

Radiation through this process of ionization has similar effects on all life it penetrates, including animal and plant life, and effects continue in such life forms genetically for generations to come. Radiation can also spread in the form of radioactive fallout through the dispersal of radioactive materials by water, air, soil, and other substances.

The unstablized nucleus in the radioactive atom relieves itself of this instability through losing energy in the form of radiation. The "half life" of a class of atom with an unstable, radiation-emitting nucleus (called a radionuclide, *e.g.* strontium-90), is defined as the amount of time it takes for one half of a mass of that type of radioactive atom to disintegrate into a more stable element and stop emitting radiation.[1240]

Radiation is measured in roentgens, rads and rem. A roentgen (R) is a measure of radiation exposure in the air; a rad (r)[1241] is a measure of radiation absorbed by living tissue; and a rem ("Roentgen Equivalent

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[1237] *See* James R. Cox, Comment, *Naturally Occurring Radioactive Materials in the Oil Field: Changing the Norm*, 67 TUL. L. REV. 1197, 1200–01 (1993); BIER V, *supra* note 33.

[1238] *See* SHAPIRO, *supra* note 33, at 10; GOFMAN, *supra* note 33, at 62; BIER V, *supra* note 33.

[1239] *See* SHAPIRO, *supra* note 33, at 9.

[1240] *See* Cox, *supra* note 34, at 1200–01. "Activity" is the measurement of the number of nuclei that disintegrate during a certain period of time. The standard measurement for activity is Curie, which is 37 billion disintegrations per second. A nuclide with a short half life would have high activity. BIER V, *supra* note 33, at 393. Hazards of radioactive substances are on life forms are calculated using "effective half-life" or "biological half-life" calculations, which take into account the time the radioactive substance remains in the body and emits its radiation directly against living tissue. *See* NATO HANDBOOK ON THE MEDICAL ASPECTS, *supra* note 2, at Part I, Chap. 5, § VI-529. *E.g.,* radioactive radium integrates itself into the bone and remains a long time; other radioactive substances get flushed out of the body quickly. *See infra* note 41.

[1241] *See generally* Robert K. Temple, N., *Regulation of Nuclear Waste and Reactor Safety within the Commonwealth of Independent States: Toward a Workable Model*, 69 CHI-KENT L. REV. 1071, 1095 n.151 (1994). The amount of radioactivity in quantitative units (curies or becquerel) to produce a rad per organ (*i.e.*, thyroid) is different than the amount that produces a rad per whole body. *Id*.

Man") is a measure of the radiation absorbed, weighted to account for the different types of radiation (alpha, beta or gamma).[1242] For most external gamma radiation, the type most relevant, 1 R = 1 rad = 1 rem.[1243]

The effect of radiation on a life form depends upon the significance to the life form of the cells that have been injured or destroyed and the health of the individual victim's immune system.[1244] The injury to human life caused by radiation manifests itself most typically as cancer and as fetal injury resulting in birth defects.[1245]

[1242] *See id.*

[1243] *See* Medora Marisseau, Comment, *Seeing Through the Fallout: Radiation and the Discretionary Function Exception*, 22 ENVTL. L. 1509, 1538 note 142 (1992). *See also* NATO HANDBOOK ON THE MEDICAL ASPECTS, *supra* note 2, at Part I, Chap. 5 (particularly at § III, "Cellular effects of Ionizing Radiation" and § IV, Systemic Effects of Whole-Body Radiation," for discussion of cellular, organ, and organ system failure following radiation exposure).

Another unit of radioactive exposure is the Gray (GY). 1 gy = 100 rad. A whole body exposure of 1 Gy produces a mild radiation sickness and may reduce life expectancy 3 to 5 years.

A becquerel (Bq) is measurement of one radioactive disintegration per second. A curie (CI) = 3.7 X 10 to the 10th power Bq or 37 billion disintegrations per second. A radionuclide is a radioactive nuclide, a radioactive variety of a basic element, *e.g.* uranium or iodine.

One rem = 10 millisieverts, the dose received to produce the same biological effects as 1 rad of x-rays. In beta or gamma, 1 rem is almost the same as 1 rad, but with alpha much lower levels of radiation are needed to produce a rem. A Sievert (SV) is equal to 100 rem. *See id.*

[1244] *See* Cox, *supra* note 34, at 1202. The biological effects of radiation vary primarily according to five factors: (1) the type of particles or photons released; (2) the energy of the particle; (3) the distance and duration of the exposure; (4) any shielding; and (5) the sensitivity of the tissue through which the particle passes. *See id.* at 1202.

Internal exposure requires consideration of additional factors, particularly 1) the manner in which the body processes the particular nuclides involved and its ability to expel them; 2) the importance of the organ and its sensitivity; and 3) the types and energies of the particle (alpha particles cause the most problems). While the skin can withstand significant bombardment of ionizing energy, internal tissues are far more sensitive. Certain radionuclides have a tendency to accumulate in specific areas of the body. Iodine gets deposited in the thyroid; radium in the bones; radon in the lungs. *See id.* at 1204–06.

[1245] *See id.*

Levels of Radiation Necessary to Cause Injury

The following effects of radiation exposure levels have been noted:

.5-10 rem	undetectable increase of cancer incidence and statistically minor genetic effects
10-100 rem	detectable increase in cancer and genetic defects.
100-200 rem	radiation sickness syndrome
200-400 rem	acute radiation sickness syndrome
400-600 rem	lethal for bone marrow
600+ rem	lethal for intestine epithelium, other tissues[1246]

According to another source, death is likely to occur within a period of a day to two weeks from a single dose of 100 rem or more.[1247] According to a further source, hemorrhaging, radiation sickness, vomiting, nausea, and fever are likely effects for a person exposed to 200-400 rem and an exposure of 500 rem would kill half of the exposed population within a few weeks, and 1000 rem would kill everyone exposed within a few days to few weeks.[1248]

According to an additional source, the "acute lethal dose" (individual doses) of ionizing radiation for an adult is 450 rads, although lower acute doses, combined with chronic doses from fallout and other sources and internal doses from food and water contamination, would also be lethal.[1249] Because of the neoplastic diseases and genetic injuries caused by radiation, infants exposed to 100 rads as fetuses would suffer mental retardation and birth defects.

The threshold level at which radiation becomes harmful is not definitively known, with scientific opinions differing.[1250] It is clear

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[1246] *See* ZHORES A. MEDVEDEV, THE LEGACY OF CHERNOBYL 320 (1990). *See also* The Effects of Nuclear War, *supra* note 7, at 19–20; NATO HANDBOOK ON THE MEDICAL ASPECTS, *supra* note 2, at Part I, Chap. 5, §§ IV-520, "Median Lethal Dose (LD_{50})," Part I, Chap. 5, fig. 5-1, "Typical Lethality as a Function of Dose."

With "[a]n outdoor radiation level of 60 rem per hour … a person outdoors for 10 hours would almost certainly be killed by radiation." The Effects of Nuclear War, *supra* note 7, at 84.

[1247] *See* Marisseau, *supra* note 40, at 1538 n.142.

[1248] *See* NUCLEAR POWER: BOTH SIDES 28 (Michio Kaku & Jennifer Trainer eds., 1982). *See also* The Effects of Nuclear War, *supra* note 7, at 7.

[1249] *See* Carl Sagan, *Nuclear War and Climatic Catastrophe: Some Policy Implications,* 62 FOREIGN AFF. 257, 273 (Winter 1983/1984).

[1250] *See* IARC Study Group, *Direct Estimates of Cancer Mortality Due To Low Doses of Ionizing Radiation: An International Study,* 344 LANCET 1039 (1994).

there is no level at which it is certain that radiation is harmless. It is also clear that the effects of radiation are cumulative, building up over time. The generally accepted theory has been that a greater dose of radiation causes a proportional increase in chromosome aberrations.[1251] In recent years, some scientists have challenged this notion, arguing that the effects are supralinear, *i.e.* that the effect rises rapidly at low doses and levels off at high doses.[1252]

Effects of low level radiation are insidious in that they are disguised, occurring not in a clearly visible way but as seemingly random incidences of cancer and other injuries. Based on a U.S. government assessment, each rem of radiation can be expected to result in .0004 fatal cancers among workers, or .0005 fatal cancers among the general population. Thus, out of every 500 workers who accumulate their permissible doses in one year, one can be expected to contract

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[1251] *See* BIER V, *supra* note 33, at 20–21. *See also* Cox, *supra* note 34, at 1203 n.29 ("Based on extensive but incomplete scientific evidence, it is prudent to assume that at low levels of exposure the risk of incurring either cancer or hereditary defects is linearly related to the dose received in the relevant tissue."); Jorge Contreras, Comment, *In the Village Square: Risk Misperception and Decision Making in the Regulation of Low-Level Radioactive Waste*, 19 ECOLOGY L.Q. 481, 492 (1992) (stating that the Nuclear Regulation Commission uses a "linear, no-threshold" model for estimating risks of low level radiation); GOFMAN, *supra* note 33, at 64 ("A very large body of information exists to show that the number of deletions produced is directly proportional to the dose of radiation delivered, in the low-dose range."); JAY M. GOULD & BENJAMIN A. GOLDMAN, DEADLY DECEIT: LOW LEVEL RADIATION AND COVER UP 16 (1990) (stating that most scientists accept the linear model and that the supralinear model probably overestimates the effects of low-level radiation). According to the linear model, an exposure of 100 rem would cause 1000 times the cancer risk of an exposure of 0.1 rem. *See* Contreras, *supra* at 490–92.

[1252] *See* GOULD & GOLDMAN, *supra* note 48, at 16–17; Contreras, *supra* note 48, at 492 (citing John W. Gofman, *George Orwell Understated the Case, in* NUCLEAR POWER: BOTH SIDES (Michio Kaku & Jennifer Trainer eds., 1982)). Dr. Gofman's research on Hiroshima and Nagasaki is part of the basis for the supralinear theory. GOFMAN, *supra* note 33, at 66.

fatal cancer.[1253] Under federal regulations, the radiation exposure limit for workers handling radioactive materials is set at 5 rem per year.[1254]

In modern society people are exposed to radiation from many sources. It has been estimated that a round trip flight between Los Angeles and Paris can result in 4.8 mrems and that airline crew personnel receive one rem a year of radiation as an occupational hazard.[1255]

[1253] *See* Contreras, *supra* note 48, at 491; Cox, *supra* note 34, at 1204. Because genetic defects often accrue over the time period of generations, no authoritative study has established the risk of genetic damage due to radiation. *See* Contreras, *supra* note 48, at 491.

[1254] *See* Elena Molodstova, *Nuclear Energy and Environmental Protection: Responses of International Law*, 12 PACE ENVTL. L. REV. 185, 208 n.132 (1994). The Nuclear Regulatory Commission has established standards for protection from ionizing radiation. *See* 10 C.F.R. § 20 (1995).

[1255] *See* Contreras, *supra* note 48, at 497

The average annual radiation dose per person from all sources in the United States has been estimated at some 363 mrem,[1256] occurring from the following sources:[1257]

300 mrem	environmental factors;
53 mrem	X-rays;
5-13 mrem	consumer products (tobacco, television, computer terminals, luminous watch dials, smoke detectors, combustible fuel, etc.);
3 mrem	fallout from nuclear weapons testing and nuclear power facilities.[1258]

[1256] *See id.* A mrem = 1/1000 of a rem.

[1257] Contreras, *supra* note 48, at 491 (citing NUCLEAR REGULATORY COMMISSION, BELOW REGULATORY CONCERN: POLICY STATEMENT 8 (1990) (reprinted at 55 Fed. Reg. 27522, 27525)). *See also* Cox, *supra* note 34, at 1204; Contreras, *supra* note 48, at 497, BIER V, *supra* note 33, at 18.

[1258] The United States, the Soviet Union and the United Kingdom detonated plutonium nuclear weapons in the late 1940s, the 1950s and the early 1960s. GOFMAN, *supra* note 33, at 296. The United States is believed to have detonated 231 above ground detonations. China and France continued atmospheric testing after other nations stopped. *Id.*

As a result, it has been estimated that 320,000 curies of plutonium radionuclides were dispersed into the atmosphere, with the equivalent of about 40,000 Hiroshima bombs. GOFMAN, *supra* note 33, at 296; GOULD & GOLDMAN, *supra* note 48, at 92.

Almost all of the released plutonium through 1962 has returned to earth and is inhaled by humans. GOFMAN, *supra* note 33, at 297. The cumulative intake of plutonium through 1972 is estimated to be 42 picocuries or 6.85×10^{-4} micrograms per person. *See id.* at 5.

Dr. Gofman estimated that the plutonium fallout will cause a total of 104,460 lung cancer deaths in the United States, and 950,000 world wide. *Id.* at 299. Investigators have also concluded that the mortality rates during the 1950–1965 atomic testing period stopped getting better after decades of improvement. *Id.* When atomic testing was banned, the mortality rate improved once again. *Id.*

Epidemiological testing has detected excess cancer rates in areas affected by nuclear fallout from weapons testing in doses that would not have been expected to cause cancer. BIER V, *supra* note 33, at 373–77; GOULD & GOLDMAN, *supra* note 48, at 15 (stating that Chernobyl fallout in the U.S. during the summer months of 1986 caused a significant increase in the U.S. death rate).

One study has described the following results from the above ground testing and the subsequent cessation of such testing:

> … By 1980, [the United States, the Soviet Union, the United Kingdom, France 1960, and China] had set off a total of 528 known nuclear explosions in the atmosphere. The lion's share of these tests—more than 80 percent—were conducted by the Soviet Union and the United States.
>
> Much of the radioactive debris from these tests rained down in the vicinity of the explosions. However, significant amounts of radioactive particles were injected high enough into the atmosphere that air currents were able to disperse them globally before they precipitated back to Earth. At the peak of aboveground nuclear testing in 1962, the world's population was exposed to a level of radiation that was 7 percent higher than the naturally occurring background levels. …
>
> Aboveground testing of nuclear weapons was prohibited by the Limited Test Ban Treaty, which was concluded by the United States, the Soviet Union, and the United Kingdom in 1963. … Underground tests were permitted so long as they did not cause radioactive debris to be deposited beyond the border of the country conducting them.

Marvin S. Soroos, *Preserving the Atmosphere as a Global Commons*, ENVIRONMENT, vol. 40., no. 2, Mar. 1998, at 6 (citing R.S. Noms and W. M. Arkin, *Known Nuclear Tests Worldwide, 1945-1993*, THE BULL. OF THE ATOMIC SCIENTISTS 52 (1996): 61; UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION, IONIZING RADIATION: SOURCES AND BIOLOGICAL EFFECTS 19 (1982); Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space, and under Water, Moscow, 1963, *in* 2 I.L.M. 889 (1963); NATIONAL ACADEMY OF SCIENCES, NUCLEAR ARMS CONTROL: BACKGROUND AND ISSUES 190–95 (1985); G. T. SEABORG, KENNEDY, KRUSHCHEV, AND THE TEST BAN (1981)).

Soroos states that, “By one more recent estimate, radioactive contamination from all the nuclear tests conducted between 1945 and 1980 and delivered to the world's people by 2000 will eventually result in 430,000 cancer deaths, mostly in the Northern Hemisphere. *See* International Physicians for the Prevention of Nuclear War and Institute for Energy and Environmental Research, Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear Weapons Testing In, On, and Above the Earth (New York: Apex Press, 1991), 42.”

Soroos’ ultimate statement of the result is that “Radiation levels from nuclear explosions fell from 7 percent of the natural level in 1963 to 2 percent by 1966 and 1 percent by 1970. *See* A. J. Damay, ed., Statistical Record of the Environment (Detroit, Mich.: Gale Research, Inc., 1992), 35–36.”

Even underground testing spreads radiation, both at the time of the initial blast and thereafter. Underground testing places a supply of radioactive material in an arbitrary storage space for an indefinite period of time, giving rise to the risk of contamination through leakage over time.

Information regarding such risks has resulted from studies of the Moruroa atoll, where France performed underground testing:

> Environmental Effects of Underground Testing at Moruroa
>
> … At the time of the explosion, fracturing of the atoll surface triggers landslides, tsunamis (tidal waves), and earthquakes. There is also evidence that radionuclides have vented to the environment. Possible long-term effects include leakage of fission products to the biosphere and transfer of dissolved plutonium from the lagoon to the ocean and the food chain.
>
> * Venting of Gaseous and Volatile Fission Products
>
> Unusual concentrations of short-lived iodine 131 in marine organisms and krypton 85 and tritium in air or water indicate that venting has occurred.
>
> The scientists of the Australia, New Zealand and Papua New Guinea Mission in 1983 were authorized to carry out a single experiment in situ at Moruroa. … The measured tritium levels were 500 Becquerels per liter while the expected concentration due to atmospheric fallout should have been in the range of 0.2 Becquerels per liter. The report of this mission offers two explanations … either venting of gaseous tritium directly from underground cavities or a faster ground water flow rate than admitted.
>
> The venting explanation appears to be more likely, based on findings of Cousteau mission in 1987. Just days after a test, iodine 131 (half life of 8.05 days) was found in all sediment samples. The same mission measured radioactivity of plankton, which is an even better indicator of venting. In plankton, they found an iodine131 concentration of 22,000 picocuries per kilogram, by far the strongest radioactivity found during their mission. ***
>
> * Medium and Long-term Leakage of Fission Products to the Biosphere
>
> According to a model formulated by Hochstein and O'Sullivan, an underground nuclear explosion in rock saturated with seawater can set up an artificial geothermal system. … The heated seawater dissolves the glassy materials, liberating the nuclear waste.
>
> … [T]he heated seawater … transfers the dissolved nuclear waste slowly upwards … Under the assumptions of this model, radionuclides from a depth of around 500 meters would reach the cracks of the lagoon in less than 50 years instead of the 500 to 1,000 years assumed by the French authorities.
>
> A first hint that the model … might be correct was the discovery of cesium-134 by the Cousteau Mission in 1987. In December 1990, too, Greenpeace found cesium-134 in plankton collected outside the 12-mile exclusion zone around Moruroa. … Global atmospheric fallout does not contain cesium134. ***

Effects of cumulative doses substantially below the potentially lethal levels discussed above are uncertain. Epidemiological testing has detected excess cancer rates among persons exposed to radiation from weapons testing, nuclear installations, high background radiation and the like, but the causative relationship appears to be a matter of debate.[1259]

Scientists are also uncertain as to the significance of the way in which the low level radiation is received, whether through long term chronic radiation exposure or acute exposure, with at least some scientists believing that acute exposure causes more severe injury.[1260]

Nuclear Weapons and Radiation

Radiation is a defining feature of nuclear weapons.[1261] All existing nuclear weapons emit radiation when detonated.[1262] The terms "clean"

> The 120 underground tests conducted at Moruroa have in effect turned it into a longterm waste dump. … [S]ome may have found its way into the lagoons and ocean. … Natural barriers play the most important role in the confinement of nuclear waste. Consequently, a planned storage site should meet very strict criteria including exclusion of water, lack of natural fractures or fissures, and a high absorption of radionuclides. …
>
> … Moruroa Atoll is a very poor site for storing nuclear waste of any type. … The discovery of cesium-134 indicates only the beginning of longterm leakage from the underground "storage" sites.

International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, *Environmental Effects of French Nuclear Testing* (updated version of Chap. 9 from the book RADIOACTIVE HEAVEN AND EARTH: THE HEALTH AND ENVIRONMENTAL EFFECTS OF NUCLEAR WEAPONS TESTING, IN, ON, AND ABOVE THE EARTH. (1991)) <http://canterbury.cyberplace.org.nz/peace/nukenviro.html#under>.

1259 *See* BIER V, *supra* note 33, at 373–85;

1260 *See* Contreras, *supra* note 48, at 492. For example: (1) some researchers suggest that long term chronic radiation exposure is less severe than acute exposure; and (2) long latency periods for genetic defects and some cancers make it difficult to trace the radiation source of these effects. *Id.*

1261 *See* UNITED NATIONS DEPARTMENT, *supra* note 2, at 6; THE NUCLEAR READER: STRATEGY, WEAPONS AND WAR, *supra* note 2, at 4; 1987 WHO Study, *supra* note 2.

1262 *See* 1987 WHO Study, *supra* note 2, at 149. "Nuclear weapons represent a historically new form of weaponry with unparalleled destructive potential. A single large nuclear weapon could release explosive power comparable to all the energy released from the conventional weapons used in all past wars." *Id.* at 7.

and "dirty" nuclear weapons are sometimes used as a gross characterization of the levels of radiation likely to be released by a nuclear weapon,[1263] but even the "cleanest" of nuclear weapons release radiation.[1264]

Modern thermonuclear weapons release energy through a combination of nuclear fission and fusion.[1265] A "primary" fission core device detonates to produce the radiation necessary to ignite a secondary fusion explosion.[1266] The yield can be increased to create "boosted" nuclear weapons by surrounding the fusion weapon with a layer of U-238 as a third stage to produce a second fission explosion.[1267] The radiation released by a thermonuclear weapon results from these two or three stages of detonation.[1268] To obtain tailored radiation and yield effects, different ratios of fission-reactions to fusion-reactions may be designed, resulting in weapons that release more or less radiation.[1269]

[1263] *See* UNITED NATIONS DEPARTMENT, *supra* note 2, at 8. Nuclear fusion weapons typically are activated by a fission "trigger." "Extra fission energy can be supplied by surrounding the fusion weapons with a shell of uranium-238. The greater the proportion of fission energy released the 'dirtier' the thermonuclear weapon becomes. It is called 'dirty' because of the quantity of highly radioactive substances (*e.g.* strontium-90 and caesium-137) that are released into the atmosphere. 'Cleaner' weapons have a much smaller release of these substances." *Id.*

[1264] *See id.*

[1265] *See* Frank Barnaby, *Civil Science Could Drive Tomorrow's Nukes*, INT'L DEF. REV., Jan. 1, 1997:

> Whereas in nuclear fission the nuclei of heavy isotopes (such as uranium or plutonium isotopes) are split into lighter ones, in nuclear fusion light nuclei (for example, hydrogen) are joined, or fused. The fusion process, like the fission process, is accompanied by the emission of energy which can be used to produce an explosion. Nuclear fusion is the process which gives the sun its energy, and extremely high temperatures and pressures—similar to those which occur in the sun—are required to produce it. Today's thermonuclear weapons consist of two separate stages: a nuclear-fission weapon which acts as a trigger for the second stage; the explosion of the fission trigger produces a high enough temperature and pressure to fuse nuclei of hydrogen contained in the second stage. The energy produces a large explosion."

Id.

[1266] *See* NUCLEAR WEAPONS DATABOOK*, supra* note 1, at 27.

[1267] *See id.* at 27–28.

[1268] *See id.*

[1269] *See id.* at 28.

All nuclear fission and fusion weapons release prompt and delayed radiation.[1270] The nuclear fission of plutonium and uranium, which is at least the trigger of all nuclear explosives, releases unstable atomic nuclei.[1271] These decay over hours or years, and release alpha, beta and gamma radiation.

The nuclear fusion involved in the explosion of thermonuclear weapons[1272] results in a burst of immediate or prompt nuclear radiation, including neutron and gamma rays,[1273] the most dangerous forms of nuclear radiation and capable of penetrating concrete, dirt and water.[1274]

There are two sources of gamma radiation, prompt gamma rays resulting from the nuclear explosion and delayed gamma rays emitted by debris susceptible to being carried by winds hundreds or thousands of miles from ground zero before falling back to earth.[1275] The intensity of the radiation declines tenfold for every sevenfold increase in time.[1276] For example, "there's one-tenth as much radioactivity after a week as after a day; only one-tenth of that after 7 weeks; another 90% gone by 7x7 = 49 weeks, etc."[1277] Radioactive fallout can be compounded by the targeting of strategic and tactical nuclear targets since their destruction would release additional nuclear materials into the atmosphere.[1278]

A distinction must be made between "yield" and radiation. "Yield," as noted above, is the amount of energy released by the bomb's explosion, with the unit of measurement being the equivalent amount of energy released per metric ton of trinitrotoluene (TNT),[1279] essentially expressing the destructiveness of the blast effect of the device. Radiation is the process of disruption of atomic and cellular structure.

[1270] *See id.*

[1271] *See* SAGAN & TURCO, *supra* note 6, at 26.

[1272] *See* NUCLEAR READER: STRATEGY, WEAPONS, AND WAR, *supra* note 2, at 26.

[1273] *See id.*

[1274] *See* SAGAN & TURCO, *supra* note 6, at 49.

[1275] *See id.* at 52.

[1276] *See id.*

[1277] *Id.*

[1278] *See, e.g., id.* at 54–55.

[1279] *See* UNITED NATIONS DEPARTMENT, *supra* note 2, at 6. *See also* THE NUCLEAR READER: STRATEGY, WEAPONS AND WAR, *supra* note 2; 1987 WHO Study, *supra* note 2.

The radiation released by nuclear weapons is generally measured in curies, roentgens, rads and rems.[1280] This radiation results from both the atomic/nuclear detonation devices used to set the bomb off and the nuclear materials in the bomb itself.[1281] The resultant radioactive isotopes have half-lives ranging from seconds to millions of years.[1282]

These radioactive nuclei are lifted by the rising clouds of a nuclear explosion and dispersed by prevailing winds. One hour after an explosion, the radioactivity released from a one megaton bomb is one hundred billion curies. Because nuclei return to a normal state by emitting energy, the fraction that remains radioactive steadily decreases in time. After one day, the radioactivity is down to one billion curies and after a month a bit below 100 million.[1283]

The most important factor in determining the extent to which this radioactivity will affect the human population in distant areas is the height at which the nuclear bomb is detonated. If the fireball does not touch the ground, the radioactive debris is lifted into the upper atmosphere, becoming widely dispersed and descending very slowly. This type of explosion is believed to likely cause only a small increase in background radiation.[1284]

However, if the nuclear weapon is exploded near the ground, the fireball carries large amounts of dirt into the atmosphere and radioactive nuclei attach to these particles. As the fireball cools, the

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[1280] *See generally* William Daugherty et al., *The Consequences of "Limited" Nuclear Attacks on the United States,* INT'L SECURITY vol. 10 no. 4 (1986), at 3–45; Frank N. von Hippel et al., *Civilian Casualties from Counterforce Attacks*, SCIENTIFIC AMERICAN vol. 259 no. 3, Sept. 1988, at 36–42; Barbara G. Levi et al., *Civilian Casualties from "Limited" Nuclear Attacks on the USSR*, INT'L SECURITY, vol. 12, no. 3, Winter 1987/1988, at 168–89. The yields, CEPs and other very precise technical information of American nuclear weapons are generally made public, but the amounts of radiation are not. Public information on released radiation is generally limited to estimates in civilian and academic sources. *See generally* Sagan, *supra* note 46.

[1281] *See* UNDDA NUCLEAR WEAPONS, A COMPREHENSIVE STUDY 8 (1991).

The direct radiation likely to be released by typical tactical fission bombs with yields of some 10 kilotons is likely to be harmful up to some 100 miles and that of the most powerful strategic weapons to be in the range of 300 miles. THE NUCLEAR ALMANAC: CONFRONTING THE ATOM IN WAR AND PEACE 91, 94 (Jack Dennis ed., 1984) [hereinafter THE NUCLEAR ALMANAC]. The radioactivity from a one-megaton weapon is 100 billion curies, fatal to humans out to 1.7 miles immediately after an explosion. *Id.* at 85, 91.

[1282] *Id.*

[1283] *See id.* at 91.

[1284] *See id.*

particles descend back to the earth. But because these particles are heavier than radioactive nuclei, they descend quicker and are not as widely dispersed.[1285]

Little published data appears to be available as to the relationship between yield and radiation levels. The greater the extent to which fission detonation devices are used in a nuclear weapon, the "dirtier" the weapon becomes, the more radiation it releases. Also, the volume of the nuclear device itself must affect the radiation released. It is generally assumed that the higher yield devices release more radiation than the lower yield ones.[1286]

Ted Postel, an MIT professor and former Pentagon nuclear war analyst, has stated that the Minuteman warhead, reported to have a yield of some 335 kt, could produce "a kills-everybody 3000 rads/per-hour dose over a 10-mile oval-shaped area one hour after a ground detonation."[1287] Postel went on to state that the Minuteman would release a deadly dose of some 1000 rads/hour of radiation for up to another 10 miles and a possibly lethal dose of 300 rads for as far as 50 miles.[1288]

The U.S. Army has estimated that a dose of 8000 rads will result in "immediate permanent incapacitation" of human beings.[1289] This is known as the "radiation-kill radius."[1290] At 650 rads, "personnel will become functionally impaired within 2 hours of exposure."[1291] It has been estimated that a 10 kt fission weapon yields 8000 rads as far as 690 meters and 650 rads as far as 1100 meters.[1292]

[1285] *See id.* at 93–93. "Airbursts deliver a smaller radiation dose, over a longer period of time, to very large (global) populations; groundbursts deliver a heavy radiation exposure, rapidly, to a relatively smaller area and population." *Id*. at 104.

[1286] *See* GRACE, *supra* note 10, at 22. Since high yield thermonuclear weapons are fission-fusion weapons, they are often considered "dirty weapons" because they produce a great deal of radioactivity. *Id.*

[1287] *See* William M. Arkin, *Bring on the Radiation*, BULL. OF THE ATOMIC SCIENTISTS, Jan. 11, 1997, at 72.

[1288] *See id.*

[1289] *See* NUCLEAR WEAPONS DATABOOK, *supra* note 1, at 28 n.34

[1290] *See id.*

[1291] *See id.*

[1292] *See id.*

Non-Radiation Releasing Nuclear Weapons, An Oxymoron

As noted, there is no currently existing nuclear weapon that does not release radiation.[1293] The neutron bomb is just the opposite: It releases "enhanced" amounts of radiation with curtailed blast and heat effects.[1294] While, as noted above, different ratios of fission-reactions to fusion-reactions may be designed to tailor the amount of radiation released, the release of radiation remains a defining feature of nuclear weapons.

As far back as 1957, nuclear scientist Edward Teller, the "Father of the H-Bomb," told President Eisenhower that the Lawrence Livermore laboratories were "within several years of perfecting a 'clean' nuclear device, one with little or no radioactive fallout, that would have myriad of peaceful uses. Such a bomb, argued Teller, also would lessen environmental damage from tests and reduce noncombatant casualties in a nuclear war."[1295] However, for technical reasons "[p]lans for a 'clean bomb' were later abandoned and to this day scientists have not figured out a way to build one."[1296]

Efforts to develop a clean nuclear weapon are still underway. According to Andre Gsponer, the director of the Independent Scientific Research Institute in Geneva, Switzerland, "compared with present-day nuclear arsenals, tomorrow's weapons will … offer significant military advantages, especially for tactical use, because most of them will produce no significant radioactivity."[1297] He projects that "future thermonuclear weapons will probably not rely on a nuclear-fission trigger to provide the conditions needed for nuclear fusion. Instead they may use new types of very powerful conventional high explosives, arranged, for example, in a spherical shell around a capsule containing the hydrogen gases tritium and deuterium. When the explosives are detonated the capsule will be crushed inward and the gases rapidly heated to a suitably high temperature to allow the fusion of hydrogen nuclei to take place."[1298]

Gsponer states that "new explosives are being developed which can produce energy concentrations much greater than those produced by

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[1293] SAGAN & TURCO, *supra* note 6, at 49–53.

[1294] *See* THE NUCLEAR ALMANAC, *supra* note 78, at 185.

[1295] *See "Teller's War" Offers Stinging Indictment of Star Wars*, NEW TECH. WK., vol. 6, no. 9, Mar. 2, 1992 (Reviewing *Teller's War*, by William Broad).

[1296] *See id.*

[1297] Barnaby, *supra* note 62, at 61–5.

[1298] *Id.* at 62–3.

today's high explosives, such as shock-sensitive HMX (Cyclotetramethylenetetranitramine). Pure-fusion weapons are likely to have explosive yields equivalent to those of up to 1,000 tons or so of TNT (trinitrotoluene). Delivered by precise navigating systems, such weapons would be sufficient to destroy virtually all military targets."[1299]

Lawrence Livermore National Laboratory in California is also "researching nuclear isomers, such as the isotope hafnium-178, as nuclear explosives without radioactivity. Because nuclear isomers release energy electromagnetically, they produce no radioactivity. Research into nuclear isomers is underway mainly in France, Russia and the US."[1300] In addition, "Congress has given scientists at the Lawrence Livermore Laboratory money to begin design of the NIF .... The results from the NIF could also help nuclear-weapon scientists to develop a laser-triggered pure-fusion bomb using miniaturized high-intensity lasers."[1301] In this way, the radioactivity from the fission stage of a fusion bomb might be entirely eliminated.

Whether these efforts will be fruitful is unknowable. For present purposes, the radiation-producing effect of nuclear weapons remains such a defining feature of the weapons that any future radiationless nuclear weapons would have to be regarded as a qualitatively different kind of weapon.

Potential Effects of a Major Nuclear Exchange

The International Physicians for the Prevention of Nuclear War, in their 1992 projection of the effects of the use of nuclear weapons, concluded, *inter alia*, as follows:

> The following descriptions summarize only the immediate injuries resulting from a single explosion of a one-megaton

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[1299] *Id.* at 62–3.

[1300] *Id.*

[1301] *See id.* at 61–5:

> The planned super-laser will cost significantly more than US$1 billion to construct, and will have a lifetime budget of more than US$4.5 billion. It will consist of 192 laser beams which together will produce a staggering 500 billion watts of power for three-billionths of a second. The beams will blast into a very small capsule of hydrogen, creating a sufficiently high temperature and pressure to cause the capsule to implode inward and the hydrogen atoms to fuse to form helium. The lasers will, in other words, produce small thermonuclear explosions.

Id.

warhead detonated on the ground—the equivalent of 1,000,000 tons of TNT, but less than 1/8000 of the destructive force that will remain after all current arms reduction plans are implemented. The immediate human casualties stem from three different sources of injury: the blast effects of the explosion itself; the burns resulting both from direct exposure to the intense heat generated by the explosion and from the resulting massive fires; and the radiation released by a nuclear detonation, delivered in the form of fallout of radioactive material down wind from the explosion itself. The most important factor in predicting most of these injuries is the distance of human beings from the explosion itself, although other factors including the weather may be critical (on a rainy day the moist atmosphere will absorb more of the heat energy released by the explosion, and burn injuries may be reduced).

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DISTANCE MEDICAL EFFECTS

Ground Zero:

At ground zero, the explosion creates a crater 92 meters deep and 367 meters in diameter. All life and structures are obliterated.

0-1.5 KM:

Within one second, the atmosphere itself in effect ignites into a fireball more than 1 km in diameter. The surface of the fireball (cooler than its center) radiates nearly three times the light and heat of a comparable area of the surface of the sun. The fireball rises to a height of six miles or more. All life below is extinguished in seconds.

1.5-5 KM:

The flash and heat from the explosion radiate outward at the speed of light, causing instantaneous severe burns. A blast wave of compressed air follows slightly more slowly, reaching a distance of 5 km in about 12 seconds. From the blast wave alone, most factories and commercial buildings collapse, and small frame and brick residences are destroyed. Debris carried by winds of 417 km/hour inflicts lethal injuries throughout this area. At least 50 percent of people die immediately, prior to any injuries from radiation or the developing firestorm.

5-10 KM:

The direct heat radiating from the explosion causes immediate third-degree burns to exposed skin, and the expanding blast wave destroys many small buildings. The combination of heat and blast causes fuel storage tanks to explode. A firestorm begins to develop, as winds and intense heat sweep individual fires together into a single raging conflagration. The firestorm consumes all nearby oxygen, sucking it out of any underground stations and asphyxiating the occupants. Shelters become ovens, and over the ensuing minutes to hours, fatalities are likely to approach 100 percent.

10-20 KM:

The shock wave reaches a distance of 15 km approximately 40 seconds after the initial explosion. People directly exposed to the electromagnetic radiation (in the form of intense light) generated by the exploding warhead suffer second-degree burns. Depending on the ability of protective structures to withstand blast and resist fire, total early casualties (killed and injured) may range from 5-50 percent.

Radiation Casualties

In the immediate proximity of the explosion (10 km or less) injuries resulting from radiation exposure have little significance, because most (perhaps all) susceptible individuals will have died from the more rapidly fatal burn and blast injuries. At greater distances, radioactive fallout becomes a major source of short-term and medium-term health problem. Accurate predictions about the location and extent of radiation injuries are much more difficult than for burn and blast injuries. The effects of radioactive fallout will depend on such factors as where the nuclear explosion takes place (an explosion in the air above a city will create much less radioactive debris and resulting fallout than an explosion at ground level), whether the local wind patterns that day are carrying fallout over heavily populated areas, and local weather conditions (on a rainy day, radioactive debris will be washed out of the air more rapidly, resulting in more intense fallout over a more localized area). Other important factors are whether individuals in the area of fallout are able to remain carefully sheltered, especially during the initial days of most intense radioactivity.

For those without effective shielding from fallout, a one-megaton nuclear explosion taking place near the ground will create a lethal radiation zone (450 rad doses in the first 48 hours) of approximately 1300 square kilometers. Serious radiation exposures, producing illness but not generally death, will occur over areas several times larger.

The most important medical problems resulting from acute radiation exposure include: central nervous system dysfunction (especially at very high doses); nausea, vomiting and diarrhea from damage to the gastrointestinal tract, leading to potentially fatal dehydration and nutritional problems; and destruction of the body's capacity to produce new blood cells, resulting in uncontrolled bleeding (because of the absence of platelets) and life-threatening infections (because of the absence of white blood cells). Many affected individuals will not be aware that they have received a potentially lethal radiation dose until days to weeks after the explosion, when the damage to their blood system becomes evident through bleeding from the gums or within their skin, or through uncontrolled infections or unhealing wounds.

Medical Care in the Aftermath of a Nuclear Explosion

Estimates of the ultimate casualties from a medical disaster often depend as much on the resources that are available to treat the victims as on the source of the original injuries themselves. In the case of nuclear explosion near human populations, the barriers to effective medical care will be enormous. The most important of these are the sheer numbers of casualties and the fact that the explosion itself will have destroyed hospitals and other medical facilities and killed or injured most medical personnel. The report of the U.S. Institute of Medicine estimated, for example, that in the United States burn injuries alone would require 142 times as many intensive care units as would be available.

Even for most of those with less severe injuries, however, effective medical care will likely be impossible. For example, many people in the aftermath of a nuclear explosion will have severe nausea and vomiting. Even if highly trained medical personnel are available, there will be no clear way for them to determine whether these symptoms are the result of lethal radiation exposure (in which case hospitalization with intravenous fluids and antibiotics is mandatory), or severe psychological stress with no significant radiation exposure at all (in which case emotional support alone is indicted). Effective use of the scarce medical resources that are available will simply not be realistic.[1302]

[1302] BRIEFING BOOK ON NUCLEAR WAR (1992) © INTERNATIONAL PHYSICIANS FOR THE PREVENTION OF NUCLEAR WAR, reprinted with permission, *quoted in* Peter Weiss, Burns H. Weston, Richard A. Falk, & Saul H. Mendlovitz, Draft Memorial in Support of the Application by the World Health

It has been estimated that a 1 megaton bomb exploding at ground level would emit the following approximate fallout pattern, assuming a constant wind direction and speed of 20 mph and stable weather conditions:[1303]

Fallout Arrival Time, hours	Downwind Distance, miles	Roentgens
1	25	3000
5	100	1000
8	160	300
12	240	100
16	320	30

A one megaton bomb exploding at ground level over Detroit, with winds from the southwest of a constant 15 mph, would deposit lethal fallout on Cleveland and hazardous fallout as far away as Pittsburgh, at such levels as the following over a seven day period: Detroit, 3000 rem; Cleveland, 900 rem; and Pittsburgh, 90 rem.[1304]

It has been estimated that a twenty-megaton explosion over New York City would:

> [D]estroy all buildings not only in Manhattan but also in the Bronx, Brooklyn, and Queens, and in Hoboken and Jersey City as well. Exposed people would receive second-degree burns out to twenty-five miles from the detonation. There would be between five and ten million casualties.[1305]

Organization for an Advisory Opinion by the Court of International Justice of the Legality of the Use of Nuclear Weapons Under International Law, Including the W.H.O. Constitution, *reprinted in* 4 TRANSNAT'L L. & CONTEMP. PROBS. 721, 729–732 (1994).

[1303] *See* THE NUCLEAR ALMANAC, *supra* note 78, at 94.

[1304] *See id.* at 104–05. *See also* The Effects of Nuclear War, *supra* note 7, at 22–25, 81.

[1305] *See* THE NUCLEAR ALMANAC, *supra* note 78, at 96. The NATO Medical Guide states "Total nuclear war with utilization of all available nuclear weapons could result in complete devastation of the involved nation's military combat and logistics systems as well as their supporting civilian social structures and economies. However, situations short of total nuclear war are possible in which nuclear weapons could be employed in limited numbers or for a limited time, along with conventional weapons. Under such circumstances, effective military operations could continue and would require the continuing support of an effective medical service." NATO HANDBOOK ON THE MEDICAL ASPECTS, *supra* note 2, at Part I, Chap. 1, §102(a). Thus this

In the 1983 "World After Nuclear War" conference in Washington, D.C., leading scientists, including Carl Sagan, concluded that the long-term collateral consequences of a limited nuclear war could lead to a "nuclear winter" that could involve global climatic and biological catastrophe.[1306]

Sagan stated: "There is a real danger of the extinction of humanity. A threshold exists at which the climatic catastrophe could be triggered … [a] major first strike may be an act of national suicide, even if no retaliation occurs."[1307] A major strategic nuclear exchange would cause up to 1.1 billion immediate casualties from direct consequences, including blast, prompt neutron and gamma radiation, and fire, while secondary consequences, such as severe social disruption, disease, and other casualties caused by the lack of electricity, fuel, transportation, food, supplies, communications, medical care and sanitation, could well cause an additional 1.1 billion casualties.[1308]

The scientists further found additional long-term adverse environmental collateral consequences that could lead to profound global climatic and environmental disruption that "make the picture much more somber still."[1309] These include obscuring smoke in the troposphere, obscuring dust in the stratosphere, the fallout of radioactive debris, and the partial damage to the ozone layer.[1310]

Sagan concluded:

> The central point of the … findings is that the long-term consequences of a nuclear war could constitute a global climatic catastrophe. The immediate consequences of a single thermonuclear weapon explosion are well known and well

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entire medical guide is hinged on the contingency of a limited use of nuclear weapons.

[1306] *See* Stanley L. Thompson & Stephen H. Schneider, *Nuclear War Reappraised,* 64 FOREIGN AFF. 981 (1986).

[1307] Sagan, *supra* note 46, at 292.

[1308] *See id.* at 262. In the U.S. alone, "[e]xecutive branch calculations show a range of U.S. deaths from 35 to 77 percent of the population (*i.e.*, from 70 million to 160 million dead)." The Effects of Nuclear War, *supra* note 7, at 8. For an extensive nuclear war, it is estimated that there would be cancer deaths and genetic damage in the millions. Because of the deaths from blasts, this would be "insignificant in the attacked areas, but quite significant elsewhere in the world." *Id.* at 10, Table 2. *See id.* at 94–106, for a extensively worked out model of political, governmental, social and economic consequences, as well as deaths and other health issues, arising from a full scale nuclear war.

[1309] Sagan, *supra* note 46, at 262.

[1310] *See id.* at 264.

> documented—fireball radiation, prompt neutrons and gamma rays, blast, and fires. … No one knows, of course, how many warheads with what aggregate yield would be detonated in a nuclear war. … [It] is generally accepted, even among most military planners, that a "small" nuclear war would be almost impossible to contain before it escalated to include much of the world arsenals. (Precipitating factors include command and control malfunctions, communications failures, the necessity for instantaneous decisions on the fates of millions, fear, panic and other aspect of nuclear war fought by real people.…) Many of the effects described … , however, can be triggered by much smaller wars.[1311]

Potential Effects of Limited Nuclear War

While the scientists focused on the effects of a major nuclear exchange, they found that even a relatively small exchange, involving some 500 warheads, could trigger "nuclear winter,"[1312] resulting in global climatic and biological catastrophe.[1313]

Others have noted the extreme effects of even lower level nuclear weapons:

> However, the collateral effects, on noncombatants and neutrals as well as on the environment, of an attack employing even a single 100 kiloton weapon would be extreme. Such an attack would likely destroy 50 to 100 armoured fighting vehicles (the equivalent of one regiment), and the direct effects would incinerate all people and structures within fifteen square miles, likely including, in the best case, villages and towns containing thousands of persons.[1314]

During the resulting uncertainty and likely escalation from battlefield to the broader combat theatre, heavily populated areas would likely, by advertence or otherwise, become targets. In 1971, two former Pentagon aides described the effects of such a "limited" war in Europe as follows:

> Even under the most favourable assumptions, it appeared that between 2 and 20 million Europeans would be killed, even in a very limited nuclear attack, with widespread damage to the

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[1311] *Id.* at 259–261.

[1312] *See id.* at 276–77.

[1313] *Id. See also* Thompson & Schneider, *supra* note 103, at 985–87.

[1314] *See* Daniel J. Arbess, *The International Law of Armed Conflict in Light of Contemporary Deterrence Strategies: Empty Promise or Meaningful Restraint,* 30 MCGILL L.J. 89, 118–19 (1984).