The Consequences of a "Limited" Nuclear War in East and West Germany

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This article, which describes two variations of a "limited" nuclear war in East and West Germany, is based on scenarios that differ from the one on which the other articles in this issue are based. The authors demonstrate that even the most limited of militarily significant uses of nuclear weapons in the two Germanies would have catastrophic consequences, with many millions of fatalities, and the likelihood of escalation to full scale, global nuclear war.

As the other articles in this issue of *Ambio* demonstrate, the use of a significant fraction of the US and Soviet strategic weapons arsenals could result in enormous destruction throughout the Northern Hemisphere. It is their ability to invoke this murder-suicide pact that the superpowers consider their ultimate deterrent against nuclear attack.

The strategic warheads which the US and Soviet Union are prepared to rain down upon each other comprise, however, less than half of the number of nuclear warheads in their arsenals. The remainder of their nuclear weapons are intended for naval warfare and for the deterrence of attacks against their "vital interests" in regional confrontations around the world.

The most heavily nuclearized regional confrontation is that between the NATO and Warsaw Pact forces in Europe, involving over 10 000 so-called "theatre" nuclear warheads. Currently there is a great debate going on in Europe about the benefits and dangers which are associated with the presence of these weapons. Frequently discussed in this debate are scenarios for the "limited" use of nuclear weapons in Europe. The purpose of this article is to provide some estimates of the consequences for the civilian population of such possible "limited" nuclear wars.

Our finding is that any use of nuclear weapons which would have militarily significant effects against targets in the densely populated and developed continent of Europe would result in the deaths of many millions of civilians. Similar estimates have previously been obtained for the consequences of limited nuclear exchanges between the superpowers (1).

Since some strategists will probably point out the "good news"—that, for the very limited and controlled attacks discussed in our scenarios, the majority of the population of Europe would survive—it is important to emphasize how unlikely it is that a nuclear war would be stopped after such initial attacks. By the time warheads were used against large fractions of significant classes of military targets (hundreds of nuclear warheads against fixed military targets and more than a thousand against battlefield targets), it is likely that the exchange of nuclear blows would be building up with such great rapidity that all-out nuclear war would be inevitable. Each side would be under enormous pressure to use its nuclear forces for fear that its weapons or command and control abilities were about to be lost due to enemy attacks (2).

The first use of nuclear weapons in Europe would probably be an act of desperation—an attempt either to reduce the strength of an apparently imminent nuclear attack by the other side or to prevent a major defeat or irreversible loss of territory in a war being fought with non-nuclear weapons. In the following two sections we will, therefore, describe and consider the consequences of two hypothetical, strictly "limited" nuclear attacks:

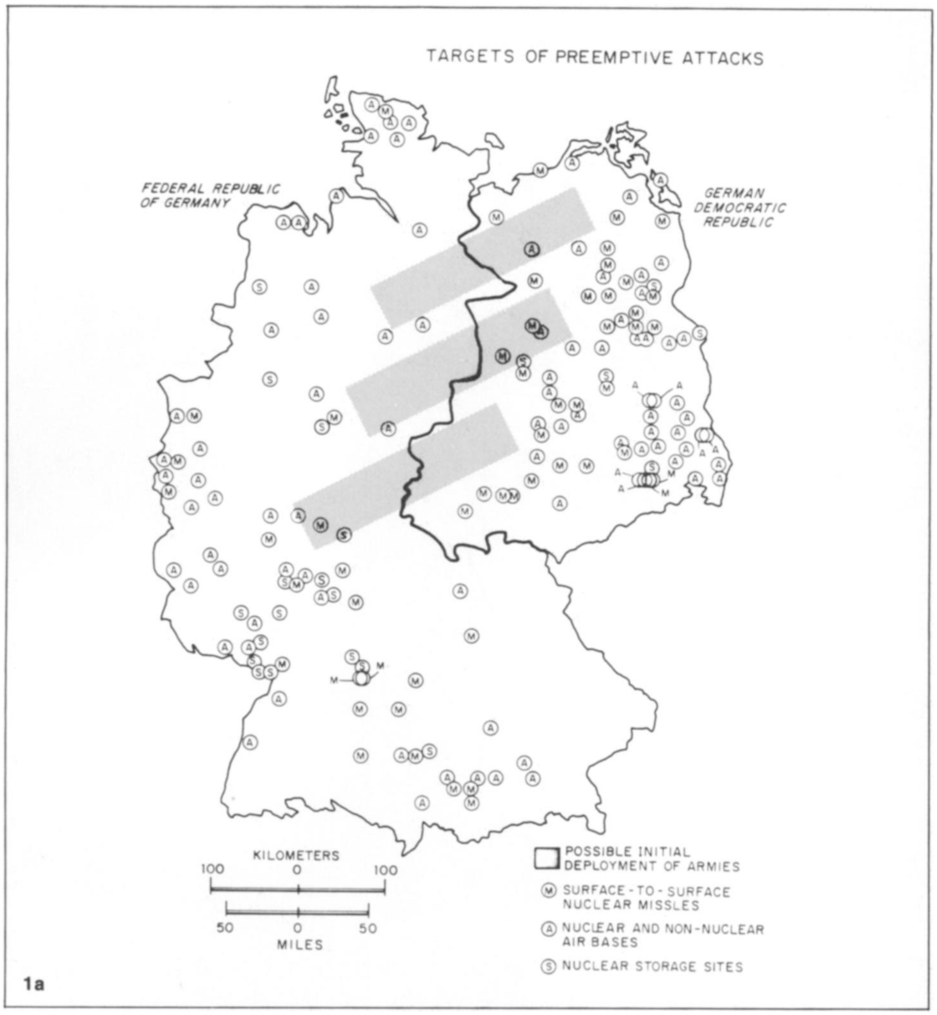


Figure 1 a. The locations of 92 military airbases in the Germanies are indicated by the circles containing the symbol "A", 56-surface-to-surface missile sites by a circle with an "M", and 24 known and inferred nuclear weapons storage depots by a circle with an "S". These are the assumed targets of the preemptive attacks discussed in the text. The area of each circle is 180 square kilometers, the estimated equivalent "area of death" below a 200 kiloton warhead exploded at an altitude of 2 kilometers.

The shaded rectangles show the sizes of the areas which might be covered in a confrontation along the border by three Soviet Armies and the opposing NATO forces. Battlefield nuclear weapons would be used against the forces in such areas.

Figure 1 b. The pattern of population density in the two Germanies.

Figure 1 c. The fallout pattern, given "typical June winds," for an attack against the targets shown in Figure 1 a with surface-burst 200 kiloton weapons.

A) preemptive attacks by each side against the nuclear weapons and nuclear weapons delivery vehicles of the other side, and
B) the battlefield exchange of nuclear weapons between the NATO and Warsaw Pact armies.

Our analysis restricts itself to a study of consequences of these nuclear exchanges for East and West Germany because a comprehensive analysis of the consequences for all of Europe was not feasible. Our choice of the two Germanies was hardly by chance, however. Across the boundary dividing their small combined area (356 000 square kilometers—equal to only 4 percent of the area of the US or 1.5 percent of the area of the Soviet Union) large fractions of both the nuclear and non-nuclear military forces of the NATO and Warsaw Pact alliances confront each other "nose to nose." As a result, should war break out in Europe, it is most likely that the Germanies would be at its focus and, should nuclear weapons be used, it is likely that they would be used both first and most intensely on these same small territories.

It is unlikely that any nuclear exchange would long remain limited to the Germanies, however. It would make little sense, in particular to conduct a preemptive attack against the nuclear weapons in the Germanies without attempting to destroy the other nuclear weapons which are controlled by the alliances in Europe. Ultimately, it would make little sense to destroy the nuclear weapons deployed by a superpower in Europe without trying to destroy the associated nuclear weapons on that superpower's home territory. Nothing but labeling prevents these weapons from being targeted against the nuclear forces of the opposite alliance—either in Europe or at home. Our analysis of the consequences of such preemptive attacks should therefore be thought of as an examination of what might occur as a result of the first nuclear exchanges in one small part of what would probably grow rapidly into a global nuclear battlefield.

Both the attacks which we will discuss are assumed to be purely countermilitary. In neither case do we assume that there is a deliberate attempt to destroy populations or their support systems. In other words, all civilian deaths would be purely "collateral" (unintentional). By focussing on the smallest plausible military use of nuclear weapons in the Germanies (apart from "demonstration" attacks), we hope, therefore, to make clear the *least* damage which would result to the population and society of this one area of Europe following any actual implementation of the doctrines of limited nuclear war on that continent.

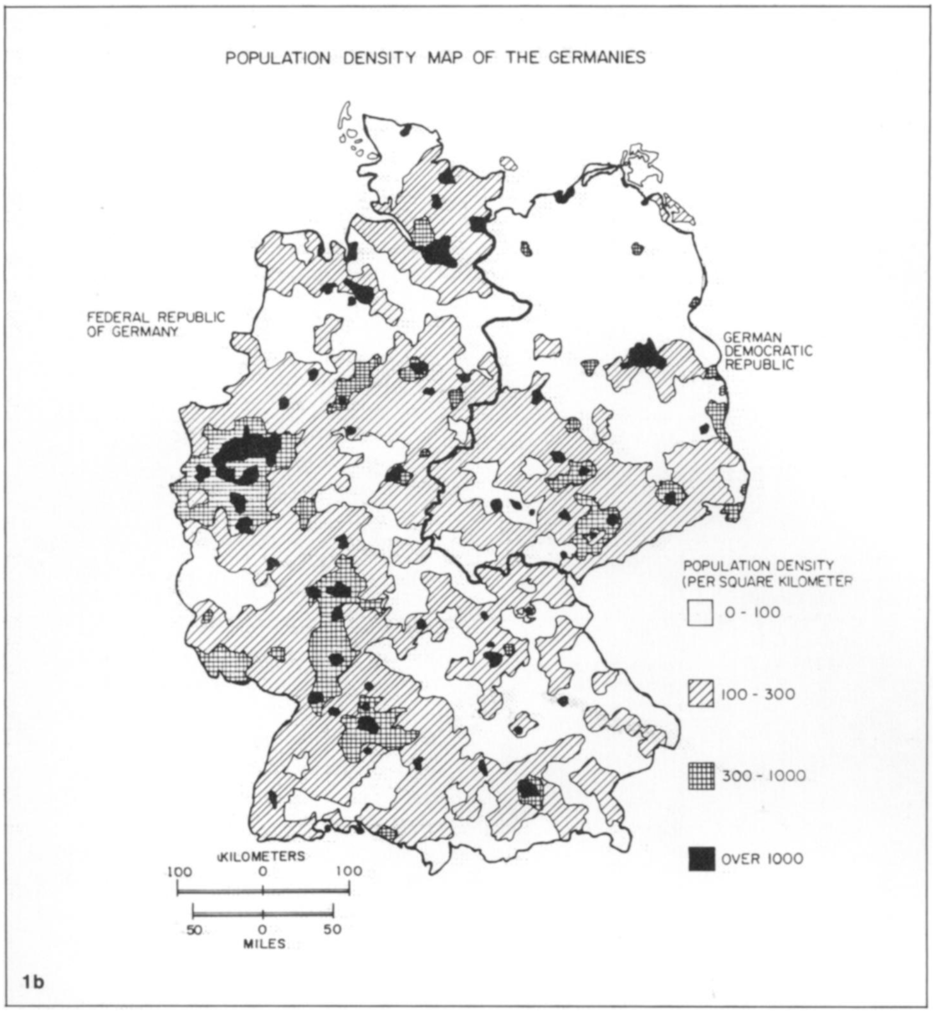
In what follows, we will discuss for each of the hypothetical attacks in turn: the targets of the attack; then the nuclear warheads which might be used in those exchanges and their individual effects; and finally, the consequences for the populations of East and West Germany of the full exchanges.

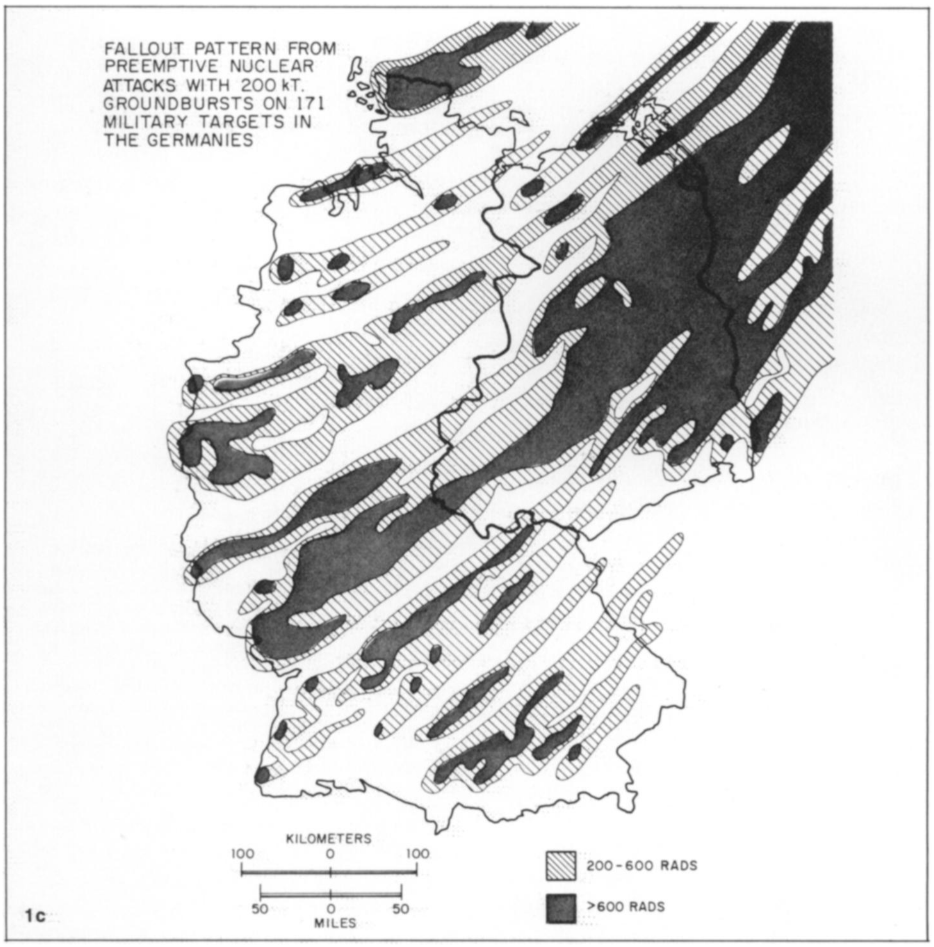
PREEMPTIVE ATTACKS AGAINST NUCLEAR FORCES

The Targets. While the introduction of nuclear weapons into Europe has made a large scale "conventional" (World War II type) war less likely, it has made nuclear war more likely. Specifically, in a period of crisis, if one side believed—correctly or mistakenly—that the other was considering using even a few nuclear weapons, there would be enormous pressure to attempt a "preemptive" attack on those weapons.

The superpowers have gone to great lengths to protect their strategic arsenals against surprise attack by placing them in thousands of widely separated underground concrete silos, in many submarines hidden in the depths of the ocean, and in bombers prepared to take off given 5–15 minutes notice. Almost all of the many thousands of nuclear warheads and delivery systems in the Germanies are, however, grouped during peacetime at about 135 known and relatively vulnerable sites. (Efforts would be made during crisis or wartime to further disperse these weapons) (3). In some situations such a dispersal might be interpreted by the other side as preparation for "going nuclear," however, and could, therefore, be the trigger for a preemptive attack before dispersal could be completed).

In addition to nuclear weapons and delivery systems, there are other classes of facilities and locations in Europe which are discussed as appropriate targets for nuclear weapons. According to one recent official listing, these include:





"IRBM/MRBM [Intermediate and Medium Range Ballistic Missiles] sites; naval bases; nuclear and chemical storage sites; airbases; command, control, and communications centers; headquarters complexes; surface-to-air missile sites; munitions and petroleum storage areas and transfer facilities; ground forces installations; choke points; troop concentrations; and bridges" (4).

Although Box 1 categorizes more than 1 100 such targets in the two Germanies, it does not include all the target categories on this list.

For the targets of the hypothetical preemptive exchange discussed in this article, we have limited ourselves to the 171 locations shown in Figure 1a which are the sites of the greatest offensive nuclear threats in the Germanies: 91 bases for military aircraft, 56 sites where surface-to-surface nuclear missiles are based, and 24 known or inferred nuclear weapons storage depots. Military airfields which are not known to host nuclear armed aircraft during peacetime are included in this list because history suggests that, under crisis conditions, nuclear armed aircraft would be dispersed for their protection to all military airfields and probably to some civilian airfields as well. During the Cuban missile crisis, for example, some US strategic bombers were even dispersed to major metropolitan airports.

All of the targets shown in Figure la could, of course, be attacked with non-nuclear weapons but with much less assurance of success than could be achieved with a nuclear attack. Storage sites for nuclear weapons and their delivery vehicles, as well as airbases and many support facilities, have been "hardened" against attack by conventional explosives. Furthermore, important installations are defended against bomber attack by surface-to-air missiles, anti-aircraft guns and fighter aircraft (5). The ballistic missiles which would probably be used to penetrate these defenses are equipped exclusively with nuclear warheads.

It is likely that an attacker would try to eliminate the reconnaissance and communications systems of the enemy and try to destroy his air defenses and command facilities at the beginning of a preemptive attack. Nevertheless, in describing the smallest plausible preemptive attack, we have excluded as targets: radar early warning sites, high level headquarters, communication centers, and the locations of air defense missiles. We have also excluded 38 nuclear-capable artillery unit locations from the preemptive attack because the short range (less than 30 kilometers) of such weapons limits the area which they can immediately threaten.

The Attacking Weapons. The nuclear weapons which are committed for use in an attack against fixed targets in Europe include approximately 2 500 warheads on short to medium range missiles plus the bombs carried by an estimated 2500 nuclear-capable fighter-bomber aircraft and medium range bombers. These delivery vehicles are located in Europe, the United States, the Soviet Union, and the waters surrounding Europe (see Box 2). The number of nuclear weapons and delivery vehicles on each side is so large that, even if a preemptive attack by one side against the other throughout Europe were 90 percent successful, the attacked side would retain enough nuclear weapons to execute a symmetrical counter-attack without resorting to strategic weapons.

The estimated yields of the warheads on the short to medium range delivery vehicles targeted on Europe range from one to over one thousand kilotons (a nuclear weapon with a one kiloton yield produces a blast equivalent to the explosion of one thousand tons of TNT). For simplicity, we will assume that all weapons used on the targets shown in Figure 1a have a yield of 200 kilotons. This is close to the yield of 150 kilotons which is ordinarily assumed for each of the three warheads on new Soviet SS-20 missiles. It is also the yield of each of the three Polaris warheads on Britain's ballistic missile submarines. (These submarines are under NATO control.) It is considerably more than the 40–50 kilotons which is the estimated yield of each of the 400 Poseidon warheads which the US has committed to NATO but it is also considerably less than the 1100 kiloton yield

BOX 1. TARGETS FOR NUCLEAR WAR IN THE GERMANIES

	Number of targets		Hardness
	West Germany	East Germany	
A. NUCLEAR THREAT			
* **Surface-to-surface missile sites**	23	33	low-moderate
* **Nuclear air bases**	9	8[a]	low-moderate
Nuclear artillery battalions	38	0	low
* **Nuclear storage sites**	18[a]	6	moderate-intermediate
	88	47	
B. OTHER MILITARY			
National/International hq.	12	6	low
Command/Communications centers	31	13	moderate-intermediate
Army/Corps/Division hq.	31	34	low
* **Air bases (non nuclear)**	37	40[a]	low-moderate
Naval bases	7	8	low
Ground forces bases	256	137	low
Radar/Early warning sites	21	10	low
Surface-to-air missile sites	90	100	low
Munitions/Petroleum storage areas	75	63	moderate
Logistic installations	27	15	low-moderate
Chemical storage sites	1	6	moderate-intermediate
	588	432	
TOTAL	**676**	**479**	

*** Targets attacked in our scenario for a preemptive attack.**
[a] At the time of this writing we have not obtained the coordinates of one of these sites. An attack on it is therefore not shown on either Figures 1a or 1c.

Sources for Table: The numbers of targets were derived by counting known locations and inferring additional locations via analysis of force structure and military organizations. While specific numbers may be inaccurate, the ratio of targets in each class and on each side are thought to be accurate enough to represent the nature of the military presence in the two countries. Estimates of target hardness were derived from the US Departments of Defense and Energy, *The Effects of Nuclear Weapons*, 3rd Edition, (Samuel Glasstone and Philip J Dolan, eds., Washington, DC, US Government Printing Office, 1977).

The theory of nuclear deterrence, as practiced by the superpowers, requires not only that they be able to destroy each other's societies, but that they also be able to use nuclear weapons against purely military targets should the nuclear threshold be crossed (1). As nuclear weapons delivery systems have become lower yield, more diverse, flexible, and accurate, so that they are effective against particular targets with less (but still enormous) damage to the surrounding civilian society, the list of military targets against which nuclear weapons could be used has become steadily longer. The Table above categorizes more than 1100 sites in the Germanies which have been designated by military authorities as appropriate targets for nuclear weapons.

Much more is known about NATO's nuclear targeting plans in Europe than those of the Warsaw Pact but NATO's plans are probably indicative of the thinking on both sides. NATO's "Nuclear Operations Plan" includes two attack plans: the "priority strike plan" and the "tactical strike plan" (2). The priority strike plan includes the "nuclear threat targets" which are targets which are assumed in the preemptive attack scenario discussed in this article. The tactical strike plan includes other military and urban industrial installations.

The targets for nuclear weapons in Europe are much "softer" than the underground silos in which intercontinental ballistic missiles are housed. These silos are designed to withstand overpressures of 140 to 400 atmospheres. Virtually all of the targets listed on the Table would be destroyed by overpressures of less than 20 atmospheres and most of them (*eg* aircraft and above ground military office buildings) would be destroyed by "low" overpressures (less than 0.3 atmospheres for equipment disablement, up to one atmosphere for essentially complete destruction). The hardest targets in Europe are probably buried and partially buried structures with steel reinforced concrete arches which occur at nuclear weapons storage sites and some command centers. These might require "intermediate" overpressures (less than 15 atmospheres overpressure for disablement and up to 20 for destruction). The remaining targets would require overpressures falling in the "moderate" range (less than 3 atmospheres for disablement and up to 4 atmospheres for destruction).

Because of the superior accuracy of delivery vehicles such as the Pershing II and cruise missiles which have been proposed by NATO for deployment in Western Europe and the relative softness of their targets, the warheads which would be deployed on these vehicles have yields in the tens rather than in the hundreds of kilotons range. Many of the targets listed in the Table are spread over considerable areas, however, and therefore may continue to require large yields for their destruction.

References and Notes

1. Targeting and target categories are discussed in: Ball, Desmond, "Counterforce Targeting: How New? How Viable?" *Arms Control Today*, February 1981; Geoffrey Kemp, *Nuclear Forces for Medium Powers: Part 1; Targets and Weapons Systems* (London: Institute for Strategic Studies, Adelphi Paper #106, 1974); US Congress, Senate Armed Services Committee Hearing, *Department of Defense Authorizations for Appropriations for Fiscal Year 1980*, Part 3, p. 871; and US Congress, Senate Armed Service Committee Hearing, *Department of Defense Authorizations for Appropriations for Fiscal Year 1981*, Part 5, p. 2721.
2. NATO's strike plans are discussed in US Congressional Budget Office, *Planning US General Purpose Forces: The Theater Nuclear Forces* (Washington, DC, US Government Printing Office, January 1977).

of the most powerful weapons carried by NATO bombers and fighter bombers. In short, it seems a reasonable mid-range choice.

The Weapons Effects. A principal determinant of the "collateral" effects of the explosion of a nuclear warhead is whether or not it is exploded close enough to the ground to cause local fallout.

If a 200 kiloton warhead were exploded at an altitude greater than about one half kilometer, the nuclear fireball would not touch the ground and therefore would create relatively little local fallout. At or above such an altitude it would still be possible to maximize the areas covered by overpressures up to about 15 atmospheres (6). Missiles and aircraft could be destroyed by much less overpressure than this. Conceivably, therefore, preemptive attacks in the Germanies might involve relatively few bursts at low enough altitudes to result in local fallout. However, if the attacker wished, for example, to make an airport unusable by cratering its runways or by blanketing it with intense fallout—both options are discussed in the military literature (7)—then lower altitude or surface bursts would be used. The predictability and relative immunity to countermeasures of contact fuses, could also introduce a strong bias in favor of surface bursts (8). In the 1980 NATO "Square Leg" exercise, which involved a hypothetical nuclear attack on strategic and other targets in the

BOX 2. NUCLEAR WEAPONS COMMITTED FOR USE IN EUROPE

Weapons Class and Type	Number of Delivery Vehicles Deployed for Possible Use in the Germanies (as of 1/82)	Number of Warheads Per Delivery Vehicle × Estimated Yield (in kt)	Range (km)	Primary Uses
Ballistic Missiles				
Submarine Launched				
Polaris A3 (NATO)	64	3×200	4600	Pre-targeted, Portion on Alert
Poseidon C4 (NATO)	(400 *warheads*)	(10–14)×(40–50)	4500	Pre-targeted, Committed to NATO, on Alert.
Intermediate Range				
SS-20 (Warsaw Pact)	190	3×150	5000	Pre-targeted, Possibly on Alert
SS-4/SS-5 (WP)	255	1×1000	1900/4100	Pre-targeted, Possibly on Alert
Short Range				
Pershing 1A (NATO)	180[a]	1×(60–400)[b]	720	Pre-targeted and Battlefield Use, Portion on Alert.
SS-12 (WP)	65[a]	1×low kt	900	Pre-targeted, Possibly on Alert
SCUD (WP)	460[a]	1×low kt	150–450	Battlefield Use and Pre-targeted
Lance (NATO)	100[a]	1×(1–100)[b]	135	Battlefield Use.
FROG (WP)	120[a]	1×(1–10)	120	Battlefield Use.
Nuclear Capable Aircraft				
Long Range Bombers (NATO)	213	(≈2)×1–1100	1900–2800	Pre-targeted and Battlefield Use, Portion on Alert.
Long Range Bombers (WP)	500	(1–4)×low-high kt	1600–4025	Pre-targeted and Battlefield Use.
Medium Range Aircraft (NATO)	680	(1–2)×1–1100	720–950	Battlefield Use and Pre-targeted, Portion on Alert.
Medium Range Aircraft (WP)	1000	1×low-high kt	600–720	Battlefield Use and Pre-targeted
Other Weapons				
Artillery (NATO)	700	(av. ≈3)×<1–10	14–29	Battlefield Use.
Atomic Demolition Munitions (NATO)	300	1×<1–15	–	Battlefield Use and Pre-targeted

[a] Does not include reloads
[b] Variable yield

Sources: William M Arkin, "Nuclear Weapons in Europe: What are They, What are They For?", in *Disarming Europe* (Mary Kaldor and Dan Smith, eds., London; Merlin, 1982); and IISS, *The Military Balance, 1981–82* (London: International Institute for Strategic Studies, 1981). These and other sources differ in detail but not in the order of magnitude of the totals.

The listing in the Table above indicates that both NATO and the Warsaw Pact have a great enough diversity of nuclear weapons and delivery vehicles to assure themselves that they will always have a "nuclear option" available for virtually any contingency (1). The warhead explosive yields range from as little as 0.01 kilotons for some nuclear land mines to 1100 kilotons for some bombs.

Almost all the missiles or aircraft listed in the Table could be used in the preemptive attack discussed in the main text. Missiles have the greatest probability of reaching their targets (there is no defense today against incoming missiles) but they are generally less accurate than nuclear bombs and must be pre-targeted. The best indication of which weapons would actually be used in a preemptive attack is the weapons which are kept constantly on alert. These are indicated in the Table. NATO has approximately 580 warheads on constant alert in Europe (2), but the number that the Warsaw Pact has on alert is unknown.

Artillery and pre-positioned land mines could be used in addition to ballistic missiles and aircraft for the delivery of nuclear weapons on the battlefield. On the NATO side, neutron warheads are being produced for delivery by both artillery and the short-range Lance missiles.

References and Notes

1. Comprehensive discussions of the nuclear weapons in Europe appear in Jeffrey Record, *US Nuclear Weapons in Europe: Issues and Alternatives* (Washington, DC, The Brookings Institution, 1974); and Stockholm International Peace Research Institute, *Tactical Nuclear Weapons: European Perspectives* (London, Taylor & Francis, Ltd., 1978).
2. Our estimates of the NATO warheads on alert include 400 Poseidon submarine launched ballistic missile warheads, 48 Polaris submarine launched ballistic missile warheads, 45 Pershing missiles, 48 bombs on long range aircraft (F-111 and Vulcan bombers), and 40 bombs on medium range aircraft (F-4, F-104, Jaguar and Buccaneer fighter aircraft).

United Kingdom, it was assumed that most "time urgent" military targets would be attacked by *both* surface burst and air burst weapons (9).

Surface Bursts: A 200 kiloton surface burst would pulverize and vaporize vast amounts of soil and rock. A considerable amount of this material would mix with the radioactive fission products from the explosion and be carried by the rising fireball to a height of about 10 kilometers. In the following hours, the larger particles in the resulting cloud of radioactive dust would filter back to the surface creating a swath of radioactive "local" fallout—typically stretching for hundreds of kilometers downwind from the explosion. Figure 2 shows contours of radiation dose for such a swath while Figure 1c shows the summed effects of 200 kiloton groundbursts landing on the targets shown in Figure 1a. Both patterns were calculated assuming "typical June day" wind conditions (10, 11). These conditions are highly simplified in that the wind speed (which is about 50 kilometers per hour averaged from the earth's surface to the 10-kilometer cloud height) and wind directions are assumed to remain constant, rainfall is assumed to be absent, and the effects on the wind of hills and mountains are ignored. If these oversimplifications were corrected, a much more complex fallout pattern would result. Also, of course, the winds of one day are quite different from those of another. Our calculated fallout patterns are therefore merely indicative of the magnitudes of the areas which would be covered by fallout at various levels of intensity.

The contours in Figures 1c and 2 measure the peak level of radiation damage at the time when the intensity of the fallout radiation field has declined to the level where the rate of biological repair exceeds that of further biological damage. This damage, the "equivalent residual dose" (ERD), is measured by the equivalent dose of radiation in units of "rads" of a single short burst of gamma radiation which would cause an equal amount of biological damage. Deaths from radiation illness would begin to occur at equivalent doses of less than 200 rads and, in the absence of access to hospital facilities, few people would survive for much more than two months after receiving equivalent doses greater than about 600 rads (see Figure 3) (12, 13). Persons spending most of their time indoors would have radiation doses only about one third as large as those shown in Figures 1c and 2. Persons able to find and stay in below-ground basements for periods on the order of one month would accumulate radiation doses only about one tenth as large.

Sheltering would be especially important for dose reduction in the early period immediately after fallout began to arrive. Twenty kilometers downwind from the 200 kiloton nuclear explosion, more than one half of the dose shown in Figure 2 would accrue in the first eight hours of exposure. Unfortunately, this is just the period during which much of the population might be caught on the roads trying to evacuate, searching for missing children, or trying to equip a basement for a lengthy stay.

For that part of the population away from areas affected by blast and fire and who had access to shelter in basements, conditions would still be quite grim. This sheltered population would be confined mostly to cramped quarters, without adequate ventilation or sanitary arrangements, without adequate supplies of uncontaminated water and food, and would often have its resistance to disease reduced by significant radiation doses.

With no access to medical help, it is quite likely that the level of serious illness and illness-caused deaths would increase more rapidly with dose than indicated in Figure 3 (14). Under these circumstances, many members of the sheltered population would have strong desires to leave the shelters early and search for help. Unfortunately, few would have adequate information to estimate the risks associated with leaving their shelters or information as to where help might be found—if at all.

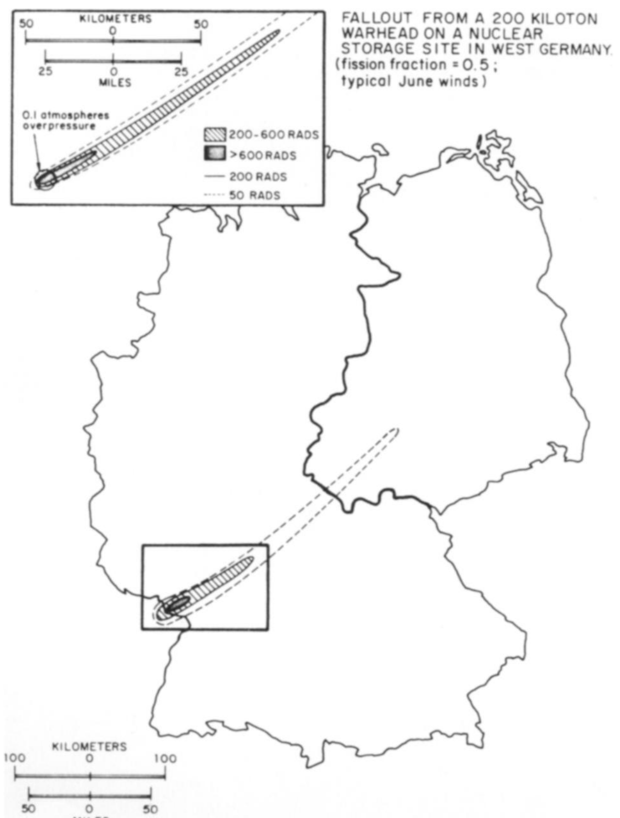


Figure 2. The fallout pattern for one of the 171 weapons whose summed effects are shown in Figure 1c.

Air Bursts: For a 200 kiloton weapon exploded at a high enough altitude to avoid local fallout, the area of destruction would be determined primarily by the effects of the blast wave and by the flash of light and heat from the fireball (15). In Figure 4 we show the areas exposed at different levels to the heat and blast wave from a 200 kiloton nuclear warhead exploded at an altitude of 2 kilometers.

The inner circle on Figure 4 has an area of approximately 80 square kilometers (30 square miles). Here, the experience in Hiroshima indicates that the collapse of buildings would crush and trap most of the population and that most of those trapped would die in the subsequent fires. For those outdoors or indoors near windows, the danger of being crushed and trapped would be less—but there would be greater danger of injury or death from shards of glass and other projectiles and from burns due to the flash of the fireball. Many fires would be started by the heat of the fireball and additional fires might be started by sparks and pilot lights igniting leaking gaseous and liquid fuels and other flammable materials in the wreckage caused by the blast. In Hiroshima many fires merged about 20 minutes after the explosion into a firestorm and completely burned an area corresponding, for the yield of the Hiroshima bomb (12.5 kilotons) to that of the inner circle in Figure 4 (16).

Over the area of the outer circle the effects would be somewhat less intense with the level of destruction declining as the outer boundary was approached. Even at a distance of 10 kilometers, however, the fireball would cover an area of the sky more than 100 times larger than the sun and the associated flash would be correspondingly brighter (17).

Figure 5 gives a more detailed representation of the probability of being killed or injured as a function of distance from ground zero for populations in various locations: outdoors near buildings, indoors but above ground, in basements, and in

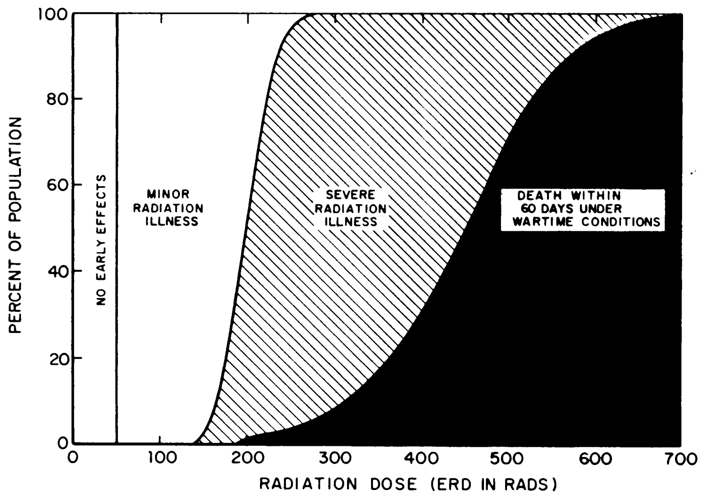


Figure 3. The expected early (within two months) outcome from radiation illness for populations exposed to various levels of radiation from fallout. Reference 6 (pp. 583–584) describes the development of severe radiation illness in the 200–1000 rad dose range as follows:
"The initial symtoms are . . . nausea, vomiting, diarrhea, loss of appetite and malaise . . . After the first day or two the symptoms disappear and there may be a latent period of several days to 2 weeks . . . Subsequently there is a return of symptoms, including diarrhea and a steplike rise in temperature which may be due to accompanying infection . . . Commencing about 2 or 3 weeks after exposure, there is a tendency to bleed into various organs, and small hemorrhages under the skin . . . are observed . . . Particularly common are spontaneous bleeding in the mouth and from the lining of the intestinal tract. There may be blood in the urine due to bleeding in the kidney . . . [These effects are due to radiation induced] defects in the blood-clotting mechanism . . . Loss of hair, which is a prominent consequence of radiation exposure, also starts after about 2 weeks . . . Susceptibility to infection of wounds, burns, and other lesions, can be a serious complicating factor [due to] loss of the white blood cells, and a marked depression in the body's immunological process. For example ulceration about the lips may commence after the latent period and spread from the mouth through the entire gastrointestinal tract in the terminal stage of the sickness . . ."

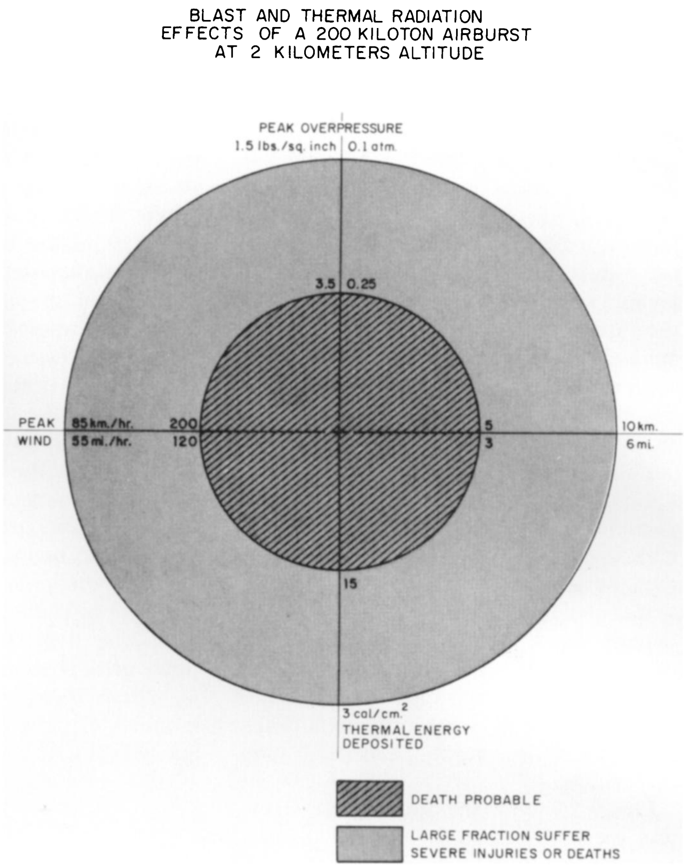
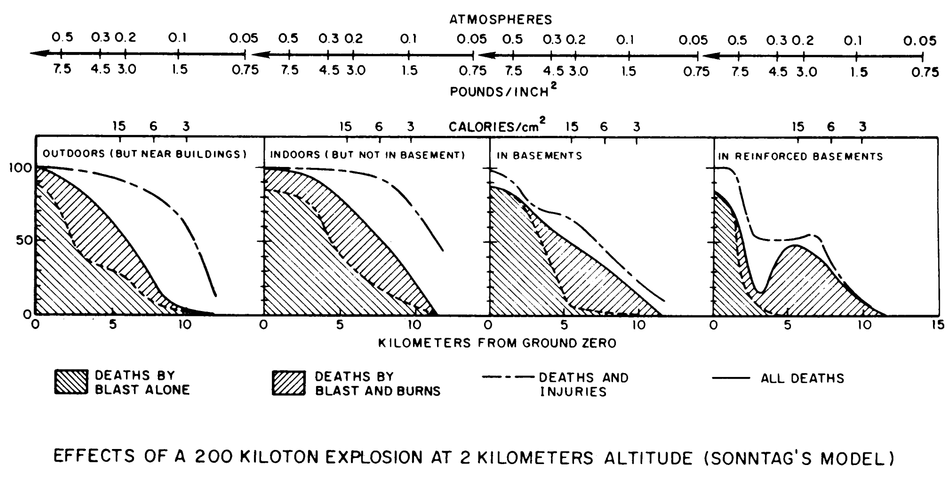


Figure 4. Blast and thermal radiation intensities at 5 and 10 kilometers from the point on the surface beneath a 200 kiloton explosion at 2 kilometers altitude. Blast damage results from the combined effects of peak overpressure (which at 0.25 atmospheres would exert a force equal to the weight of 2.5 metric tons per square meter) and the drag of the wind accompanying the blast shock wave. The thermal radiation would cause burns on exposed areas of skin (ranging from first degree burns for a deposited energy of about 3 calories per square centimeter to third degree burns at about 9 cal/cm²) and would set fire to various materials (leaves at about 5 cal/cm², clothes and curtains at about 15 cal/cm², etc.) (See Reference 6.) In an environment of broken gas lines and spilled fuels of various types, a conflagration and possibly a firestorm would ensue.

reinforced basement shelters. The results shown are based on a model developed by Phillip Sonntag (18). Naturally, models of this type involve considerable uncertainties due to the small data base and the variability in the numerous factors that determine the severity of blast or fire effects. This particular model assumes a surprisingly small reduction in risk associated with being in basement shelters. The reason given is that, close to the point under the nuclear explosion ("ground zero"), the overpressures would be great enough to crush even reinforced basement ceilings. Further out, where basement ceilings could survive the overpressure, the people underneath would still frequently be trapped by the debris above and would therefore be unable to escape the effects of the subsequent fires.

The consequences. Sonntag assumes that the population would have some warning of an imminent nuclear attack and that most would seek refuge in basements (75 percent in ordinary basements, and 5 per-

Figure 5. The probabilities of death and injury (according to a model put forward in Reference 13) as a function of distance from the point on the surface ("ground zero") beneath a 200 kiloton warhead exploded at 2 kilometers (1.2 miles) altitude. It will be seen that, within a radius of 5 kilometers, the probability of death by blast or burns is high—even for a population sheltered in residential basements. Outdoors the hazard from burns is associated primarily with direct exposure to the fireball. Indoors the hazard is due primarily with being trapped inside a collapsed building which subsequently burns.



cent in reinforced basements). He assumes that, of the remaining 20 percent of the population, half would be indoors above ground and half outdoors. Clearly there is no definite area such that people within it would die and people outside would not. As Figure 5 shows, the probability of death decreases to zero over a large radius. However, one may select a radius so that the number of people dying outside that area equals the number who survive inside the area. That radius determines the equivalent "area of death" in the present context. With the population sheltered as assumed by Sonntag, a single 200 kiloton airburst would kill the equivalent of the population of 180 square kilometers (70 square miles). This corresponds to the area of a circle 15 kilometers (9 miles) in diameter which would fall half way between the inner and outer circles in Figure 4. The circles in Figure 1a show this equivalent "area of death" around each of the targets of the hypothetical preemptive attacks. Together they cover almost ten percent of the area of the two Germanies. These could, therefore, hardly be called "surgical" strikes.

Figure 1b shows the population distribution of the Germanies (19). Their combined population is about 76 million (59 million in West Germany and 17 million in East Germany). Their population density averages about 200 persons per square kilometer overall and about 3000 persons per square kilometer in large urban areas. A 200-kiloton airburst would therefore kill about 40 000 people in an area of average population density and about 500000 in an average urban area. For comparison, the 12.5 kiloton airburst over Hiroshima killed about 70000 persons and seriously injured approximately the same number (20).

The area of death from blast and heat associated with a ground burst would be somewhat less than for an airburst but there would be additional casualties downwind due to the associated fallout. As noted above, Figure 1c shows our calculated distribution of fallout radiation doses in the Germanies associated with surface bursts on each of the targets shown in Figure 1a—given the winds of "a typical June day."

In order to estimate the casualties which would result in the affected areas shown in Figures 1a and 1c, it is necessary to take into account the population densities in each target and fallout area. At the time of this writing, we have not completed this task. The results of calculations done by Sonntag (13) for West Germany will serve, however, to indicate ranges within which our results will likely fall.

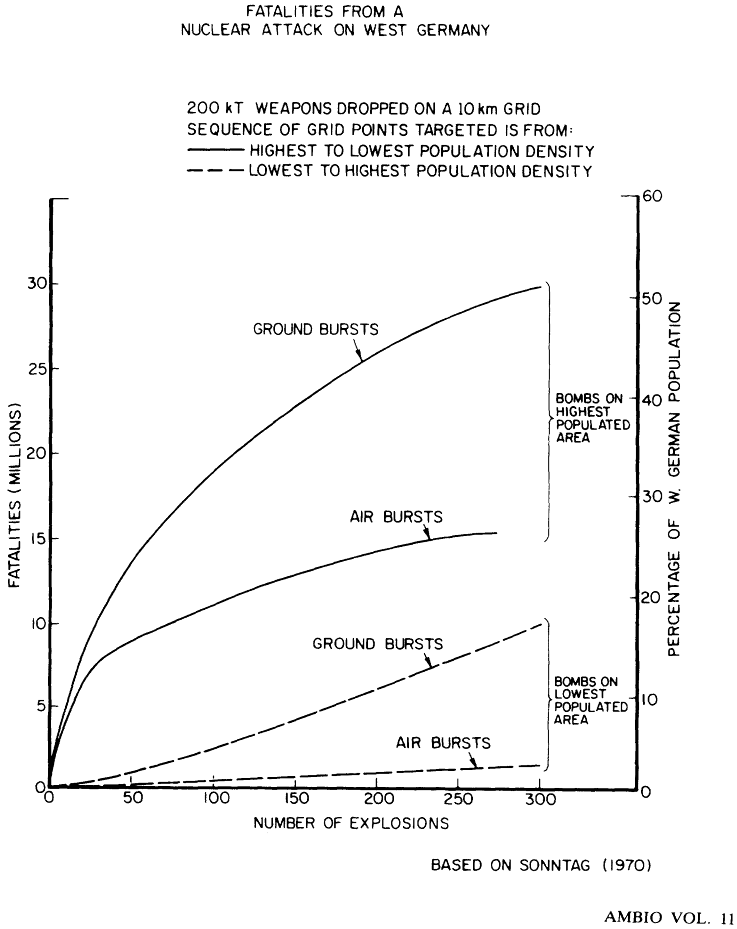
Sonntag's results, shown in Figure 6, were derived as follows: The area of West Germany was divided into squares 10 kilometers on a side. High and low estimates of the number of casualties which would result from the explosion of a given number (N) of airbursts were then calculated by assuming respectively that they were exploded over the (N) least densely and (N) most densely populated squares of West Germany.

For the 86 two hundred kiloton airbursts over West Germany assumed in our minimal preemptive attack, the dashed curves in Figure 6 show between 0.5 and about 10 million fatalities. Since the average population density of East Germany is comparable to that of West Germany (160 vs. 240 per square kilometer), it is reasonable to assume a similar range of fatalities for the same sized preemptive attack on that nation. The total number of fatalities in the Germanies following a preemptive attack using 200 kiloton airbursts would therefore lie somewhere in the range 1–20 million. A comparison of Figures 1a and 1b shows that many of the targets are in densely populated areas. As a result, the number of fatalities for a preemptive attack on these targets would be many times greater than Sonntag's lower limit, *ie*, many millions. In addition, similar numbers of individuals would be severely injured (21).

Sonntag also calculated ranges for the numbers of the deaths and injuries which would result from varying numbers of groundbursts in West Germany, using the same approach outlined above for airbursts. The upper two curves on Figure 6 show that in this case it was estimated that 2–20 million people or up to 30 percent of the population would die from the consequences of 86 two hundred kiloton groundbursts on West Germany—even assuming that 80 percent of the population was able to stay for weeks in basement fallout shelters. The total population of East Germany is only 17 million so that one would expect somewhat lower casualties from the same number of groundbursts in that country. The fallout fatalities in adjoining nations—Poland in particular—would, however, probably considerably raise the total.

Thus we have found that a preemptive nuclear attack using 200 kiloton weapons against the targets shown in Figure 1a would probably result in between 1 and 40 million fatalities in the Germanies and surrounding areas and a similar number of

Figure 6. Maximum and minimum estimates from Reference 13 of the fatalities which would result from attacks on West Germany with 200 kiloton bombs as a function of the number of weapons. Both airburst (at an altitude of 0.7 km.) and surface burst were considered. For the fallout from the surface bursts, it was assumed that all the energy yield is due to fission and that winds of 20 kilometers per hour are blowing. The maximum (minimum) estimates of fatalities are obtained by assuming that the weapons are exploded in the N most (least) densely populated areas of the country. A spacing between explosions of at least 10 kilometers was assumed.



BASED ON SONNTAG (1970)

severely injured persons. It appears likely that more exact estimates will yield numbers in the middle of this range, *ie*, on the order of 10 million killed and a similar number seriously injured.

BATTLEFIELD USE OF NUCLEAR WEAPONS

The Targets. A preemptive nuclear attack against key nuclear and other military targets is one way in which a nuclear war might start in central Europe. Another possibility is that war would cross the nuclear threshold via the use of "battlefield" nuclear weapons—because one side in a confrontation limited to non-nuclear weapons was about to suffer a serious defeat or because the attacking side was not able to achieve its objective without the use of nuclear weapons. Both NATO and the Warsaw Pact have integrated into their armed forces thousands of nuclear warheads deliverable by artillery, aircraft, or short-range missiles. These weapons would be used against the ground forces of the opposing side, including nuclear capable units, tank concentrations, artillery batteries, field level military headquarters, and structures such as bridges (22).

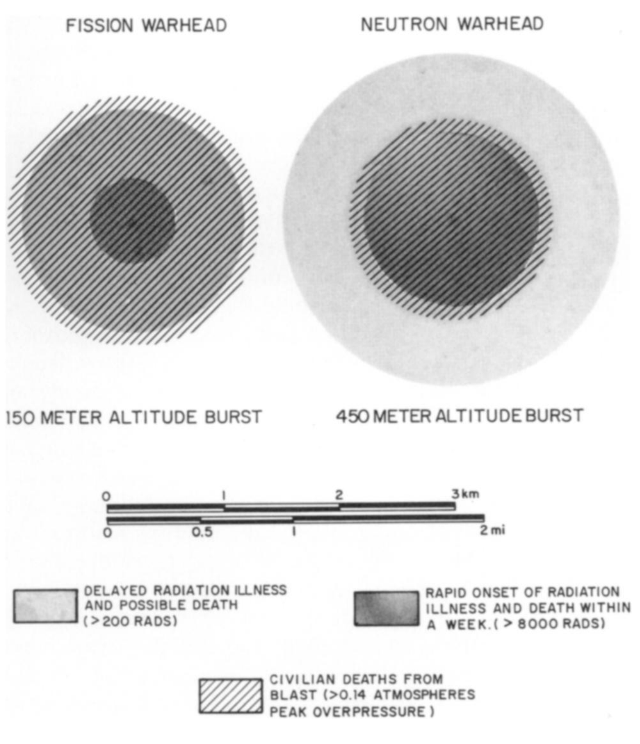
The use of battlefield nuclear weapons would probably be authorized by the political authorities, initially at least, in "packages." According to NATO doctrines, all the warheads within a given package are intended to explode approximately simul-

BOX 3. THE EFFECTS OF NEUTRON BOMBS

The attributes of nuclear weapons make them uniquely effective for destroying large area targets such as cities and industrial complexes. On the battlefield, however, the indiscriminate nature of these weapons has continually put their usability into question. This has led to an effort to design nuclear weapons which minimize "collateral damage" for a given level of military effectiveness. The most recent products of this effort are enhanced radiation warheads ("neutron bombs"). In the diagram we compare areas of radiation and blast effects of one of these weapons with those of an ordinary fission bomb which releases the same amount of energy (one thousand tons TNT equivalent) (1).

The larger lightly shaded circle indicates the area within which people not protected by thick shields of concrete or dirt could receive large enough doses of neutron and gamma radiation from the blast to result in death by radiation illness in the short term and cancer deaths in the longer term (2).

The smaller darker shaded circle indicates the area of the desired military effect: a radiation dose sufficient to render the occupants of tanks at most "partially effective" due to vomiting, diarrhea, and other radiation sickness symptoms during the hours to days before they died (3).



Finally, the crosshatched area indicates the area subjected to blast sufficient to cause some fatalities among the above ground occupants of residential structures (greater than 0.14 atmospheres peak overpressure) (4).

It will be seen that the larger amount of radiation emitted by the neutron bomb increases the area of its military effect almost fourfold—to about 2 square kilometers (0.8 square miles). The larger radius of this military effect also makes it possible to explode the neutron warhead at a greater altitude, reducing the area of its blast damage somewhat. More important to any civilians in the environs, however, is likely to be the fact that the area covered by doses leading to longer term radiation illness and death is more than doubled—to 6 square kilometers (2.5 square miles) (5).

The expected density of tanks in an attack in the Germanies is a column or row in which the spacing would be 100 meters or greater (6). The average population density of the Germanies is about 200 per square kilometer. And the area of lingering civilian deaths following the explosion of a neutron bomb would be about three times that of prompt effects on tank crews. Given these facts and the likelihood that a large fraction of battlefield nuclear weapons would probably be mistargeted under the conditions which would prevail on a nuclear battlefield, a crude calculation suggests that there might be on the order of two hundred civilian deaths for every tank crew that is rendered "partially effective" by a neutron bomb, or a million civilian deaths per five thousand tank crews so affected.

References and Notes

1. This figure is based on a table of numbers given by S T Cohen in "Enhanced Radiation Warheads: Setting the Record Straight," *Strategic Review*, Winter 1978, p. 9, and on a figure in Samuel Glasstone and Phillip Dolan (eds), *The Effects of Nuclear Weapons*, 3rd Edition (US Departments of Defense and Energy, 1977), p. 115.
2. According to Glasstone and Dolan (Ibid, p. 583), "For doses between 200 and 1000 rems [rems equal rads for the present purpose] the probability of survival is good at the lower end of the range and poor at the upper end." Assuming a relative biological effectiveness for cancer induction of 10 for neutrons relative to X-rays, the likelihood of cancer death due to a 200 rad dose of neutron radiation would be 20 percent or greater. [US National Academy of Sciences, *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation* (1980), pp. 141, 147].
3. US Army Field Manual, *Operations*, Chapter 10 "Tactical Nuclear Operations," p. 10–3 (FM 100-5, 1976).
4. Glasstone and Dolan (*op cit* 1 p. 180).
5. The military, however, compares the 1 kt neutron bomb to a 5–10 kt fission warhead which would have a comparable military effect. In this context the neutron bomb would exact a somewhat lower human toll.
6. See S T Cohen and W R Van Cleave, "Western European Collateral Damage from Tactical Nuclear Weapons," (*Royal United Services Institute (RUSI) Journal*, June 1976, p. 323).

taneously—both to maximize the shock effect and to create a "pause" for negotiations or force movements (23). A single nuclear warhead would, however, typically kill the crews of only a few tanks (see Box 3). It would, therefore, require hundreds of battlefield nuclear explosions to destroy a significant fraction of the 20 000 tanks which might be involved in a full scale battle between NATO and the Warsaw Pact in the Germanies (24).

Since a tank could drive across either East or West Germany in a single day, the use of tactical nuclear weapons could occur almost anywhere in the Germanies. In order to be specific, however, we show on Figure 1a, areas where these weapons might be used if the nuclear threshold were crossed while the battle was still raging at the border between the two nations. The rectangles spanning the border correspond to the areas where three Soviet armies in East Germany might confront NATO troops in West Germany (25). The size of these rectangles was chosen on the basis of the stylized descriptions of US and Soviet formations in US defense literature (26). Although the combined area of these three rectangles is 45 000 square kilometers, or one-eighth the combined areas of the two Germanies, they would contain only about one-half of the military forces deployed in those countries. The 60 kilometer widths of the rectangles are such that they almost cover the entire north-south section of boundary dividing the two Germanies. The depth of the nuclear battlefield on each side of the border, 125 kilometers, corresponds to the expected depth of deployment of the military units on which battlefield nuclear weapons would be delivered: by artillery at short range, and by missiles and aircraft at longer range (26). Mobile artillery and missiles, due to their short range, would be concentrated near the "battlefields." (Figure 1a does not show the locations of nuclear capable artillery batteries).

The Attacking Weapons. The types of nuclear weapons which are designed only for battlefield use—low yield bombs, nuclear artillery shells, nuclear land mines, and short-range missiles—generally have explosive yield in the range of 0.1 to 100 kilotons of TNT equivalent. For simplicity, in the discussion below we will describe the consequences of their use in terms of the consequences of the use of a similar number of "enhanced radiation" or neutron warheads of one kiloton yield (see Box 3).

The Weapons Effects. The area of destruction by blast for a one kiloton weapon exploded at the surface is 1–2 square kilometers. For nuclear weapons in this range of explosive yield, however, the area bathed by intense "direct" or "prompt" nuclear radiation (*ie* from the explosion itself, in distinction to the "indirect" or "delayed" radiation associated with fallout) exceeds the area affected by severe blast effects. In the case of a one kiloton enhanced radiation weapon, the effective "area of death" by radiation illness for exposed soldiers and civilians would be approximately 5 square kilometers (2 square miles).

The Consequences

In a war involving the use of battlefield nuclear weapons there would probably be both attempts to spare towns and a perceived necessity to attack some. Towns could be largely spared if the enemy were to be found in the countryside outside. However, much of the time that would not be the case. On average there is one populated place in the Germanies per 4 square kilometers, hence, the well known complaint of nuclear weapons officers in Europe: "The towns and villages in Germany are only 1–2 kilotons apart" (27). Roads naturally pass through towns, so presumably would the tanks and convoys which would be the principal targets of battlefield nuclear weapons. In addition there is considerable discussion in the military literature of the possibility of both attackers and defenders using towns as protective cover (28). It would be difficult under these circumstances to use a large number of battlefield nuclear weapons without causing a great number of civilian deaths.

A reasonable estimate is that the net effect of all these countervailing pressures bearing on the targeting of battlefield nuclear weapons would be that the resulting casualties would accumulate as if the nuclear weapons were exploded over areas with an average population density of 200 persons per square kilometer. After multiplying by the 5 square kilometer "area of death" for a neutron bomb, this leads to the estimate that, in addition to the occupants of perhaps 0–15 armored vehicles, an average of about one thousand civilians would die from radiation illness as a result of each nuclear explosion. If one thousand nuclear weapons were used, the number of deaths could be on the order of one million. These people would suffer the various stages of radiation sickness for up to two months before they eventually died.

LONGER TERM EFFECTS

The use of one thousand small battlefield nuclear weapons in the Germanies could lead to the deaths of a million and the use of 170 larger nuclear weapons against fixed military targets would result in the deaths of perhaps ten million. Similar numbers of people would be seriously injured. What about the people who survived? What type of future could they look forward to?

After a nuclear war involving the explosion of hundreds to thousands of nuclear weapons in the Germanies, in Europe or worldwide, the survivors would not be as "lucky" as the survivors of Hiroshima and Nagasaki. The Hiroshima and Nagasaki bombs were exploded at great enough altitudes so that there was little residual radioactive fallout and the cities were surrounded by a damaged but still functioning society which could supply them with medical treatment, food, and shelter. Perhaps most importantly, there was no fear of further bombings.

There is no experience of a modern society whose technical and social infrastructure has both broken down to the degree which would prevail in the Germanies following the preemptive attack which we have described and where there would be so little hope of outside help. And, with the recent emphasis on developing the capability of fighting a nuclear war lasting months or longer, it is not clear when the postwar struggle to survive could begin.

Most likely, the future would appear as described in the accompanying articles in which the consequences of a global nuclear war are dicussed. It is difficult to imagine that such a holocaust as we have described in the Germanies could be prevented from turning into a global nuclear conflagration.

CONCLUSION

Nuclear weapons are so terrible that their existence has a sobering ("deterrent") effect on leaders who might otherwise pursue military options. With nuclear weapons leaders can no longer dream that battles can be fought far from home. They must face the facts that no one is out of range and that the physical and human fabric of the social organizations which support them could easily be destroyed in a nuclear war. In this way, as Herbert York has stated, the "placing at risk of the entire future of the continent and its people" has bought "the current happy political stability in Europe" (29).

Unfortunately, while the catastrophic consequences of a deliberate attempt to destroy Eastern or Western Europe with nuclear weapons are generally understood, both sides are prepared to use nuclear weapons against "purely military" targets, if it is necessary to avoid defeat in a major conflict. Europe, however, is densely populated; the intermixing of military and civilians is intimate; and the areas of death which would be caused by the use of even "small" battlefield nuclear weapons are very large. In this article it has been shown that, as a result, even the purely military use of nuclear weapons in Europe on any scale large enough to achieve militarily significant results would result in the unintentional deaths of many millions of civilians.

Political and military leaders must be made to understand, therefore, that, to the extent that they develop security policies which depend upon the use of nuclear weapons in Europe, they are committing themselves to a policy which involves the mass slaughter of civilians *no matter how purely military the nominal targets of attack!*

References and Notes

1. Sidney Drell and Frank von Hippel, "Limited Nuclear War," *Scientific American*, p 27 (November 1976).
2. See Desmond Ball, *Can Nuclear War Be Controlled?* (London International Institute for Strategic Studies) Adelphi Paper #169, 1981; and John Steinbruner, "Nuclear Decapitation" in *Foreign Policy*, Winter 1981–'82, p. 16.
3. See the discussion in US Senate Armed Services Committee Hearing, *Department of Defense Authorizations for Appropriations for Fiscal Year 1981*, Part 5, pp. 2827–2828, 3019.
4. US Senate Foreign Relations Committee and US House Committee on Foreign Relations, Joint Committee Print, *Fiscal Year 1981 Arms Control Impact Statements*, (May 1980) p. 243.
5. See reference 4, p. 235; and US Senate Armed Services Committee Hearing, *Department of Defense Authorizations for Appropriations for Fiscal Year 1981*, Part 3, p. 872.
6. US Departments of Defense and Energy, *The Effects of Nuclear Weapons*, 3rd edition (Samuel Glasstone and Philip J Dolan, eds. 1977), Fig. 3.73a.
7. See US Defense Intelligence Agency, *Physical Vulnerability Handbook: Nuclear Weapons* (AP-550-1-2-69-INT, revised 1976).
8. See Richard L Garwin, "Defense of Minuteman Silos Against ICBM Attack," reprinted in *Effects of Limited Nuclear Warfare*, Hearing before the Subcommittee on Arms Control, International Organizations and Security Agreements of the US Senate Committee on Foreign Relations, September 18, 1975, pp. 56–59.
9. Duncan Campbell, "World War III: An Exclusive Preview", in *Britain and the Bomb* (London, The New Statesman, NS Report #3, 1981) p. 65.
10. We have used the WSEG-10 Fallout Model which is used in US government assessments of fallout effects. This model is documented in Leo A Schmidt, Jr., *Methodology of Fallout-Risk Assessment* (Washington, DC, Institute for Defense Analyses, Paper P-1065, 1975) and has been incorporated in a set of computer programs which are described by the same author in *Development of Civil Defense Damage Assessment Programs* (Washington, DC, Institute for Defense Analyses, Paper P-1526, 1980). We have adapted the program GUISTO to our needs.

    The wind data used in this program are summarized in two sets of parameters: wind vectors averaged from ground level to the level from which the fallout is descending (10 kilometers for a 200 kiloton weapon); and a "wind shear" which provides a measure of the rate of change of the wind vector with height at that level. The wind vector determines the direction and the distance that the fallout is carried while the transverse wind shear determines the rate at which the fallout cloud grows in a direction transverse to the direction in which it is being carried.
11. Northern Hemisphere wind data for a "typical day" in each month of the year have been compiled by the Defense Communications Agency Command and Control Technical Center of the US Defense Department (unclassified tapes EA 275 and EB 275.)
12. Figure 3 is adapted from Figure 5.36–1 of reference 13.
13. Phillip Sonntag, "Matematische Analyse der Wirkungen von Kernwaffen Explosionen in der BRD," in *Kriegsfolgen und Kriegsverhutung*, (Carl Friedrich von Weizsacker, ed., Munich, Carl Hanser, 1971).
14. See the discussion by Herbert L Abrams, "Infection and Communicable Diseases," in *The Final Epidemic: Physicians and Scientists on Nuclear War* (Ruth Adams and Susan Cullen, eds., Chicago, University of Chicago Press, 1981), p. 192.
15. Because absorption by the atmosphere of neutrons and gamma rays is quite strong, the radii at which radiation doses from these forms of nuclear radiation exceed a given level, grow much more slowly than do the radii of blast and flash effects. For neutron radiation, for example, the distance at which the dose exceeds 100 rads only approximately doubles (from 1.1 to 2 kilometers) in going from a 1 kiloton fission weapon to a 200 kiloton thermonuclear weapon. The growth of the corresponding radius for gamma radiation is from 1.1 to 2.5 kilometers (reference 6, pp. 332–335, 345–348). As a result, while, for a one kiloton weapon, nuclear radiation has a larger lethal radius than blast or heat, the situation is reversed for a 200 kiloton weapon.
16. *Op cit* 6, pp. 300–304.
17. Figure 4 is based on material in reference 6—especially that on pp. 71, 115, 123, 178–184, 219, 291, 300–304, 554–555, 564.
18. *Op cit* 13, pp. 75–198. The minimum shown for the probability of death in a reinforced shelter at 3 kilometers reflects Sonntag's assumptions that, at that distance, the shelter would survive but that the debris above would be so flattened that it would not support an intense fire.
19. Figure 1b is derived from data given in: (West Germany) *Bevolkerung und Kultur, Reihe 1, Bevolkerungsstand und -entwicklung, 1969* (FGR, Statistisches Bundesamt, Wiesbaden, Verlag W Kohlhammer), and (East Germany) *Bevolkerungsstatistiches Jahrbuch der Deutschen Demokratischen Republik, 1977* (DDR, Staatliche Zentralverwaltung für Statistik).
20. *Op cit* 6, p. 544.
21. In calculating fatalities from airbursts, Sonntag assumed an altitude of burst of 700 meters for a 200 kiloton warhead, while the results shown in Figures 4 and 5 are for an airburst at an altitude of 2000 meters. Sonntag's casualty estimates for airbursts are therefore probably significantly smaller than we would calculate. On the other hand, in calculating the casualties which would result from the fallout from groundbursts, Sonntag assumed that 100 percent of the explosive yield of a 200 kiloton weapon would come from fission while, in Figures 1c and 2, we have made the more conventional assumption of 50 percent. This difference would tend to lower our estimate of casualties from fallout relative to those of Sonntag. In all fallout calculations, Sonntag assumed a constant 20 kilometer per hour wind blowing from south to north with a 0.3 kilometers per hour per kilometer altitude transverse wind shear, while we have used wind data at 5 altitudes at each of 9 points spaced on an approximately 400 kilometer grid over and around the Germanies to construct an interpolated wind field for a "typical June day" (see note 11). The median wind (averaged from ground level to 10 kilometers) for this day is about 50 kilometers per hour and the median transverse wind shear is about 0.36 kilometers per hour per kilometer altitude.
22. "Critical combat units that might be targeted for nuclear strikes include the following:
    (a) Nuclear capable units.
    (b) Tanks and mechanized units.
    (c) Conventional artillery units.
    (d) Other units or locations such as command and control headquarters, nuclear supply points, or bridges."

    [US Army, Staff Officers' Field Manual, *Nuclear Weapons Employment Doctrine and Procedures* (FM 101-31-1, 1977), p. 5.]
23. John P Rose, *The Evolution of US Army Nuclear Doctrine, 1945–1980* (Boulder, Colorado, Westview Press, 1980), p. 172.
24. Within the area of 5000–10000 square kilometers covered by one typical Soviet Army formation, the numbers of military equipment would include 3020 tanks, 2230 armored fighting vehicles, 930 artillery guns, and 425 air defense weapons. This considerable amount of military equipment gives some insight into the number of neutron weapons which might be used in an attempt to immobilize it. See US Senate Armed Services Committee, *Department of Defense Authorizations for Appropriations for Fiscal Year 1981, Part 5*, pp. 3054–3060.
25. John M Collins, *US—Soviet Military Balance, Concepts and Capabilities*, 1960–1980, (New York, McGraw-Hill Publications, 1980) pp. 311, 315.
26. See the discussion in reference 24.
27. Based on the numbers of names of populated places listed in US Board of Geographic Names, Gazetteer Numbers 47 (*Germany—Federal Republic and West Berlin*, 1960) and 43 (*Germany—Soviet Zone and East Berlin*, 1959).
28. See Paul Bracken, "Urban Sprawl and NATO Defense," in *Survival* Vol. 18, #6, p. 254 (1976); and "Collateral Damage and Theatre Warfare," *ibid.* Vol. 22, #5, p. 203 (1980).
29. Herbert York, "The Nuclear 'Balance of Terror' in Europe," *Ambio* **4**, 203 (1975).

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