Environmental Consequences of Nuclear War Volume I:
Physical and Atmospheric Effects
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CHAPTER 2
Scenarios for a Nuclear Exchange

2.1 INTRODUCTION

It is impossible to forecast the initiation and detailed conduct of a nuclear war. Despite this fact, all nations with nuclear weapons have elaborate plans for the deployment, targeting—and firing—of their warheads. Because of the reality of massive nuclear arsenals, and the unprecedented nature of nuclear conflict, many strategists believe that almost any use of nuclear weapons could escalate into global nuclear warfare (Ball, 1981; Bracken and Shubik, 1982). Others believe that a nuclear exchange could be controlled or limited; or if not controlled, that it might be automatically self-limiting, ending as soon as the combatants perceived their own imminent destruction, or with the fading of any rational military goals (Wohlstetter, 1983, 1985). This argument cannot be settled. Therefore, lacking solid evidence that nuclear warfare could be contained or limited in scale or magnitude, a prudent scientific approach demands that—in assessing potential long-term environmental effects—a possible and plausible nuclear exchange involving existing weapons and deployments must be considered.

2.2 WORLD ARSENALS

The actual nuclear weapons inventories of all nations are officially kept secret. Nevertheless, authoritative unclassified tabulations of existing and projected inventories are available, and these are roughly in agreement (The Military Balance, 1984; Jane's, 1984; SIPRI, 1984). Table 2.1 summarizes the principal nuclear weapons systems that have been deployed by the major nuclear alliances, or that may be deployed in the near future. Both strategic (intercontinental) and theater (intracontinental) nuclear forces are counted, but smaller tactical (battlefield) weapons and munitions—amounting to perhaps 25,000 explosives and several hundred megatons of aggregate yield—are omitted. (A typical tactical nuclear weapon has an explosive yield similar to that of the Hiroshima or Nagasaki bomb; viz, 10–20 kt.) In total, the strategic and theater nuclear arsenals hold some 24,000 warheads having nearly 12,000 Mt of explosive yield.

TABLE 2.1.
STRATEGIC/THEATER NUCLEAR WEAPONS IN CURRENT INVENTORIES[a]

Warhead yield (Mt)	Type of system[b]	Number of warheads[c]	Aggregate yield[c] (Mt)
5.0	Bomber	280	1400
1.0	ICBM	1050	1050
1.0	SLBM	680	680
1.0	IRBM	293	293
1.0	Bomber	2520	2520
0.5	ICBM	5660	2830
0.5	SLBM	1200	600
0.5	IRBM	100	50
0.3	ICBM	1650	495
0.3	IRBM	108	32
0.2	SLBM	672	134
0.2	Cruise	1920	384
0.2	SRAM	1200	240
0.15	IRBM	1500	225
0.1	SLBM	2304	230
0.05	SLBM	3040	152
Total strategic/theater		24177	11315[d]
Tactical warheads		~25000	~300

[a] Compiled from the following reports: The Military Balance, 1984; Jane's, 1984; SIPRI, 1984.

[b] The abbreviations are: ICBM = intercontinental ballistic missile; SLBM = submarine launched ballistic missile; IRBM = intermediate range ballistic missile; Cruise = air, sea or ground launched cruise missile; SRAM = short range attack missile.

[c] These figures include the nuclear arsenals of the United States, Britain, France, and the Soviet Union.

[d] The Chinese nuclear forces are not included, as they are very uncertain at this time. Their weapons may include about 230 warheads on bombers and ICBMs with a total yield of about 500 Mt.

In studying global effects, precise information about weapons systems (warheads, launch vehicles, controls, deployments, and targets) is not really necessary as long as the general characteristics of the systems (as well as the broad strategic doctrines governing their use) are known. The weapons parameters in Table 2.1 are probably accurate to within 35 percent, and can be used as a reasonable basis for drawing implications about the use of nuclear forces.

The arsenals are constantly changing, and the present tabulation may already be outdated in some respects. Nevertheless, dramatic changes in the aggregate warhead count and yield are not expected through this decade, and likely the next, under existing development programs and treaty limitations. For example, the present Strategic Arms Limitation Treaties (SALT I and II) limit both the United States and the Soviet Union to 1200 land or sea based multiple warhead strategic missiles with 10 warheads or less per missile (except for submarine launched missiles, which can carry up to to 14 warheads). On the other hand, dramatic changes in nuclear armaments could occur if, for example, existing treaties were to lapse, if major new arms restrictions were negotiated, or if major breakthroughs in strategic defense systems triggered an offensive response.

A number of developments in nuclear warhead technology have been discussed recently (Arkin et al., 1984). The advanced concepts include "penetrators" (which can burrow into the ground before detonating, producing stronger ground shock and less fallout than surface bursts); terminal guidance and maneuvering (which allows precise targeting, and reduction in warhead yields); and enhanced radiation weapons (which generate greater neutron fluxes but require relatively less explosive energy than weapons designed specifically for blast effects). Nevertheless, despite such technological possibilities, all of the major nuclear weapons programs underway, or planned, utilize more-or-less standard nuclear fission-fusion devices exceeding 100 kt in yield. Typical examples are the MX warhead (approximately 300 kt) and Trident D-5 warhead (approximately 400 kt) of the U.S. forces, and the modern SS-18 warhead (approximately 500 kt) and the new SS-24 and SS-25 long-range missiles (probably carrying warheads in the 200–500 kt range) of the U.S.S.R. (Cochran et al., 1984; Arkin and Fieldhouse, 1985). While average strategic warhead yields had been decreasing steadily since the 1950s, that trend may now have halted.

Strategic defense systems currently under discussion have no impact on the present study. The feasibility of such systems has not yet been demonstrated, and deployment would be decades away. Moreover, it is not clear whether nuclear arsenals would decrease or increase in response to defensive deployments.

2.3 TARGETS

Nuclear weapons normally on station, and certainly those on alert in a crisis, have specific targets or missions assigned to them. Both superpowers have lists of potential targets, which probably number up to 40,000 or more (Ball, 1982). These lists are unavailable to us. Nonetheless, based on published discussions of strategic doctrine, most of the likely target categories, as well as the general targeting philosophy, can be deduced (Kemp, 1974; Katz, 1982; Ambio Advisers, 1982; Ball, 1983; Meyer, 1984; NRC, 1985; Arkin and Fieldhouse, 1985).

In most credible strategies, fixed strategic military installations garner the highest targeting priority; these include intercontinental ballistic missile silos and command centers, major airfields, nuclear submarine pens, weapons production and storage facilities, and command, control, communication and intelligence (C^3I, or C^3) centers. There are also a number of other important military targets including: mobile missiles and launchers; military formations of troops, artillery and armour; tactical weapons storage sites; support and tactical airbases; naval surface vessels and submarines at sea; other army, navy, and air force bases and logistic centers; and military satellite communication links. Targeting of warheads against military facilities—fixed and mobile—is referred to as "counterforce" targeting.

Some potential military targets might be thought of as civilian targets. For example, major airports with long runways, jet fuel supplies, and equipment that could be utilized by military forces, and industries that directly support a war effort, could be subject to nuclear attack. Among the most vulnerable industries are petroleum, oil and lubricants, electric power, steel, and chemicals (Katz, 1982). Transportation and communication nodes and principal storage sites might also be subject to destruction. These facilities represent some of the classical targets of warfare. It is also known that these facilities are included on the general nuclear targeting lists (Ball, 1982). Hence, it is possible that nations such as Japan, the Middle-Eastern countries, Australia, and South Africa might be targeted in a military campaign in order to deny their use as staging areas and forward bases, or their support through manufacturing and supply of raw materials.

Consumer-oriented production, commercial enterprises, and the infrastructure of society—concentrated in urban areas—comprise a distinct category of targets for nuclear weapons. Such "countervalue" targeting (and the implied civilian casualties) provides the basis for the deterrence doctrine of Mutually Assured Destruction (MAD). Although the publicly proclaimed strategic doctrines of the nuclear powers now place less emphasis on countervalue targeting, the direct bombing of population centers, as a final blow or as retaliation is the most fearsome potential application of nuclear weapons. Furthermore, many, if not most, major urban areas have targets within them, or nearby. Also, in the closing volleys of a major nuclear exchange, a broad range of countervalue targeting might be anticipated to cripple the ability of an enemy to recover and rebuild (and presumably, re-arm). For the same reason, targeting of noncombatants who might be perceived as a post-war threat could occur.

Some strategists believe that, in a nuclear exchange, cities would not be purposefully struck by nuclear warheads. However, cities could still suffer massive collateral damage in attacks on priority military and industrial targets. Collateral damage is the destruction caused in the area surrounding a target; with existing nuclear warheads, the zone of massive destruction (and intense radioactive fallout in the case of surface bursts) would extend far beyond the actual perimeters of most military and industrial targets (as noted in Chapter 1, typical strategic warheads are capable of devastating areas of 50 to 500 km^2). Most major cities in the U.S., U.S.S.R., and Europe have important military facilities in them or near them (bases, ports, airfields, C^3I facilities). Some recent assessments of potential urban collateral damage in a counterforce nuclear exchange suggest that hundreds of cities could be affected unless great restraint were exercised (e.g., NRC, 1985). Realistically, extensive urban devastation should be expected in any sizeable exchange of nuclear weapons, even perhaps in otherwise noncombatant nations such as Japan and Australia. It is well established that industrial capacity is highly correlated with population density in cities (Kemp, 1974; Katz, 1982). Hence, any attempt to cripple industrial capacity using existing nuclear weapons would cause enormous collateral physical damage and human casualties. For example, Katz (1982) estimates that approximately 300 Mt (carried by approximately 600 warheads) could destroy up to 60% of all industry in the United States and kill up to 40% of the U.S. population. Industry and population in the Soviet Union are nearly as vulnerable to nuclear attack as in the U.S. (Kemp, 1974).

Both long-range and short-range nuclear tipped missiles can suffer mechanical failure, damage, or deflection in flight. Accordingly, while the target point of a warhead can be precisely determined prior to battle, the eventual detonation point cannot. Warheads would fall at varying distances from the planned targets, some probably far off. This uncertainty in the reliability and accuracy of a strike force, together with the hardness of missile silos and the mobility of bombers and submarines, allows for the possible survival of the opposing forces. However, the uncertainty also introduces a dispersion, or randomness, into the application of nuclear force. Such randomness could increase the collateral damage in cities that are close to, but not coincident with, military targets or in forested areas adjacent to missile fields. Conversely, in the event that a missile were to go astray, the randomness might also reduce collateral damage since the warhead would be more likely to detonate over unpopulated areas than populated areas, given the much larger fractional area of the former. Factors of system reliability and accuracy (determined primarily by engineering constraints) are not explicitly defined in the scenario to be discussed. The additional destructive effects of wildly errant or deflected warheads are difficult to quantify, and will be ignored.

2.4 STRATEGIC CONCEPTS

A variety of strategies have been proposed for the use of nuclear forces. Tactical nuclear weapons (artillery shells, bombs, mines, and depth charges) could be used in the battlefield to blunt attacks, and at sea to stop ships and submarines. In space, nuclear detonations could be used to disable satellite systems with military missions. Theater nuclear weapons (on aircraft and missiles) could be used against rear echelon forces.

Strategic counterforce exchanges would involve deep missile and bomber strikes against opposing strategic forces and support facilities. Counterforce strategies also countenance strikes against key industrial elements, to blunt the capacity to sustain a war. By contrast, countervalue strategies, utilizing tactical, theater, and strategic weapons, are conceptually designed to maximize economic and civic destruction and to impede industrial and social recovery. A countervalue attack would be the ultimate cost levied in a nuclear war.

Other strategic concepts include limited nuclear warfare, flexible response, controlled escalation, launch under attack, and so on (e.g., Openshaw et al., 1983). However, since none has ever been used in actual conflict, the potential outcomes are highly uncertain. It should also be obvious that any nation suffering a massive nuclear strike might well retaliate by attacks on cities.

Much thought and concern have focused on the problem of escalation in a nuclear exchange. While some strategists argue that maintaining sufficient control of nuclear hostilities is a practical and logical goal (Wohlstetter, 1983, 1985), others question the possibility of effective nuclear battle management and argue that greater perceived control lowers the threshold for use (Ball, 1981; Carter, 1985). The official position of the Soviet Union on this matter is that controlled escalation or limited nuclear warfare is not possible (Military Encyclopedic Dictionary, 1983). We shall not pursue here the complex arguments in this debate, except to note that command and control operations in the environment of a nuclear exchange would be extraordinarily difficult and unprecedented.

A surprise nuclear attack without prior crisis or conflict is possible, but not considered very likely. Although one side might gain some military advantage in a massive first strike, the present structure of the superpower forces assures that the victim would retain a devastating retaliatory capacity. It seems more likely that a strategic nuclear exchange would follow from initial tactical or theater nuclear strikes. The doctrine of limited nuclear warfare, if adopted, might increase the possibility of initial nuclear use (or it might deter the aggression that presumably would trigger such use). Importantly, escalating nuclear conflict implies that all forces would be on alert; hence, the magnitude and speed of the eventual strategic exchange could be greatly enhanced.

While the possibility of nuclear detonations through accident or terrorism exists, it is thought that a global nuclear war caused by such events is unlikely (Wohlstetter, 1983). In normal times, and even in a crisis, there would be little reason or incentive for one side to respond immediately to isolated accidental or terrorist nuclear explosions with a nuclear counterstrike. Without strong supporting indications of a massive pre-emptive nuclear strike, massive retaliation would clearly be inappropriate. On the other hand, one cannot rule out the possibility that a series of unprecedented events and misperceptions could move the superpowers closer to the brink of a nuclear conflict, particularly during a period of confrontation or conventional warfare.

The concept of a massive pre-emptive strategic nuclear strike in a global crisis could be a real military option (Ford, 1985). Thus, if in a deepening crisis nuclear war seemed imminent, the side striking first might be expected to gain certain advantages in forces, targeting options, and C^3I operations, assuming, of course, that enough weapons of sufficient accuracy were available to destroy the key targets of the other side. (Note that this is a quite different situation from a surprise attack "out of the blue", in which an attacking nation, not under duress, risks its own destruction). The existence of pre-emptive strike options in nuclear war plans implies a fundamental potential instability in the deployment of large strategic forces; depending to some extent on the types of delivery systems, the more weapons each side has available, the greater the advantages that might accrue from a pre-emptive attack in a serious crisis. Pre-emptive nuclear strike options would seem to enhance the danger of escalation in any confrontation or conflict between the superpower alliances.

2.5 SCENARIOS

Possible scenarios for a global nuclear war are described in a number of documents (NAS, 1975; OTA, 1979; Ambio Advisors, 1982; Turco et al., 1983a; Knox, 1983; NRC, 1985). These scenarios are summarized in Table 2.2. For the most part, the scenarios are derived from analyses of nuclear weapons stockpiles, and assessments of nuclear doctrines and strategies (to the extent these are publicly available). Nevertheless, many of the scenarios have been criticized as representing extreme and unrealistic cases (Wohlstetter, 1985). The number of possibilities is obviously very large and the probability associated with any particular scenario is unknown. Hence, only the general structure of a nuclear scenario is considered here to determine if massive exchanges (amounting to thousands of megatons) could occur within the limits circumscribed by existing arsenals and deployments and the inevitable attrition of forces. Lesser exchanges would also be possible.

A hypothetical strategic nuclear exchange can be divided into four phases that might occur in an escalating conflict between NATO and Warsaw Pact forces (neglecting a possible initiating tactical phase): (1) an initial "counterforce" strike and response against key strategic military targets, with minimal

TABLE 2.2.
PUBLISHED NUCLEAR WAR SCENARIOS

Source	Description
National Academy of Sciences (1975)	10,000 Mt in 1500 detonations Warhead sizes: 1 to 10 Mt Targeting not specified
Office of Technology Assessment (1979)	7800 Mt in 8985 detonations Warhead sizes: 0.1 to 20 Mt Other parameters not described
Ambio (1982)	5742 Mt in 14,747 detonations (163 Mt on the Southern Hemisphere) Warhead sizes: 0.1 to 10 Mt 1941 Mt on cities, 701 Mt against industry
Turco et al. (1983a)	5000 Mt (baseline) in 10,400 detonations Warhead sizes: 0.1 to 10 Mt 2850 Mt in surface bursts, 1000 Mt in urban zones 3000 Mt (counterforce excursion) in 5433 detonations Warhead sizes: 0.3 to 5 Mt 1500 Mt in surface bursts, no detonations in urban zones 100 Mt (city excursion) in 1000 detonations Warhead size: 0.1 Mt 100 Mt in urban zones
Knox (1983)	5300 Mt in 6235 detonations Warhead sizes: 0.1 to 20 Mt 2500 Mt in surface bursts
National Research Council (1985)	6500 Mt in 25,000 detonations Warhead sizes: 0.05 to 1.5 Mt, plus tactical 1500 Mt in surface bursts, 1500 Mt in urban zones, 500 Mt tactical

direct destruction of population centers; (2) extended counterforce attacks against secondary military bases to disable support and logistics missions, which would necessarily involve some collateral damage to urbanized areas (Kemp, 1974); (3) massive strikes against the industrial base which supports military operations; and finally, (4) direct attacks against economic infrastructures to retaliate or retard postwar recovery. A strategic conflict could escalate within a matter of days from one phase to the next, although termination is possible at each phase, at least in theory.

The important characteristics of such a hypothetical escalating nuclear exchange are summarized in Table 2.3. Two general target categories are identified: military, and industrial/urban. Collateral damage to urban areas caused by strikes against military targets near or in cities has been counted. Detonation heights are divided into two regimes: airbursts (in which the fireball does not touch the ground, although the explosion occurs within several kilometers of the surface), and surface bursts (in which the fireball is in contact with land or water). Airbursts maximize the area of damage from blast and thermal radiation, but minimize contamination from early local radioactive fallout (although delayed global fallout may be enhanced). Surface bursts maximize the damage to nearby "hard" targets and reduce the overall area of thermal (fire) effects, but also contaminate large areas with lethal doses of radioactive fallout.

TABLE 2.3.
NUCLEAR EXCHANGE SCENARIO[a]

Phase of the exchange	Aggregate weapon yield (Mt)	Number of warheads	Military yield (Mt)		Industrial and/urban yield[b] (Mt)	
			Air	Surface[c]	Air	Surface[c]
Initial counterforce and response	2000	5000	1000	1000	0	0
Extended counterforce	2000	3800	750	750	250	250
Industrial	1000	1200	250	250	500	0
Final phase	1000	2600	250	250	500	0
Total[d]	6000	12600	2250	2250	1250	250

[a] Tactical weapons are not included. These could add 100–500 Mt in the less than 50 kt yield range. The warhead yields and numbers are taken from Table 2.1. It is assumed that the weapons have a fission yield fraction of 0.5.

[b] Includes weapons directed at industrial and economic targets as well as weapons directed at military targets that would generate significant urban collateral damage.

[c] Land surface.

[d] Cumulative targets include:

2500 missile silos and command centers (2 warheads per silo)
1100 military facilities and airfields throughout NATO and the Warsaw Pact (2 warheads per target)
100 naval targets
500 mobile missiles (barraged by 1200 warheads)
1100 miscellaneous military detonations
3000 military/industrial and energy resource sites worldwide.

The illustrative scenario in Table 2.3 was constructed using the following general guidelines (details will not be given here):

1. The weapons employed reflect the data in Table 2.1.
2. The targets within the NATO and Warsaw Pact countries include (at different phases of conflict):
   - Fixed and mobile strategic and theater missiles
   - Strategic airfields and submarine bases
   - Other military (air force, army, navy) bases
   - Military units in the field and vessels at sea
   - Logistics and communications centers
   - Military satellites
   - Nuclear weapons production and storage sites
   - Civil airfields having potential military utility
   - Fossil fuel and nuclear energy facilities
   - Cities with key industrial and/or economic functions.
3. The conflict develops over time (approximately days to weeks) from confrontation to crisis to conventional hostilities to tactical nuclear strikes, so that all major military forces are on alert and can respond in short order; a precipitous strike without warning is not considered.
4. Forces are assumed to be destroyed during the early phases of conflict (and thus do not deliver their weapons) as follows (roughly half of the nuclear weapons are depleted in this manner):
   - 90% of unfired ICBMs
   - 1/3 of strategic bombers
   - 1/3 of nuclear submarines with unfired missiles
   - 1/3 of reserve mobile missiles
   - 1/3 of reserve tactical bombers
5. Damage to industrial/urban areas, either through direct or collateral effects (neglecting radioactive fallout) is caused by a fraction of the explosive power during each phase of conflict as follows:

Initial counterforce:	0%
Extended counterforce:	25%
Industrial phase:	50%
Countervalue phase:	50%
Average over all phases:	25%

   The average over all phases is determined by multiplying the fraction for each phase by the number of megatons detonated in that phase, adding, and then dividing by the total megatonnage.
6. Each side would retain only a relatively small reserve force, consisting mainly of spare missiles and warheads.

Although each of these assumptions can be argued, the overall scenario appears to be consistent with the technical facts and strategic concepts reviewed earlier. For example, a cursory analysis of the present balance of nuclear forces indicates that massive nuclear exchanges are clearly possible (even if, as some believe, not likely). Moreover, it is plausible that many urban and industrial zones would be destroyed by volleys of nuclear weapons, given the collocation of military and industrial targets with population centers. Although each of the conflict levels in Table 2.3 is enormous with respect to the destructive power of previous wars, it is not so with respect to the actual destructive potential of the current and projected nuclear arsenals (Arkin et al., 1984). While one could propose smaller nuclear exchanges, or perhaps isolated tactical phases, it is appropriate to remain skeptical of controlled or limited nuclear warfare. It should also be noted that the scenario in Table 2.3 is not the worst possible case since less than one-half of the existing arsenals are assumed to be detonated; scenarios may be envisioned in which larger fractions of the arsenals could be detonated.

2.6 IMPLICATIONS

The full-exchange scenario in Table 2.3, which was assembled through an analysis of nuclear forces, target categories, and stated strategies, is similar to the scenario developed by the U.S. National Research Council panel (NRC, 1985) through different lines of reasoning. While this agreement does not validate either scenario, it reinforces the credibility (if not the probability) that such an outcome is possible in a nuclear conflict between the superpowers.

The critical parameters in Table 2.3 (from the perspective of an assessment of global effects) are:

1. The total yield in surface bursts with yields greater than 100 kt; these explosions lift dust into the upper troposphere and lower stratosphere, and produce large plumes of radioactive fallout. The cumulative yield of these dust-raising and fallout-generating bursts ranges from 1000 to 2500 Mt, depending on the phase of the exchange (virtually all ground-burst strategic warheads are included in this category). In the case of local fallout, it is also important to know the fission yield fractions of the weapons, and the proximity of population to the fallout plumes.
2. The total yield detonated in industrial/urban zones; these explosions ignite fires in the highly combustible and soot-generating materials accumulated in urbanized areas, including fuel storage sites. The fire-ignition yield varies from 0 to 1500 Mt, and is associated primarily with air bursts.

The tactical component of an exchange is not included in these figures, but is important in its own right, particularly in densely populated and industrialized areas such as Europe. Tactical explosions, perhaps numbering in the thousands, could produce extensive fires and radioactive fallout, and might represent the trigger for a strategic exchange. Hiroshima and Nagasaki provide examples of the potential destructiveness of modern tactical weapons (see Chapter 1).

Of all the explosions in a nuclear war, only relatively few might be detonated in the upper atmosphere (to create electromagnetic pulse, EMP) or on ocean surfaces (to destroy ships). The high altitude explosions could have an importance exceeding their relative number if they were to encourage nuclear escalation through the disruption of communications and control networks. Future ballistic missile (and other) defensive systems might one day lead to a military posture in which bursts above the atmosphere were predominant. For the present study, however, it is reasonable to assume that the fraction of such bursts is fairly small.

Turco et al. (1983a) have suggested that the number of nuclear explosions required to create severe climatic disturbances (their "nuclear winter") may be relatively small. They suggest that on the order of one thousand 100-kt detonations over major industrial and urban centers might be sufficient, because the greatest fuel densities are contained in a rather small number of urban industrial complexes and fossil fuel storage sites. According to Chapter 3 and the NRC (1985) report, about 10 percent of the total urban area may hold 50 percent of the total urban combustible material. These areas also might be subject to collateral damage in attacks against critical strategic targets, even if the cities are not bombed purposefully. Because of this concentration of fuel in a relatively few target regions, it is possible that more restricted scenarios (phases) than those described in Table 2.3 could lead to major environmental impacts, depending much more, however, on the details of the targeting and the uncertainties in the physical outcomes. Likewise, the significance of tactical explosions could be amplified to the extent that cities and industries, and fire-susceptible natural environments, were subject to collateral effects.

This general discussion of scenarios for nuclear warfare is only meant to provide information and guidelines, and to establish plausibility. The scenario described in Table 2.3 is not explicitly used, except in its most general aspects, in the following analyses of fires, smoke, dust, and climatic responses. Indeed, most of the climatic impact studies surveyed in the following chapters are not predicated on any particular targeting scenario, but rather on a particular initial amount of smoke and/or dust injected into the atmosphere. In the case of radioactive fallout, the scenario just described is used in Chapter 7 to provide an example of potential nuclear radiation effects.

There is no objective way to attach a probability to any particular scenario describing a nuclear war. For the present purposes, it is sufficient to determine whether a massive nuclear exchange is credible or not credible. Although the concept of nuclear warfare involving the use of many nuclear weapons seems incredible and even irrational, the weapons for conducting such a war have been deployed and elaborate plans of action exist. It is unacceptable simply to dismiss the potential for global nuclear conflict on philosophical grounds. The deployment of nuclear warheads implies, in a very real sense, the possibility of their use.