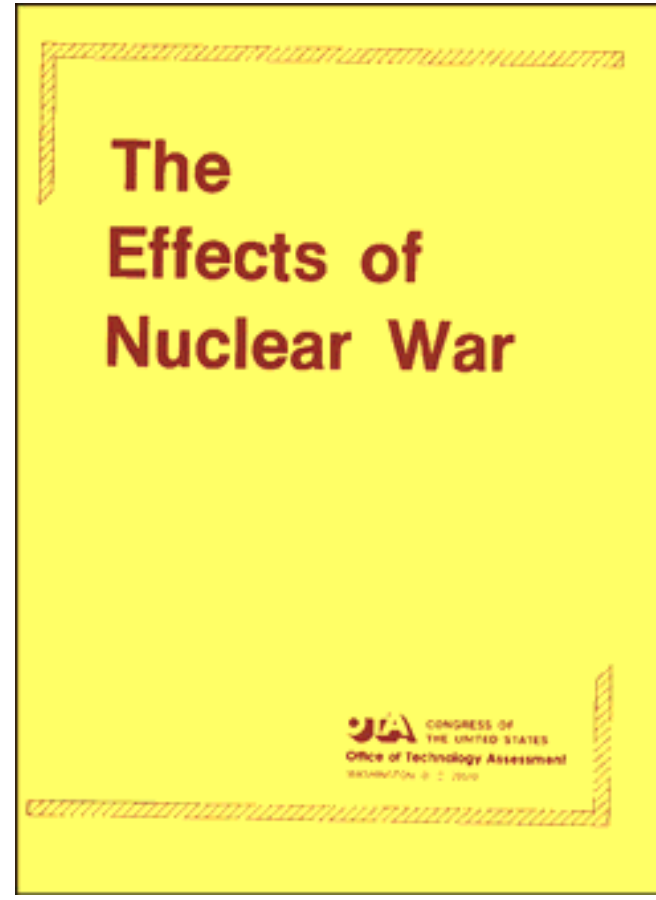
The Effects of Nuclear War

May 1979

NTIS order #PB-296946



Library of Congress Catalog Card Number 79-600080

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D C, 20402

Foreword

This assessment was made in response to a request from the Senate Committee on Foreign Relations to examine the effects of nuclear war on the populations and economies of the United States and the Soviet Union. It is intended, in the terms of the Committee's request, to "put what have been abstract measures of strategic power into more comprehensible terms. "

The study examines the full range of effects that nuclear war would have on civilians: direct effects from blast and radiation; and indirect effects from economic, social, and politicai disruption. Particular attention is devoted to the ways in which the impact of a nuclear war would extend over time. Two of the study's principal findings are that conditions would continue to get worse for some time after a nuclear war ended, and that the effects of nuclear war that cannot be calculated in advance are at least as important as those which analysts attempt to quantify.

This report provides essential background for a range of issues relating to strategic weapons and foreign policy. It translates what is generally known about the effects of nuclear weapons into the best available estimates about the impact on society if such weapons were used. It calls attention to the very wide range of impacts that nuclear weapons would have on a complex industrial society, and to the extent of uncertainty regarding these impacts.

Several years ago, OTA convened a panel of distinguished scientists to examine the effects of a limited nuclear war. The report and testimony of that panel, which were published by the Senate Foreign Relations Committee, remain valid. That panel recommended that a more thorough and comprehensive study of the effects of nuclear war be undertaken. This study is such an effort.

The Director of this assessment was Dr. Peter Sharfman, Group Manager for National Security Studies. OTA is grateful for the assistance of its Nuclear War Effects Advisory Panel, chaired by Dr. David S. Saxon, President of the University of California, and for the assistance of the Congressional Research Service, the Department of Defense, the Arms Control and Disarmament Agency, and the Central Intel Intelligence Agency. 1 t should be understood, however, that OTA assumes full responsibility for this report and that it does not necessarily represent the views of any of these agencies or of the individual members of the Advisory Panel.

DANIEL DE SIMONE
Acting Director

Nuclear War Effects Project Staff

Lionel S. Johns, Assistant Director
Energy, Materials, and Global Security Division

Peter Sharfman, *National Security* Group Manager and Project Director

Jonathan Medalia *(on detail from Congressional/ Research Service)*

Robert W. Vining (under contract *with Systems* Science and Software)

Kevin Lewis

Gloria Proctor

Supplemental OTA Staff

Henry Kelly Marvin Ott

Consultants

Advanced Research and Applications Corporation
Analytical Assessments Corporation
General Research Corporation
Santa Fe Corporation
Systems Science and Software

Stuart Goldman
Nan Randall
George R. Rodericks
Ronald Stivers

OTA Publishing Staff

John C. Holmes, Publishing Officer
Kathie S. Boss Joanne Heming

Nuclear War Effects Project Advisory Panel

David S. Saxon, *Chairman*
President, University of California

Donald G. Brennan
Director of National Securit y Studies
Hudson Institute Inc.

Charles Cooper
Department of Biology
San Diego State University

Russell E. Dougherty
General, USAF(retired)

Sidney Drell
Deputy Director, Stanford linear Accelerator Center
Stanford University

Richard Garwin
IBM Fellow
IBM Thomas J. Watson Research Center

Gene R. La Rocque
Rear Admiral, USN *[retired)*
Director, Center for Defense /formation

Cecil Leith
Director, Atmospheric Analysis and Prediction Division
National Center for Atmospheric Research

J, David Linebaugh
Washington, D.C.

J. Carson Mark
Los *Alamos Scientific Laboratory*

James V. Neel
Chairman, Department of Human Genetics
University of Michigan Medical School
University of Michigan

Jack Ruina
Massachusetts Institute of Technology

Harriet Scott
McLean, Va.

Huston Smith
Syracuse University

John Steinbruner
Director of Foreign Policy Studies
Brookings Institution

Jeremy Stone
Director, Federation of American Scientists

Hilary Whitaker
Director, Emergency Preparedness Project
National Governors Association

The Advisory Panel provided advice and constructive criticism throughout this project. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full respon-sibility y for the report and the accuracy of its contents.

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2. Small Attacks on U.S. and Soviet Energy Production and Distribution Systems (Santa Fe Corp).
3. Long-Term Health Effects From Nuclear Attack Radiation Exposures (Aracor)
4. The Effects of Nuclear War Economic Damage (Analytical Assessment Corp.)*

NOTE: A limited number of copies of the working papers will be available for congressiorral use from **OTA by the** end of June 1979 Others can obtain the working papers from the National Technical Information **Service about the beginning of August 1979**

***** indicat's **that a classified version is also available to qualified requesters**

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Chapter I. EXECUTIVE SUMMARY

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Chapter I

EXECUTIVE SUMMARY

At the request of the Senate Committee on Foreign Relations, the Office of Technology Assessment has undertaken to describe the effects of a nuclear war on the civilian populations, economies, and societies of the United States and the Soviet Union.

Nuclear war is not a comfortable subject. Throughout all the variations, possibilities, and uncertainties that this study describes, one theme is constant—a nuclear war would be a catastrophe. A militarily plausible nuclear attack, even "limited, " could be expected to kill people and to inflict economic damage on a scale unprecetiented in American experience; a large-scale nuclear exchange would be a calamity unprecedented in human history. The mind recoils from the effort to foresee the details of such a calamity, and from the careful explanation of the unavoidable uncertainties as to whether people would die from blast damage, from fallout radiation, or from starvation during the following winter. But the fact remains that nuclear war is possible, and the possibility of nuclear war has formed part of the foundation of international politics, and of U.S. policy, ever since nuclear weapons were used in 1945.

The premise of this study is that those who deal with the large issues of world politics should understand what is known, and perhaps more importantly what is not known, about the likely consequences if efforts to deter and avoid nuclear war should fail. Those who deal with policy issues regarding nuclear weapons should know what such weapons can do, and the extent of the uncertainties about what such weapons might do.

FINDINGS

1 The effects of a nuclear war that cannot be calculated are at least as important as those for which calculations are attempted. Moreover, even these limited calculations are subject to very large uncertainties

Conservative military planners tend to base their calculations on factors that can be either control led or predicted, and to make pessimistic assumptions where control or prediction are impossible. For example, planning for strategic nuclear warfare looks at the extent to which civilian targets will be destroyed by blast, and discounts the additional damage which may be caused by fires that the blast could ignite. This is not because fires are unlikely to cause damage, but because the extent of fire damage depends on factors such as weather and details is of building construction that make it much more difficult to predict than blast damage. While it is proper for a military plan to provide for the destruction of key targets by the surest means even in unfavorable circumstances, the nonmilitary observer should remember that actual damage is likely to be greater than that reflected in the military calculations. This is particularly true for indirect effects such as deaths resulting from injuries and the unavailability of medical care, or for economic damage resulting from disruption and disorganization rather than from direct destruction.

For more than a decade, the declared policy of the United States has given prominence to a concept of "assured destruction:" the capabilities of U.S. nuclear weapons have been described in terms of the level of damage they

can surely inflict even in the most unfavorable circumstances. It should be understood that in the event of an actual nuclear war, the destruction resulting from an all-out nuclear attack would probably be far greater. In addition to the tens of millions of deaths during the days and weeks after the attack, there would probably be further millions (perhaps further tens of millions) of deaths in the ensuing months or years. In addition to the enormous economic destruction caused by the actual nuclear explosions, there would be some years during which the residual economy would decline further, as stocks were consumed and machines wore out faster than recovered production could replace them. Nobody knows how to estimate the likelihood that industrial civilization might collapse in the areas attacked; additionally, the possibility of significant long-term ecological damage cannot be excluded.

2. The impact of even a "small" or "limited" nuclear attack would be enormous. Although predictions of the effects of such an attack are subject to the same uncertainties as predictions of the effects of an all-out attack, the possibilities can be bounded. OTA examined the impact of a small attack on economic targets (an attack on oil refineries limited to 10 missiles), and found that while economic recovery would be possible, the economic damage and social dislocation could be immense. A review of calculations of the effects on civilian populations and economies of major counterforce attacks found that while the conse quences might be endurable (since they would be on a scale with wars and epidemics that nations have endured in the past), the number of deaths might be as high as 20 million. Moreover, the uncertainties are such that no government could predict with any confidence what the results of a limited attack or counterattack would be even if there was no further escalation.

3. It **is therefore reasonable to suppose that the extreme uncertainties about the effects of a nuclear attack, as well as the certainty that the minimum consequences would be enormous, both play a role in the deterrent effect of nuclear weapons.**

4. There are major differences between the United States and the Soviet Union that affect the nature of their vulnerability to nuclear attacks, despite the fact that both are large and diversified industrial countries. Differences between the two countries in terms of population distribution, closeness of population to other targets, vulnerability of agricultural systems, vulnerability of cities to fire, socioeconomic system, and political system create significant asymmetries in the potential effects of nuclear attacks. Differences in civil defense preparations and in the structure of the strategic arsenals compound these asymmetries. By and large, the Soviet Union is favored by geography and by a political/economic structure geared to emergencies; the United States is favored by having a bigger and better economy and (perhaps) a greater capacity for effective decentralization. The larger size of Soviet weapons also means that they are likely to kill more people while aiming at something else.

5. **Although it is true that effective sheltering and/or evacuation could save lives, it is not clear that a civil defense program based on providing shelters or planning evacuation would necessarily be effective.** To save lives, it is not only necessary to provide shelter in, or evacuation to, the right place (and only extreme measures of dispersion would overcome the problem that the location of safe places cannot be reliably predicted), it is also necessary to provide food, water, medical supplies, sanitation, security against other people, possibly filtered air, etc. After fallout diminishes, there must be enough supplies and enough organization to keep people alive while production is being restored. The effectiveness of civil defense measures depends, among other things, on the events leading up to the attack, the enemy's targeting policy, and sheer luck.

6. **The situation in which the survivors of a nuclear attack find themselves will be quite unprecedented.** The surviving nation would be far weaker—economically, socially, and politically— than one would calculate by adding up the surviving economic assets and the numbers and skills of the surviving people. Natural resources would be destroyed; surviving equip-

ment would be designed to use materials and skills that might no longer exist; and indeed some regions might be almost uninhabitable. Furthermore, prewar patterns of behavior would surely change, though in unpredictable ways. Finally, the entire society would suffer from the enormous psychological shock of having discovered the extent of its vulnerability.

7. From an economic point of view, and possibly from a political and social viewpoint as well, conditions after an attack would get worse before they started to get better. For a period of time, people could live off supplies (and, in a sense, off habits) left over from before the war. But shortages and uncertainties would get worse. The survivors would find themselves in a race to achieve viability (i. e., production at least equaling consumption plus depreciation) before stocks ran out completely. A failure to achieve viability, or even a slow recovery, would result in many additional deaths, and much additional economic, political, and social deterioration. This postwar damage could be as devastating as the damage from the actual nuclear explosions.

APPROACH

The scope of this study is both broader and narrower than that of most other studies on this subject. It is broader in three respects:

1. it examines a full range of possible nucle ar attacks, with attacking forces ranging in extent from a single weapon to the bulk of a superpower's arsenal;
2. it deals explicitly with both Soviet attacks on the United States and U.S. attacks on the Soviet Union; and
3. it addresses the multiple effects of nuclear war, indirect as well as direct, long term as well as short term, and social and economic as well as physical.

Those effects that cannot be satisfactorily calculated or estimated are described qualitatively. But this report's scope is narrower than most defense analyses because it avoids any consideration of military effects; although it hypothesizes (among other things) missile attacks against military targets, only the "collateral" damage such attacks would inflict on the civilian society are examined.

The approach used was to look at a series of attack "cases," (table 1) and to describe the various effects and overall impact each of them might produce. By analyzing the impact of the same attack case for both a U.S. attack on the Soviet Union and a Soviet attack on the United States, the report examines the significance of the different kinds of vulnerabilities of the two countries, and offers some insights about the consequences of the differences between the two countries' nuclear weapon arsenals. The cases were chosen primarily to investigate the effects of variations in attack size and in the kinds of targets attacked. It is believed that the analysis is "realistic," in the sense that the hypothetical attacks are possible ones. Patterns of nuclear explosions were examined that are not very different from those that, OTA believes, the existing nuclear forces would produce if the military were ordered to make attacks of the specified size on the specified targets.

Case 1: In order to provide a kind of tutorial on what happens when nuclear weapons are

Table 1. –Summary of Cases

Case	Description
1 (pp. 27-44)	Attack on single city: Detroit and Leningrad; 1 weapon. or 10 small weapons.
2 (pp. 64-80)	Attack on oil refineries, limited to 10 missiles.
3 (pp. 81-94)	Counterforce attack; includes attack only on ICBM silos as a variant.
4 **(pp. 94-106)**	Attack on range **of military and economic targets using large fraction of existing arsenal.**

For each case the first section describes a soviet attack on the United States and the following section a U S attack on the Soviet Union

detonated, the study describes the effects of the explosion of a single weapon. Then it examines the effects of such an explosion over a single U.S. city (Detroit) and single Soviet city (Leningrad) of comparable size. The base case was the detonation of a l-megaton weapon (1 Mt = energy released by one million tons of TNT), since both the United States and the Soviet Union have weapons of roughly this size in their arsenals. Then, in order to look at the ways in which the specific effects and overall impact would vary if other weapons that might be available were used, the effects of a 25-Mt weapon over Detroit, the effects of a 9-Mt weapon over Leningrad, and the effects of 10 weapons of 40 kilotons (kt) each over Leningrad are described. An attempt was made to describe as well the effects of a small weapon in a large city (such as a terrorist group might set off) but was unsuccessful because the effects of such a weapon in a metropolitan setting cannot be inferred from the existing body of knowledge regarding military weapons. This is explained in the body of the report.

The casualties from such attacks could range from 220,000 dead and 420,000 injured to 2,500,000 dead and 1,100,000 injured (many of the injured would wind up as fatalities), depending on the details of the attack and the assumptions made regarding conditions. The discussion in chapter II shows how the time of day, time of year, weather conditions, size of weapon, height of burst, and preparation of the population could all make a great difference in the number of casualties resulting from such an attack. The extent of fire damage is a further uncertainty, Even if only one city is attacked, and the remaining resources of a nation are available to help, medical facilities would be inadequate to care for the injured. A further imponderable is fallout (if the attack uses a surface burst), whose effects depend on the winds.

Case 2: In order to examine the effects of a small attack on urban/industrial targets, the study examines a hypothetical attack limited to 10 SNDVs (strategic nuclear delivery vehicles, the term used in SALT to designate one missile or one bomber) on the other superpower's oil refineries. In "planning" this attack, which is not analogous to any described in recent U.S. literature, it was hypothesized that the political leadership instructed the military to inflict maximum damage on energy production using only 10 SNDVs without regard to the extent of civilian casualties or other damage, It was assumed that the Soviets would attack such targets with SS-18 missiles (each carrying 10 multiple independently targetable reentry vehicles, or MIRVs), and that the United States would use 7 MIRVed Poseidon missiles and 3 MIRVed Minuteman III missiles.

The calculations showed that the Soviet attack would destroy 64 percent of U.S. oil refining capacity, while the U.S. attack would destroy 73 percent of Soviet refining capacity. Calculations were also made of "prompt fatalities," including those killed by blast and fallout, assuming no special civil defense measures: they showed about 5 million U.S. deaths and about 1 million Soviet deaths. The results were different for the two countries for several reasons. Soviet oil refining capacity is more concentrated than U.S. oil refining capacity, so that a small attack can reach more of it. At the same time, Soviet refineries tend to be located away from residential areas (the available data on population location deals with where people live rather than with where they work) to a greater extent than U.S. refineries. A further difference is that a limitation on the number of delivery vehicles would lead each side to use weapons with many MIRVs, so the United States would attack most of the targets with Poseidon missiles which have small warheads, while the Soviets would use SS-18 intercontinental ballistic missiles (ICBMs) which carry much larger warheads, and large warheads cause more damage to things not directly targeted (in this case, people) than do small warheads.

One can only speculate about the consequences of such extensive destruction. There would have to be drastic changes in both the U.S. and Soviet economies to cope with the sudden disappearance of the bulk of oil refining capacity. Productivity in virtually every industrial sector would decline, and some sectors would be largely wiped out. There would

have to be strict allocation of the remaining available refined petroleum products. Some Soviet factory workers might end up working in the fields to replace tractors for which fuel was unavailable. The United States might have to ban commuting by automobile, forcing suburban residents to choose between moving and long walks to a bus stop. The aftermath of the war might lead to either an increase or a decrease i n the amount of petroleum products required by the military. Changes in people's attitudes are impossible to predict. Calm determination might produce effective responses that would limit the damage; panic or a breakdown in civic spirit could compound the effects of the attack itself.

It is instructive to observe the asymmetries between the problems which the United States and the Soviets would face. Soviet agricultural production, which is barely adequate in peacetime, would probably decline sharply, and production rates would slow even in essential industries However, the Soviet system is well adapted for allocating scarce resources to high-priority areas, and for keeping everybody employed even if efficient employment is unavailable. The relative wealth and freedom of the United States brings both advantages and disadvantages: while agriculture and essential industry would probably continue, there would be a staggering organizational problem in making use of resources that now depend on petroleum — one must ask what the employees of an automobile factory or a retail establishment on a highway would do if there were virtually no gasoline for cars,

A major question relating to these results is how much they could vary with changed assumptions, The figures for fatalities were based on air bursts, which would maximize destruction of the refineries. (As an excursion, U.S. fatalities were recalculated on the assumption of surface bursts, and use of the best fallout shelters within 2 miles of where each person lives. This reduced fatalities by one-third,) There was no data available on the types of Soviet residential construction in the vicinity of oil refineries: treating it parametrically gave casualty figures of about 1,5OO,OOO if the construction is all houses, and about 800,000 if it is al I apartment buildings. Perfect accuracy was assumed for missiles that are in fact somewhat inaccurate — some inaccuracy might reduce the extent of damage to the refineries, but it might well increase the number of deaths.

Case 3. I n order to examine the effects on civilian populations and economies of counterforce attacks, the study examined attacks on ICBM silos and attacks on silos, bomber bases, and missile submarine bases. Such attacks have received fairly extensive study in the executive branch in recent years, so OTA surveyed a number of these studies in order to determine the range of possible answers, and the variations in assumptions that produce such a range, An unclassified summary of this survey appears as appendix D of this volume. (The complete survey, classified secret, is available separately.)

A counterforce attack would produce relatively little direct blast damage to civilians and to economic assets; the main damage would come from radioactive fallout, The uncertainties in the effects of fallout are enormous, depending primarily on the weather and on the extent of fallout sheltering which the population makes use of. The calculations made by various agencies of the executive branch showed a range in "prompt fatalities" (almost entirely deaths from fallout within the first 30 days) from less than 1 to 11 percent of the U.S. population and from less than 1 to 5 percent of the Soviet population. This shows just how great a variation can be introduced by modifying assumptions regarding population distribution and **shelter**

What can be concluded from this? First, if the attack involves surface bursts of many very large weapons, if weather conditions are unfavorable, and if no fallout shelters are created beyond those that presently exist, U.S. deaths could reach 20 m i l l ion and Soviet deaths more than 10 million. (The difference is a result of geography; many Soviet strategic forces are so located that fallout from attacking them would drift mainly into sparsely populated areas or into China.) Second, effective fallout

sheltering (which is not necessarily the same thing as a program—this assumes people are actually sheltered and actually remain there) could save many lives under favorable conditions, but even in the best imaginable case more than a million would die in either the United States or the U.S.S.R. from a counterforce attack. Third, the "limited nature" of counterforce attacks may not be as significant as the enormous uncertainty regarding their results.

There would be considerable economic damage and disruption as a result of such attacks. Almost all areas could, in principle, be decontaminated within a few months, but the loss of so many people and the interruption of economic life would be staggering blows. An imponderable, in thinking about the process of recovery, is the extent of any lasting psychological impacts.

Case *4:* In order to examine the kind of destruction that is generally thought of as the culmination of an escalator process, the study looked at the consequences of a very large attack against a range of military and economic targets. Here too calculations that the executive branch has carried out in recent years were used. These calculations tend to assume that Soviet attacks on the United States would be a first strike, and hence use most of the Soviet arsenal, while U.S. attacks on the Soviet Union would be retaliatory strikes, and hence use only those weapons that might survive a Soviet counterforce attack. However, the difference in damage to civilian populations and economies between a "first strike" and a "second strike" seems to lie within the range of uncertainty created by other factors.

The resulting deaths would be far beyond any precedent. Executive branch calculations show a range of U.S. deaths from 35 to 77 percent (i. e., from 70 million to 160 million dead), and Soviet deaths from 20 to 40 percent of the population. Here again the range reflects the difference made by varying assumptions about population distribution and sheltering, and to a lesser extent differences in assumptions about the targeting policy of the attacker. Soviet casualties are smaller than U.S. casualties because a greater proportion of the Soviet population lives in rural areas, and because U.S. weapons (which have lower average yields) produce less fallout than Soviet weapons.

Some excursions have been run to test the effect of deliberately targeting population rather than killing people as a side effect of attacking economic and military targets. They show that such a change in targeting could kill somewhere between 20 million and 30 million additional people on each side, holding other assumptions constant.

These calculations reflect only deaths during the first 30 days. Additional millions would be injured, and many would eventually die from lack of adequate medical care. In addition, millions of people might starve or freeze during the following winter, but it is not possible to estimate how many. Chapter V attempts to calculate the further millions who might eventually die of latent radiation effects.

What is clear is that from the day the survivors emerged from their fallout shelters, a kind of race for survival would begin. One side of the race would be the restoration of production: production of food, of energy, of clothing, of the means to repair damaged machinery, of goods that might be used for trade with countries that had not fought in the war, and even of military weapons and supplies. The other side of the race would be consumption of goods that had survived the attack, and the wearing-out of surviving machines. If production rises to the rate of consumption before stocks are exhausted, then viability has been achieved and economic recovery has begun. If not, then each postwar year would see a lower level of economic activity than the year before, and the future of civilization itself in the nations attacked would be in doubt. This report cannot predict whether this race for economic viability would be won. The answer would lie in the effectiveness of postwar social and economic organization as much as in the amount of actual physical damage. There is a

controversy in the literature on the subject as to whether a postttack economy would be based on centralized planning (in which case how would the necessary data and planning time be obtained?), or to individual initiative and decentralized decision making (in which case who would feed the refugees, and what would serve for money and credit?).

An obviously critical question is the impact that a nuclear attack would have on the lives of those who survive it. The case descriptions discuss the possibilities of economic, political, social, and psychological disruption or collapse. However, the recital of possibilities and uncertainties may fail to convey the overall situation of the survivors, especially the survivors of a large attack that included urban-industrial targets. In an effort to provide a more concrete understanding of what a world after a nuclear war would be like, OTA commissioned a work of fiction. It appears as appendix C and presents some informed speculation about what life would be like in Charlottesville, Va., assuming that this city escaped direct damage from the attack. The kind of detail that such an imaginative account presents—detail that proved to be unavailable for a comparable Soviet city–adds a dimension to the more abstract analysis in the body of the report.

Civil Defense: Chapter 11 I provides some basic information about civil defense measures, discusses the way in which they might mitigate the effects of nuclear attack, and discusses the uncertainties regarding their effectiveness. There is a lively controversy among experts as to the effectiveness of existing Soviet civil defense programs, and another controversy as to whether existing U.S. programs ought to be changed. The major points in dispute were identified, but no attempt was made to assess the merits of the arguments. For the purposes of this study, it was assumed that the existing civil defense programs, as described in this report, would be in effect, and that a full-scale preattack evacuation of cities (sometimes called "crisis relocation") would not take place. This assumption was made because it appeared to be the only way to describe existing vulnerabilities while avoiding predictions about the course of events leading up to a nuclear war. While both the U.S. and the Soviet Governments profess to believe that urban evacuation prior to an attack on cities would save lives, ordering such an evacuation would be a crisis management move as well as a civil defense precaution.

Long-Term Effects: While the immediate damage from the blasts would be long term in the sense that the damage could not be quickly repaired, there would be other effects which might not manifest themselves for some years after the attack. It is well established that levels of radiation too low (or too slowly absorbed) to cause immediate death or even illness will nevertheless have adverse effects on some fraction of a population receiving them. A nuclear attack would certainly produce both somatic effects (largely cancer) and genetic effects, although there is uncertainty about the numbers of victims. OTA calculated the ranges of such effects that might be produced by each of the attack cases analyzed. Cancer deaths and those suffering some form of genetic damage would run into the millions over the 40 years following the attack. For the comprehensive attack (Case 4), it appears that cancer deaths and genetic effects in a country attacked would be small relative to the numbers of immediate deaths, but that radiation effects elsewhere in the world would appear more significant. For counterforce attacks, the effects would be significant both locally and worldwide.

A 1975 study by the National Academy of Sciences (NAS)[1] addressed the question of the possibility of serious ecological damage, and concluded that while one cannot say just how such damage would occur, it cannot be ruled out. This conclusion still stands, although the NAS report may have been more alarmist about the possibility of damage to the ozone layer than recent research would support.

Table 2 summarizes the results of the case studies.

[1] *Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations* **(Washington, D.C.: National Academy of Sciences, 1 975).**

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Table 2. –Summary of Effects

Case	Description	Main causes of civilian damage	Immediate deaths	Middle-term effects	Long-term effects
1 (pp. 27-44)	Attack on single city: Detroit and Leningrad; 1 weapon or 10 small weapons,	Blast, fire, & loss of infrastructure, fallout is elsewhere,	200,00-2,000,000	Many deaths from injuries; center of city difficult to rebuild,	Relatively minor
2 (pp. 64-80)	Attack on oil refineries, limited to 10 missiles,	Blast, fire, secondary fires, fallout, Extensive economic problems from loss of refined petroleum,	1,000,000-5,000,000	Many deaths from injuries; great economic hardship for some years; particular problems for Soviet agriculture and for U.S. socioeconomic organization	Cancer deaths in millions only if attack involves surface bursts
3 (pp. 81-94)	Counterforce attack: Includes attack only on ICBM silos as a variant	Some blast damage if bomber and missile sub marine bases attacked	1,000>000-20,000,000	Economic impact of deaths, possible large psychological impact	Cancer deaths and genetic effects in millions, further millions of effects outside attacked countries
4 (pp. 94-106)	Attack on range of military and economic targets using large fraction of existing arsenal	Blast and fallout, subsequent economic disruption; possible lack of resources to support surviv - ing population or economic recovery, Possible breakdown of social order. Possible Incapacitating psychological trauma.	20,000,000-160,000,000	Enormous economic destruction and disruption, If Immediate deaths are in low range, more tens of millions may die subsequently because economy is unable to support them Major question about whether economic viability can be restored–key variables may be those of political and economic organization Unpredictable psychological effects,	Cancer deaths and genetic damage in the millions; relatively Insignificant in attacked areas, but quite significant elsewhere in the world. Possibility of ecological damage.

For each case, the first section describes a Soviet attack on the United States, and the following section a U.S. attack on the Soviet Union

UNCERTAINTIES

There are enormous uncertainties and imponderable involved in any effort to assess the effects of a nuclear war, and an effort to look at the entire range of effects compounds them. Many of these uncertainties are obvious ones: if the course of a snowstorm cannot be predicted 1 day ahead in peacetime, one must certainly be cautious about predictions of the pattern of radioactive fallout on some unknown future day. Similar complexities exist for human institutions: there is great difficulty in predicting the peacetime course of the U.S. economy, and predicting its course after a nuclear war is a good deal more difficult. This study highlights the importance of three categories of uncertainties:

- Uncertainties in calculations of deaths and of direct economic damage resulting from the need to make assumptions about matters such as time of day, time of year, wind, weather, size of bombs, exact location of the detonations, location of people, availability and quality of sheltering, etc.
- Effects that would surely take place, but whose magnitude cannot be calculated. These include the effects of fires, the shortfalls in medical care and housing, the extent to which economic and social disruption would magnify the effects of direct economic damage, the extent of bottlenecks and synergistic effects, the extent of disease, etc.
- Effects that are possible, but whose likelihood is as incalculable as their magnitude. These include the possibility of a

long downward economic spiral before viability is attained, the possiblity of political disintegration (anarchy or regionalization), the possibility of major epidemics, and the possibility of i reversible ecological changes.

One major problem in making calculations is to know where the people will be at the moment when the bombs explode. Calculations for the United States are generally based on the 1970 census, but it should be borne in mind that the census data describes where people's homes are, and there is never a moment when everybody in the United States is at home at the same time If an attack took place during a working day, casualties might well be higher since people would be concentrated in factories and offices (which are more likely to be targets) rather than dispersed in suburbs. For the case of the Soviet population, the same assumption is made that people are at home, but the inaccuracies are compounded by the unavailability of detailed information about just where the Soviet rural population lives. The various calculations that were used made varying, though not unreasonable assumptions about population location.

A second uncertainty in calculations has to do with the degree of protection available. There is no good answer to the question: "Would people use the best available shelter against blast and fallout?" It seems unreasonable to suppose that shelters would not be used, and equally unreasonable to assume that at a moment of crisis all available resources would be put to rational use, (It has beep pointed out that if plans worked, people behaved rationally, and machinery were adequately maintained, there would be no peacetime deaths from traffic accidents.) The Defense Civil Preparedness Agency has concluded from public opinion surveys that in a period of severe international crisis about 10 percent of all Americans would leave their homes and move to a "safer" place (spontaneous evacuation); more reliable estimates are probably impossible, but it could make a substantial difference to the casualty figures

A third uncertainty is the weather at the time of the attack at the various places where bombs explode. The local wind conditions, and especially the amount of moisture in the air, may make an enormous difference in the number and spread of fires. Wind conditions over a wider area determine the extent and location of fallout contamination. The time of year has a decisive effect on the damage that fallout does to agriculture–while an attack in January might be expected to do only indirect damage (destroying farm machinery or the fuel to run it), fallout when plants are young can kill them, and fallout just before harvesttime would probably make it unsafe to get the harvest in. The time of year also has direct effects on population death — the attack in the dead of winter, which might not directly damage agriculture, may lead to greater deaths from fallout radiation (because of the difficulty of improvising fallout protection by moving frozen dirt) and from cold and exposure.

The question of how rapid and efficient economic receovery would be— or indeed whether a genuine recovery would be possible at all — raises questions that seem to be beyond calculation. I t is possible to calculate direct economic damage by making assumptions about the size and exact location of bomb explosions, and the hardness of economic assets; however, such calculations cannot address the issues of bottlenecks and of synergy. Bottlenecks would occur if a key product that was essential for many other manufacturing processes could no longer be produced, or (for the case of a large attack) if an entire industrial sector were wiped out. I n either case, the economic loss would greatly exceed the peacetime value of the factories that were actually destroyed. There does not appear to be any reliable way of calculatin the likelihood or extent of bottlenecks because economic input/output models do not address the possibility or cost of substitutions across sectors. Apart from the creation of bottlenecks, there could be synergistic effects: for *example, the* fire that cannot be controlled because the blast destroyed fire stations, as actually happened at Hiroshima. Here, too, there is no reliable way to

estimate the likelihood of such effects: would radiation deaths of birds and the destruction of insecticide factories have a synergistic effect? Another uncertainty is the possibility of organizational bottlenecks. In the most obvious instance, it would make an enormous difference whether the President of the United States survived. Housing, defined as a place where a productive worker lives as distinct from shelter for refugees, is another area of uncertainty. Minimal housing is essential if production is to be restored, and it takes time to rebuild it if the existing housing stock is destroyed or is beyond commuting range of the surviving (or repaired) workplaces. It should be noted that the United States has a much larger and more dispersed housing stock than does the Soviet Union, but that American workers have higher minimum standards.

There is a final area of uncertainty that this study does not even address, but which could be of very great importance. Actual nuclear attacks, unlike those in this study, would not take place in a vacuum. There would be a series of events that would lead up to the attack, and these events could markedly change both the physical and the psychological vulnerability of a population to a nuclear attack. Even more critical would be the events after the attack. Assuming that the war ends promptly, the terms on which it ends could greatly affect both the economic condition and the state of mind of the population. The way in which other countries are affected could determine whether the outside world is a source of help or of further danger. The post-attack military situation (and nothing in this study addresses the effects of nuclear attacks on military power) could not only determine the attitude of other countries, but also whether limited surviving resources are put to military or to civilian use.

Moreover, the analyses in this study all assume that the war would end after the hypothetical attack. This assumption simplifies analysis, but it might not prove to be the case. How much worse would the situation of the survivors be if, just as they were attempting to restore some kind of economy following a massive attack, a few additional weapons destroyed the new centers of population and of government?

Chapter II

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

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

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Chapter II

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

INTRODUCTION

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

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

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

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

GENERAL DESCRIPTION OF EFFECTS

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

- an explosive blast, which is qualitatively similar to the blast from ordinary chemical explosions, but which has somewhat different effects because it is typically so much larger;
- direct nuclear radiation;
- direct thermal radiation, most of which takes the form of visible light;
- pulses of electrical and magnetic energy, called electromagnetic pulse (EM P); and
- the creation of a variety of radioactive particles, which are thrown up into the air by the force of the blast, and are called radioactive fallout when they return to Earth.

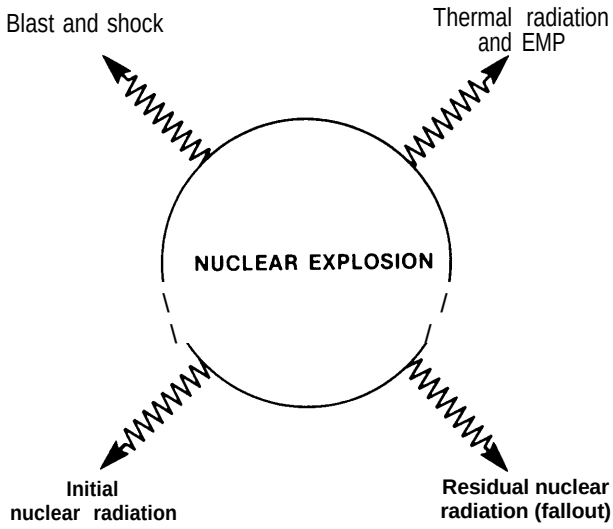
The distribution of the bomb’s energy among these effects depends on its size and on

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

Blast

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

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



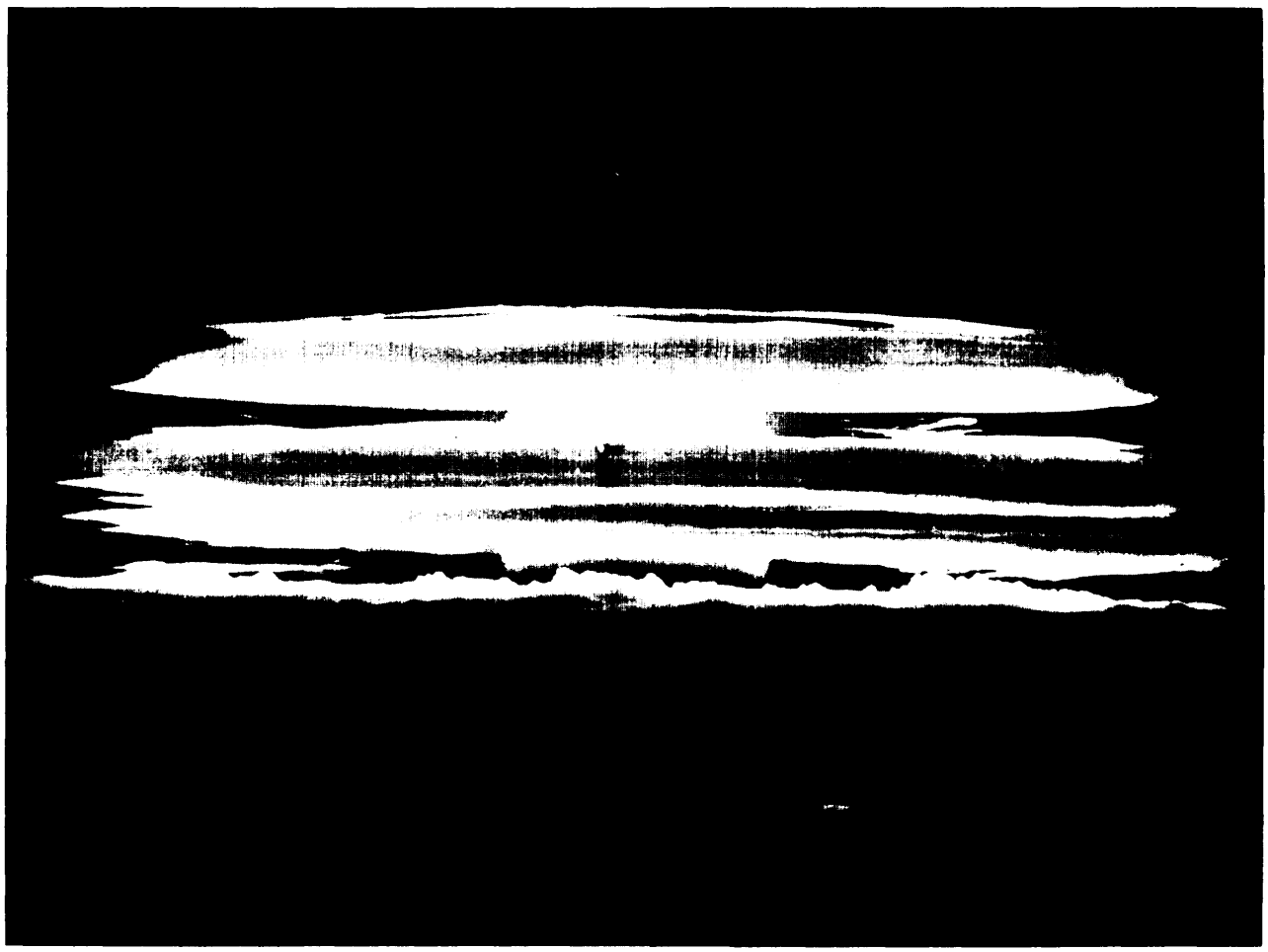
Effects of a nuclear explosion

Thermonuclear ground burst

Photo credit: U S Department of Energy

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

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



Fireball from an air burst in the megaton **energy range**

Photo credit: U S Air Force

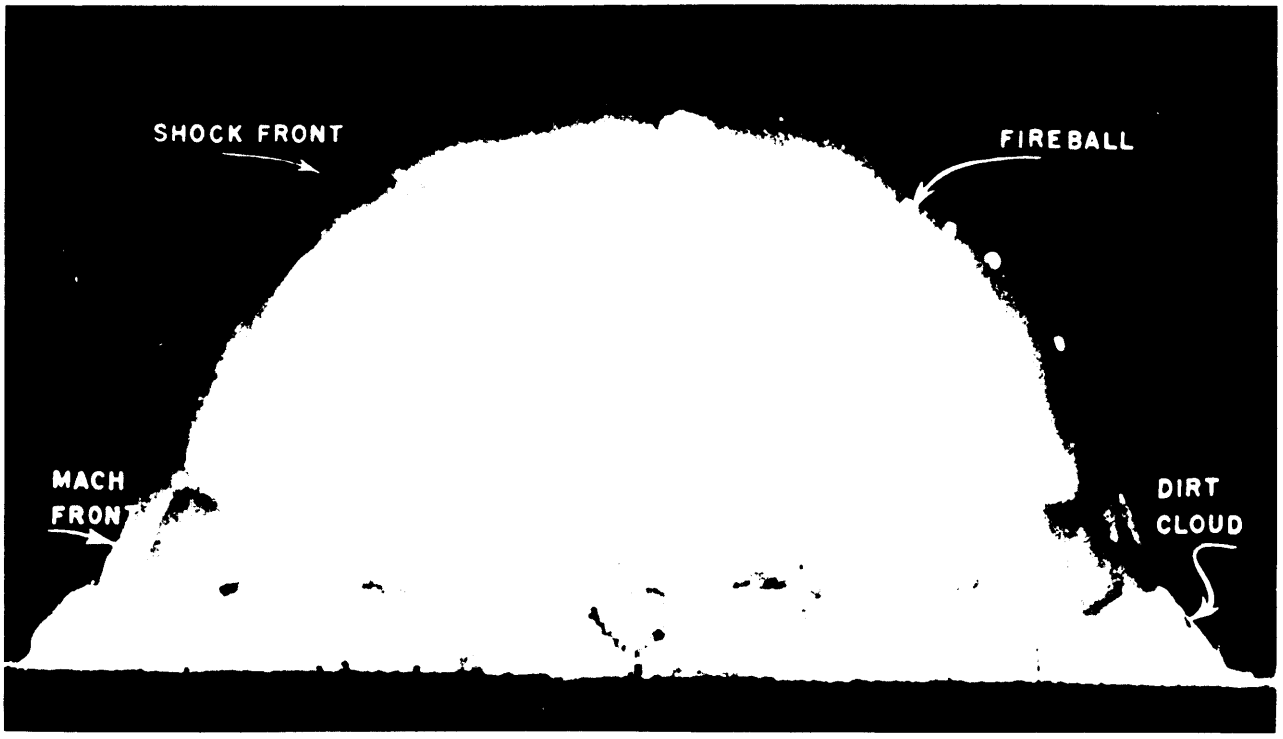


Photo credit U S Department of Defense

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

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

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

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

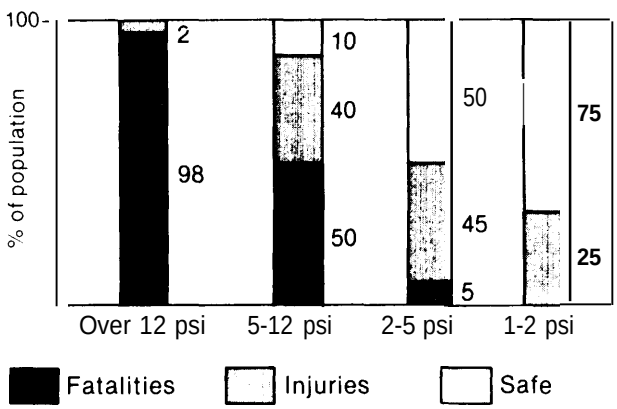
Table 3.–Blast Effects of a 1-Mt Explosion 8,000 ft Above the Earth's Surface

Distance from ground zero (stat. miles)	Distance from ground zero (kilometers)	Peak overpressure	Peak wind velocity (mph)	Typical blast effects
.8	1,3	20 psi	470	Reinforced concrete structures are leveled.
3 0	4 8	10 psi	290	Most factories and commercial buildings are collapsed. Small wood-frame and brick residences destroyed and distributed as debris,
4.4	7.0	5 psi	160	Lightly constructed commercial buildings and typical residences are destroyed, heavier construction is severely damaged
5.9	9 5	3 psi	95	Walls of typical steel-frame buildings are blown away: severe damage to residences. Winds sufficient to kill people in the open.
11 6	18.6	1 psi	35	Damage to structures, people endangered by flying glass and debris

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

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

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



Direct Nuclear Radiation

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

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

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

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

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

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

Thermal Radiation

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

Photo credit U S Air force

Burn injuries from nuclear blasts

Photo credit' U S Department of Defense

The patient's skin is burned in a pattern corresponding to the dark portions of a kimono worn at the time of the explosion

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

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

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

Fires

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

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

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

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

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

Electromagnetic Pulse

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

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

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

Fallout

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

The radioactive particles that rise only a short distance (those in the "stem" of the familiar mushroom cloud) will fall back to earth within a matter of minutes, landing close to the center of the explosion. Such particles

are unlikely to cause many deaths, because they will fall in areas where most people have already been killed. However, the radioactivity will complicate efforts at rescue or eventual reconstruct ion.

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

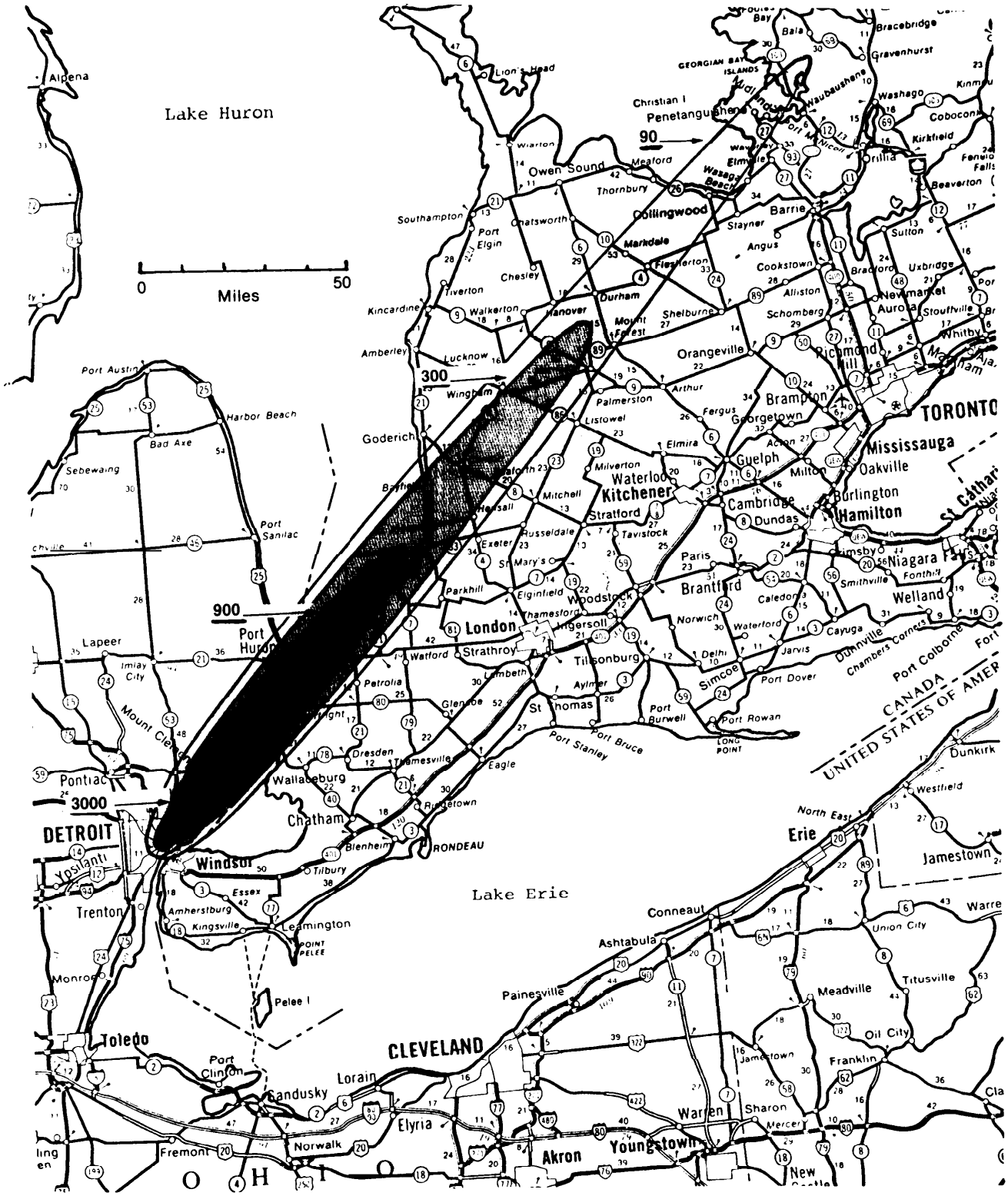
The amount of radiation produced by fallout materials will decrease with time as the radioactive materials “decay. ” Each material decays at a different rate, Materials that decay rapidly give off intense radiation for a short period of time while long-lived materials radiate less intensely but for longer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

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

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

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

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



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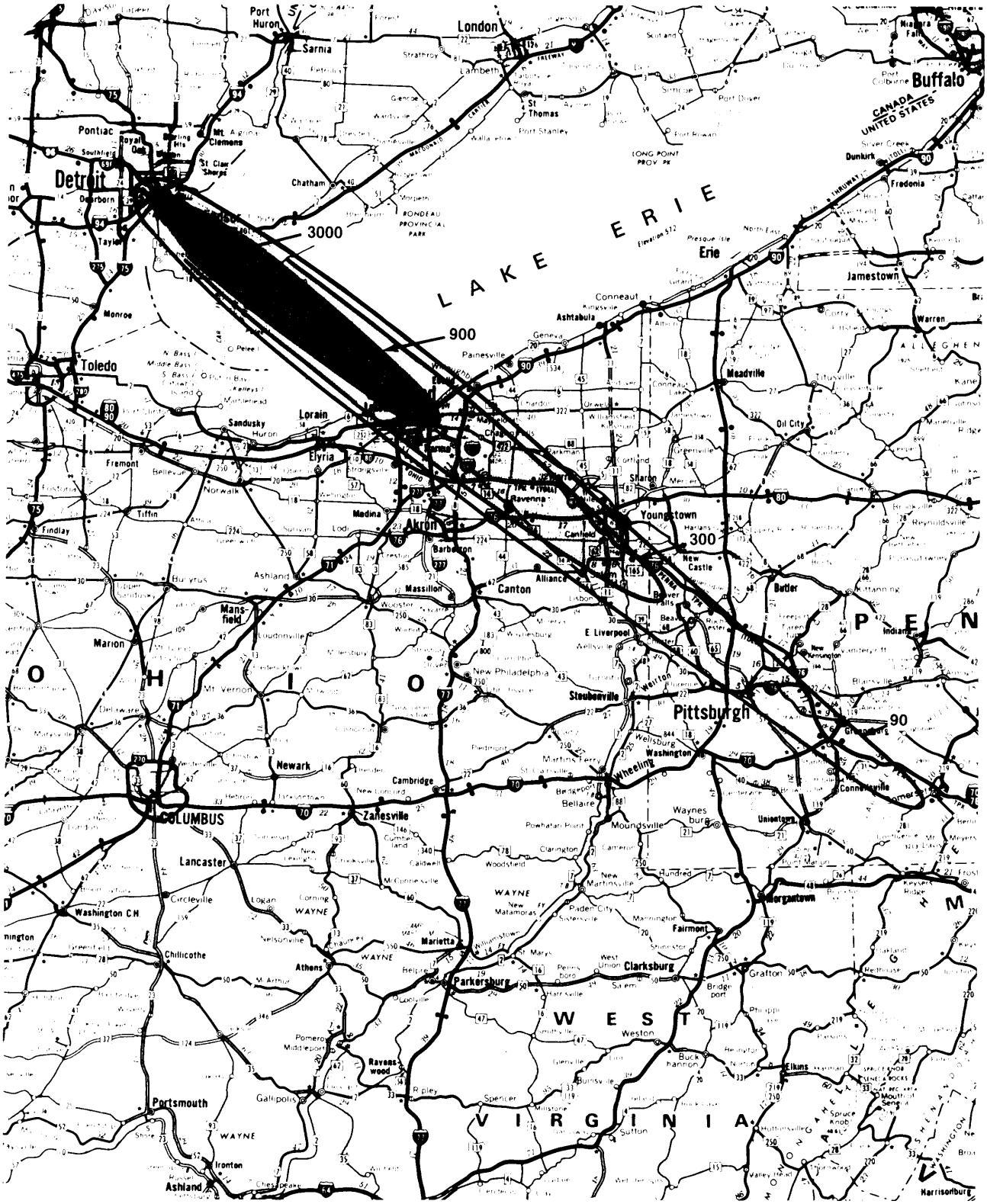

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Combined Injuries (Synergism)

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

- **Nuclear Radiation Combined With Thermal Radiation.–** Severe burns place considerable stress on the blood system, and often cause anemia. It is clear from experiments with laboratory animals that exposure of a burn victim to more than 100 reins of radiation will impair the blood's ability to support recovery from the thermal burns. Hence a sublethal radiation dose could make it impossible to recover from a burn that, without the radiation, would not cause death.
- **Nuclear Radiation Combined With Mechanical Injuries. –Mechanical injuries, the indirect results of blast, take many forms. Flying glass and wood will cause puncture wounds. Winds** may blow people into obstructions, causing broken bones, concussions, and internal injuries. Persons caught in a collapsing building can suffer many similar mechanical injuries. There is evidence that all of these types of injuries are more serious if the person has been exposed to 300 reins, particularly if treatment is delayed. Blood damage will clearly make a victim more susceptible to blood loss and infection. This has been confirmed in laboratory animals in which a borderline lethal radiation dose was followed a week later by a blast overpressure that alone would have produced a low level of prompt lethality. The number of prompt and delayed (from radiation) deaths both increased over what would be expected from the single effect alone.
- **Thermal Radiation and Mechanical Iniuries.** — There is no information available about the effects of this combination, beyond the common sense observation that since each can place a great stress on a healthy body, the combination of injuries that are individually tolerable may subject the body to a total stress that it cannot tolerate. Mechanical injuries should be prevalent at about the distance from a nuclear explosion that produces sublethal burns, so this synergism could be an important one.

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

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

DETROIT AND LENINGRAD

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

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

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

1 Mt on the Surface in Detroit

Physical Damage

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

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

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

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

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

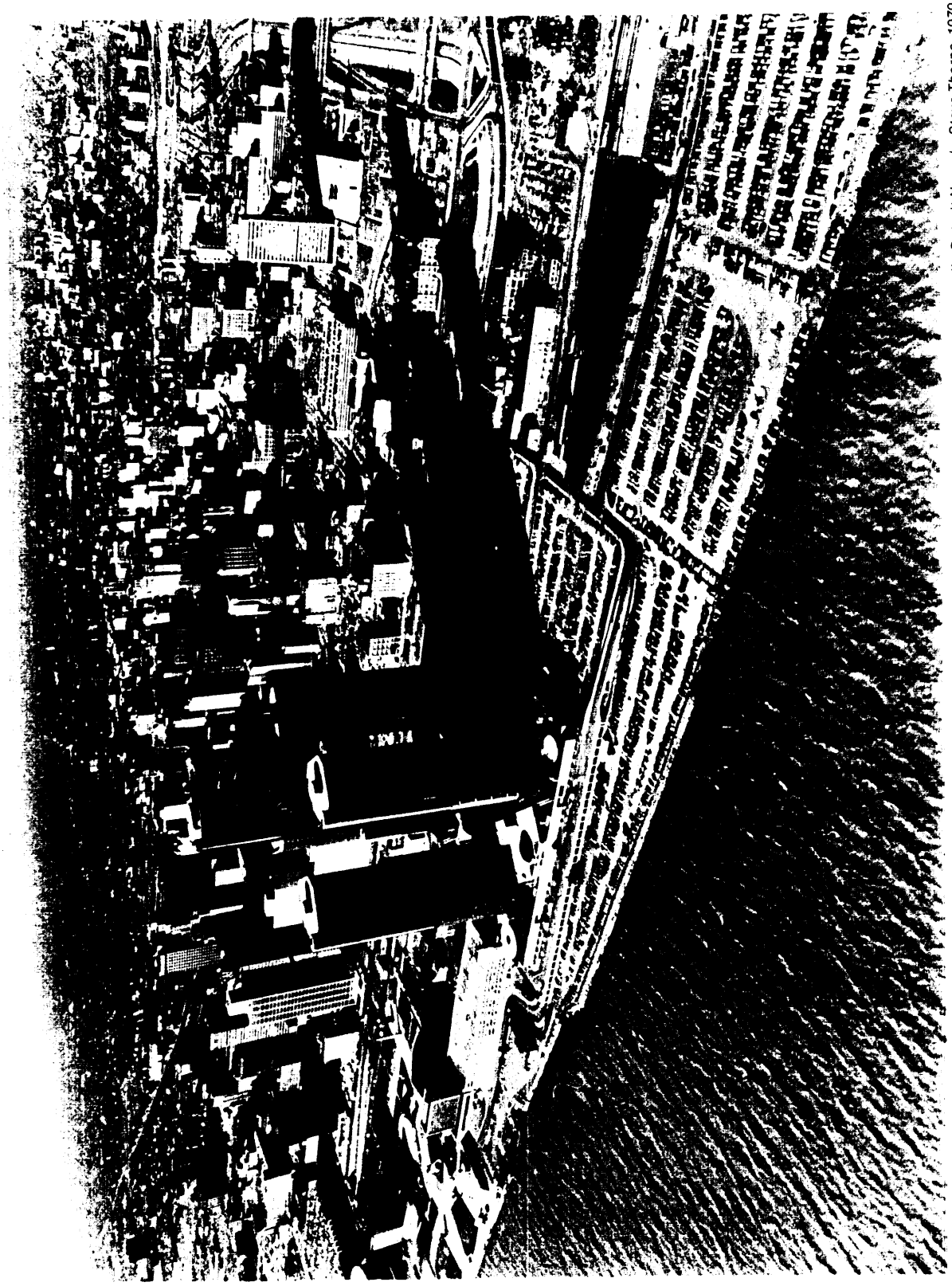


Photo credit: Detroit News by Steve Thorpe, 1979

Skyline of Detroit, Mich.

Figure 4.—Detroit 1-Mt Surface Burst

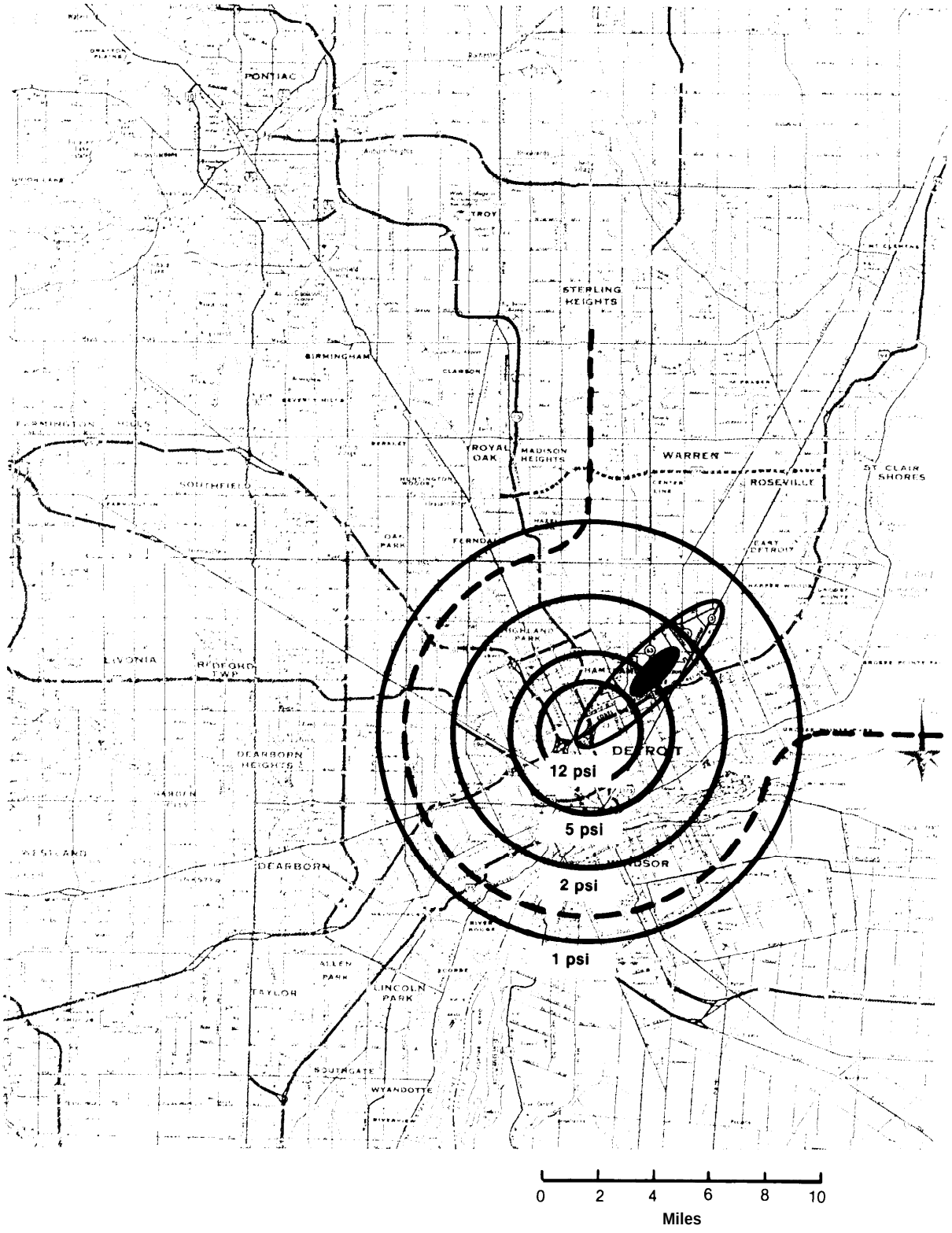


Photo credit: Nuclear Defense Agency

Damage to unreinforced brick house (5-psi overpressure)

Table 4.—Casualty Estimates (in thousands)

Region (mi)	Area (mi²)	Population	Fatalities	Injuries	Uninjured
o-1 7	9 1	70	70	0	0
1 7-27	13.8	250	130	100	20
2 7-4 7	4 6 5	400	20	180	200
4 7-7 4	1026	600	0	150	450

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

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

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

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

In this ring only 5 percent of the population of about 400,000 will be killed, but nearly half will be injured (table 4). This is the region of the most severe fire hazard, since fire ignition and spread is more likely in partly damaged buildings than in completely flattened areas. Perhaps 5 percent of the buildings would be initially ignited, with fire spread to adjoining

buildings highly likely if their separation is less than 50 feet [15 m]. Fires will continue to spread for 24 hours at least, ultimately destroying about half the buildings. However, these estimates are extremely uncertain, as they are based on poor data and unknown weather conditions. They are also made on the assumption that no effective effort is made by the uninjured half of the population in this region to prevent the ignition or spread of fires.

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

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

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

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

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

Distance from blast (mi)	Survivors of blast effects	Fatalities (eventual)		Injuries	
		2-mile visibility	10-mile visibility	2-mile visibility	10-mile visibility
(1 percent of population exposed to line of sight from fireball)					
0 - 1 . 7	0	0	0	0	0
1 7 - 2 7	120,000	1,200	1,200	0	0
2 7 - 4 . 7 .	380,000	0	3,800	500	0
47-74.	600,000	0	2,600	0	3,000
Total (rounded		1,000	8,000	500	3,000
(25 percent of population exposed to line of sight from fireball)					
0 - 1 7 .	0	0	0	0	0
1 7 - 2 7 ,	120,000	30,000	30,000	0	0
2 . 7 - 4 7	380.000	0	95,000	11,000	0
4 , 7 - 7 4 .	600,000	0	66,000	0	75,000
Total (rounded)		30,000	190.000	11.000	75,000

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

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

Infrastructure Status

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

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

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

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

The gas distribution system will receive similar damage: loss of pressure from numerous broken service connections, some broken mains, particularly in the 5- to 12-psi ring, and

numerous resulting fires. Service will be slowly restored only as utility repairmen and service equipment are brought in from surrounding areas.

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

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

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

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

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

Radioactive Fallout

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

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

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

plosion and it would be most dangerous during the first few days. In the case of an attack on a single city (using a surface burst, as our example does), people living downwind would probably evacuate. Those who neither evacuated nor found adequate fallout shelters would be subjected to dangerous levels of radiation: people in the inner contour would receive a fatal dose within the first week; people in the next contour out would contract very severe radiation sickness if they stayed indoors and would probably receive a fatal dose if they spent much time outdoors; people in the next contour out would contract generally nonfatal radiation sickness, with increased hazards of deaths from other diseases. People in the outer contour (9o roentgens in the first week) would suffer few visible effects, but their life expectancy would drop as a result of an increased risk of eventual cancer.

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

Summary

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

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

l-Mt Air Burst on Detroit

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

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

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

Figure 5.— Detroit I-Mt Air Burst

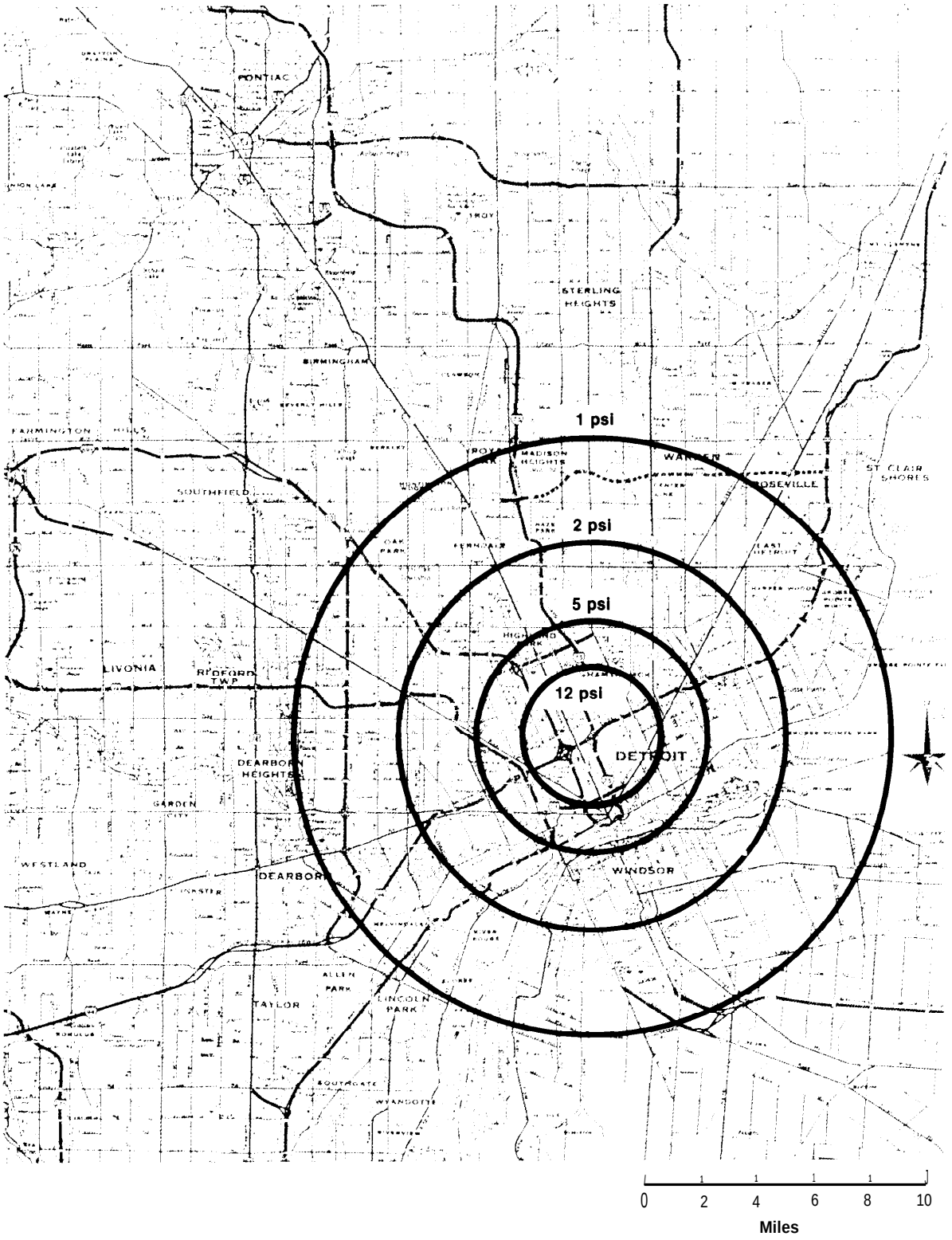
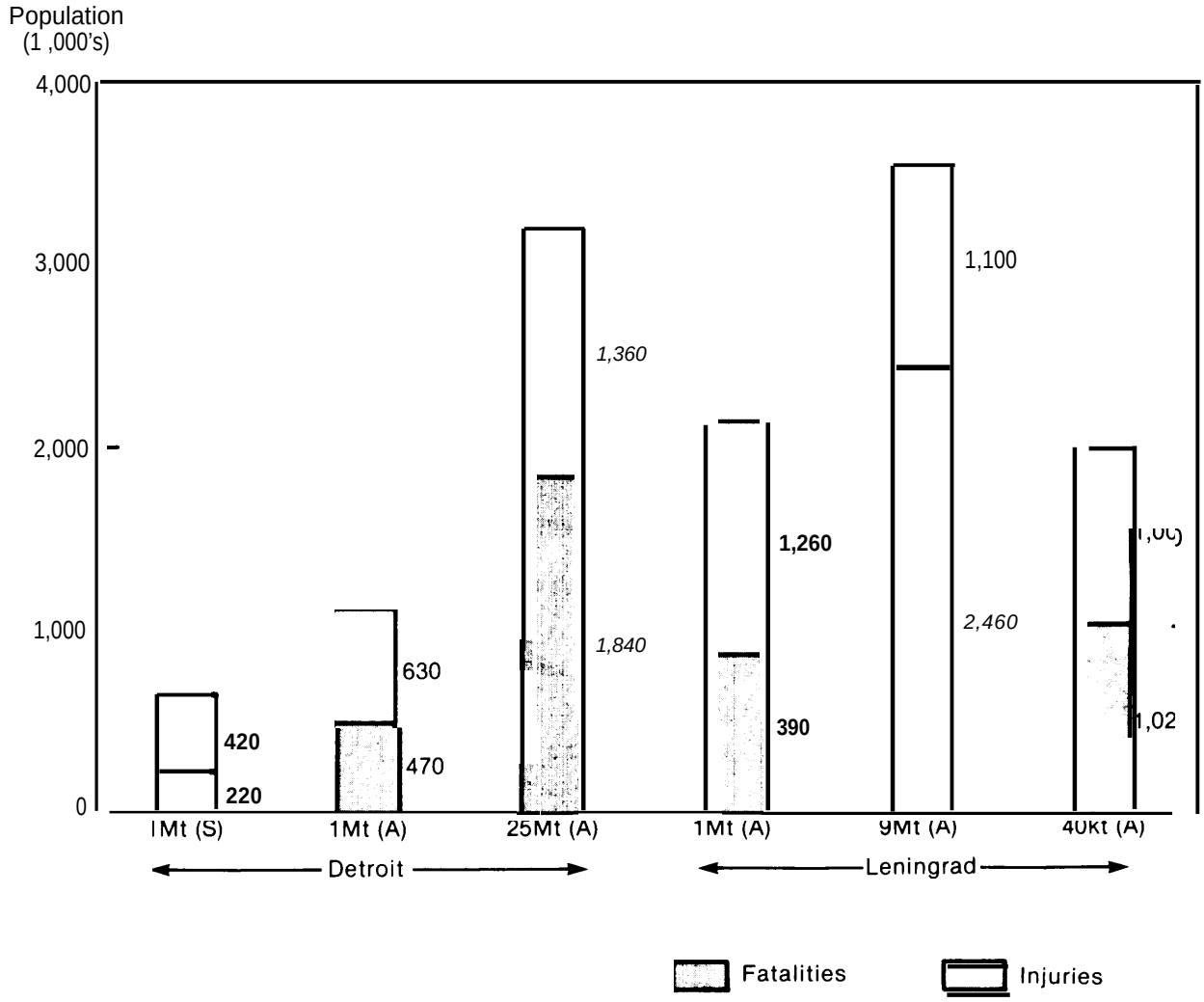


Figure 6.—Casualties (thousands)



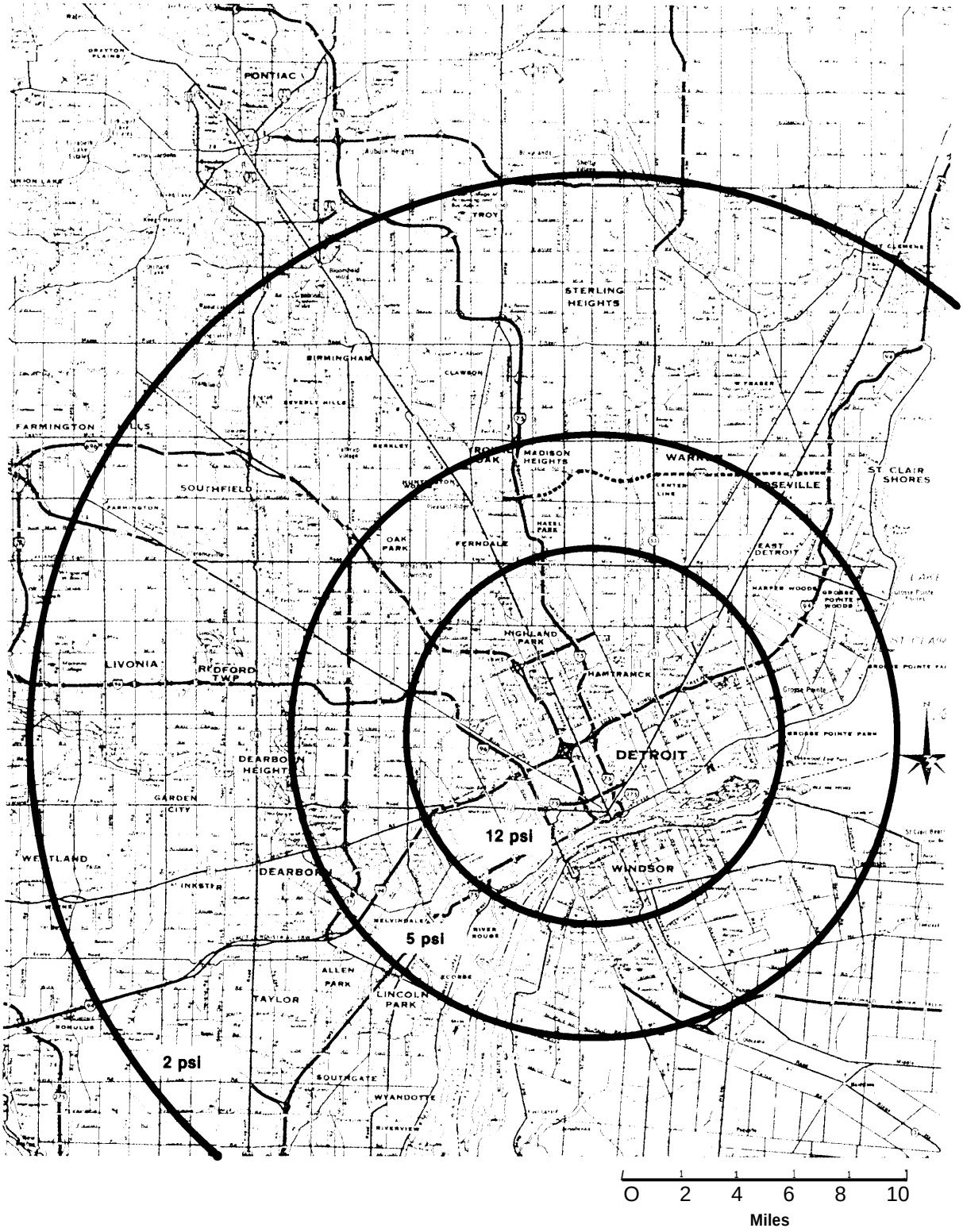
dustrial facilities is becoming significant, with the Chrysler plant in the middle of the 2- to 5-psi band, and the Ford River Rouge plant in the 1- to 2-psi band.

25-Mt Air Burst on Detroit

For 25 Mt, we assumed a burst altitude of 17,500 feet [5.3 km], over the same detonation point. Figure 7 shows the 12-, 5-, and 2-psi rings, but the 1-psi ring at 30.4 miles [48.9 km] is completely off the map. It is obvious that damage and casualties would be increased even further had the detonation point been moved about 5 miles [8 km] to the northwest. But even without this shift, it is clear that the whole metropolitan area has been heavily damaged by the explosive power of this huge weapon. The casualties are again shown on figure 6 (column 3). The contrasts to the l-Mt surface burst are stark:

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

Figure 7.— Detroit 25-Mt Air Burst



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

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

Leningrad

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

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

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

l-Mt and 9-Mt Air Bursts on Leningrad

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

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

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

Ten 40-kt Air Bursts on Leningrad

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

Figure 8.— Leningrad—Commercial and Residential Sections

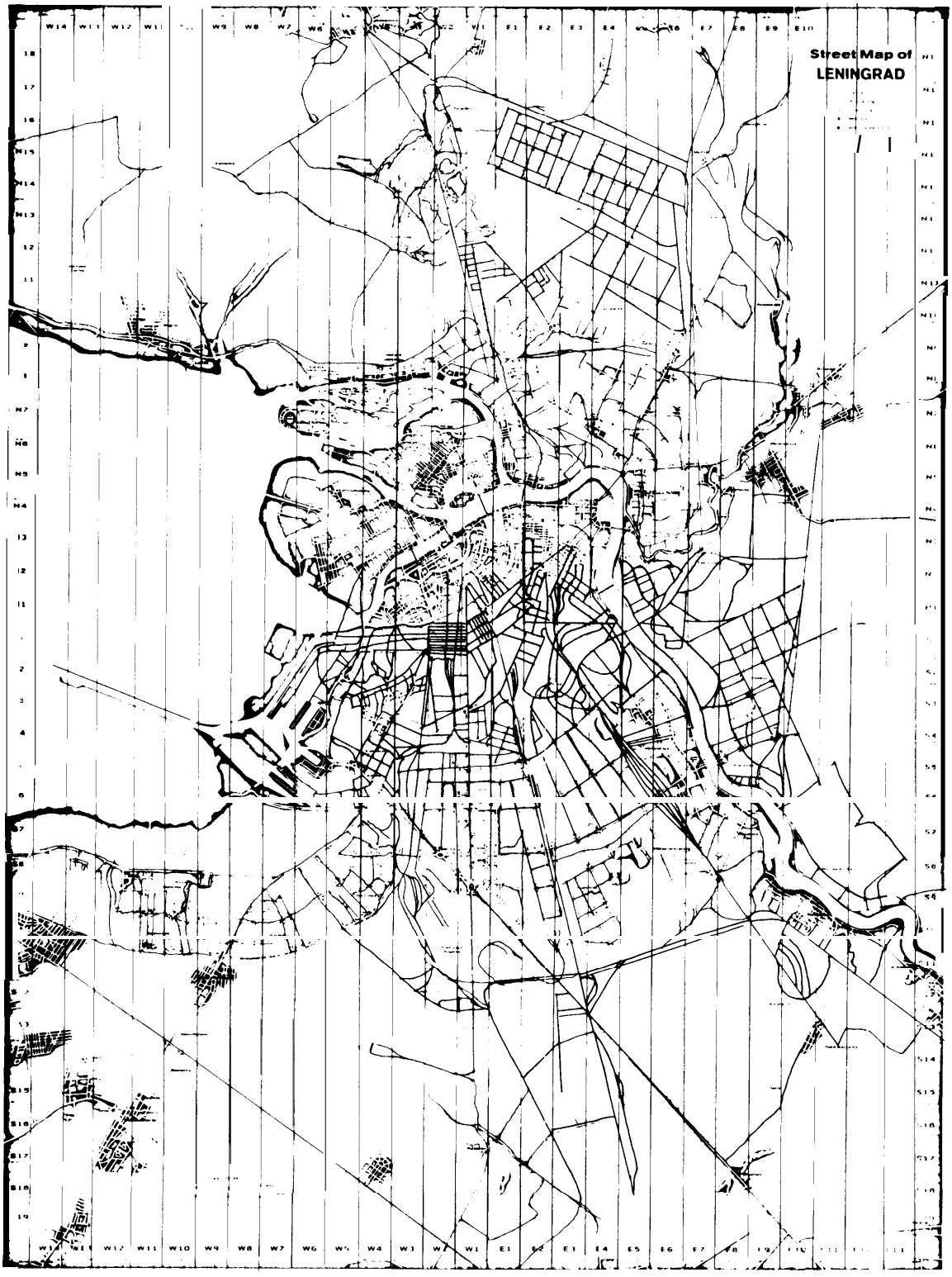


Figure 9.—Leningrad—Populated Area

40-407 O - 79 - 4

Figure 10.— Leningrad 1"Mt Air Burst

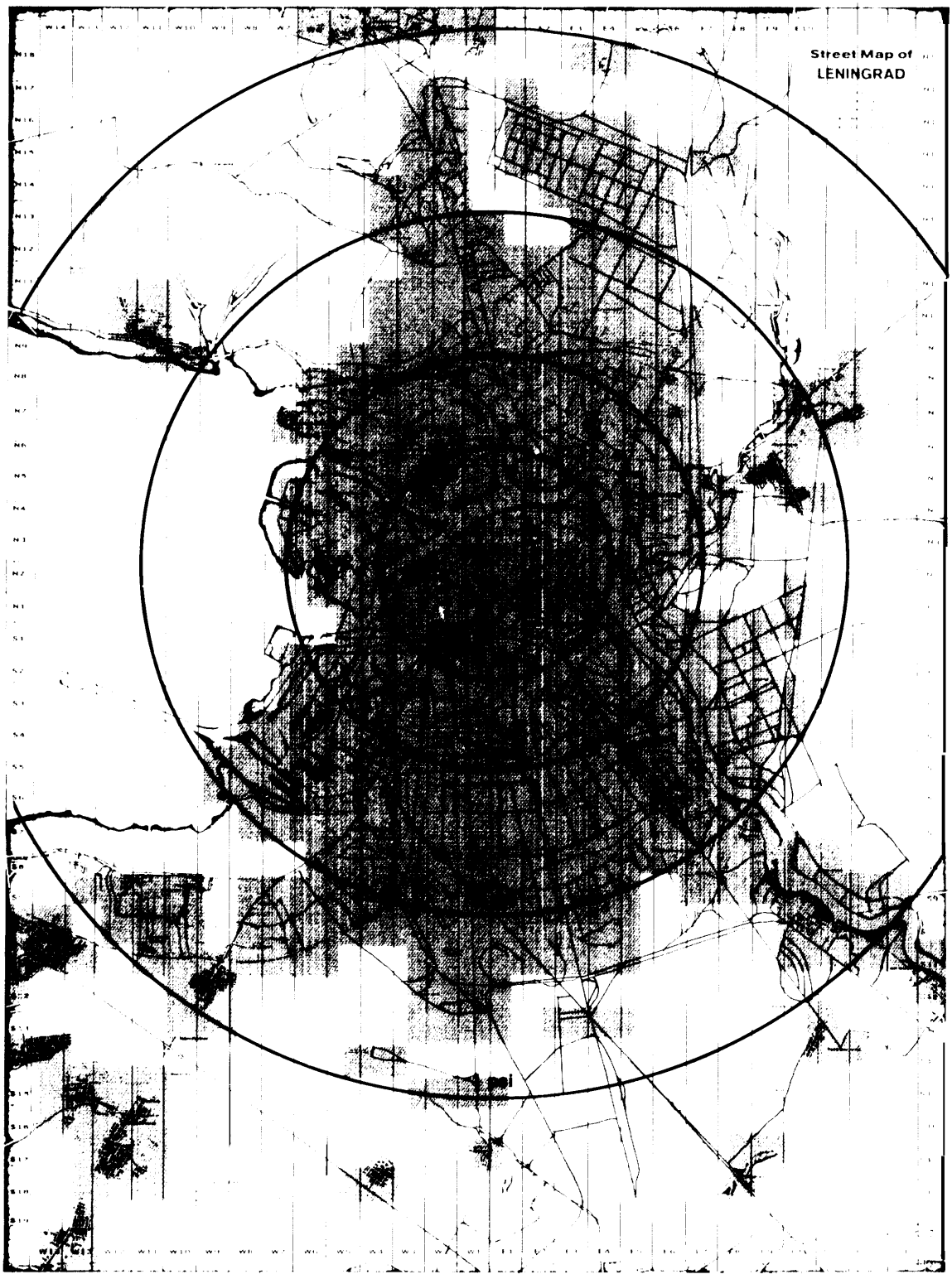


Figure 11 .—Leningrad 9-Mt Air Burst

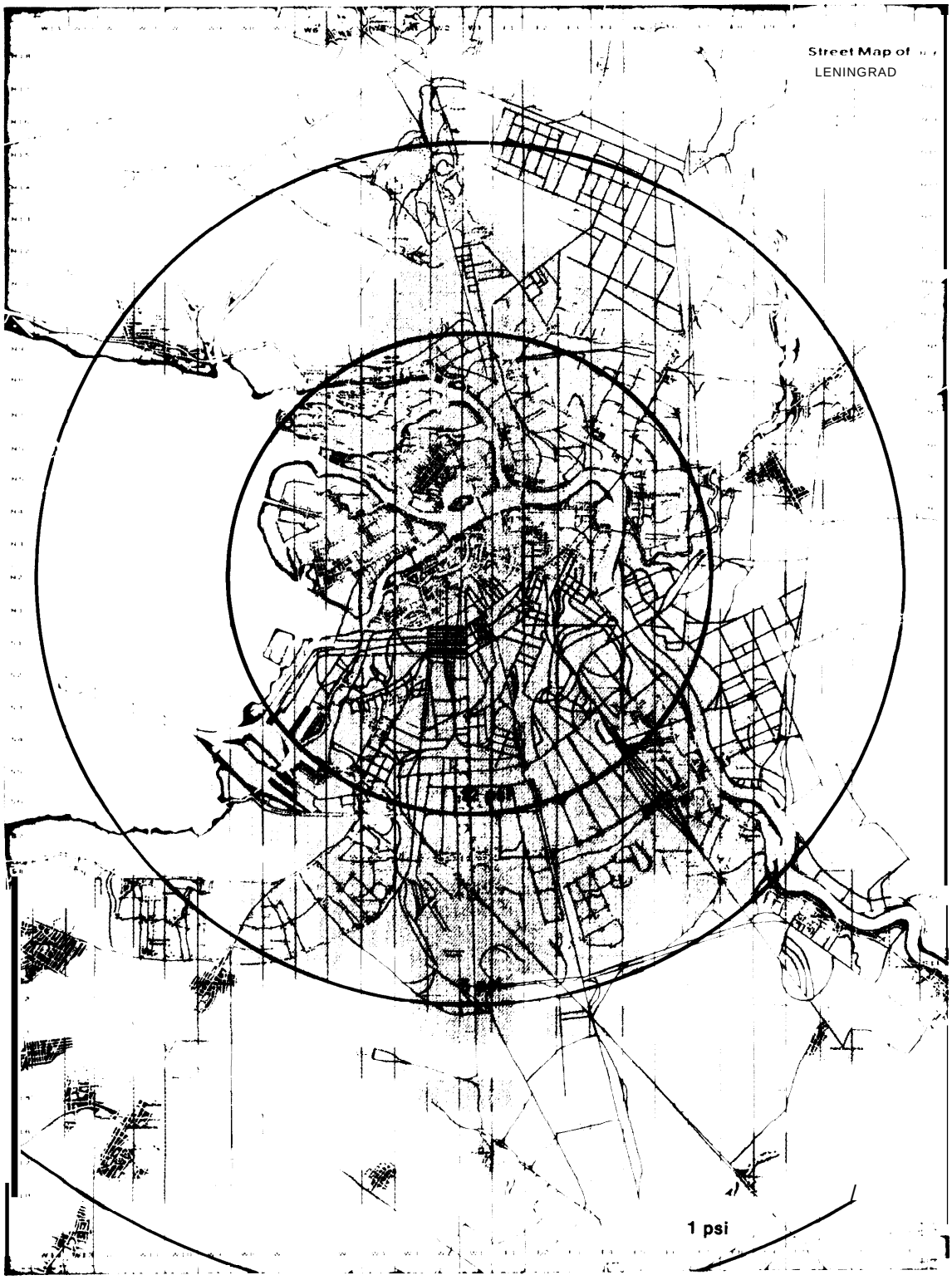
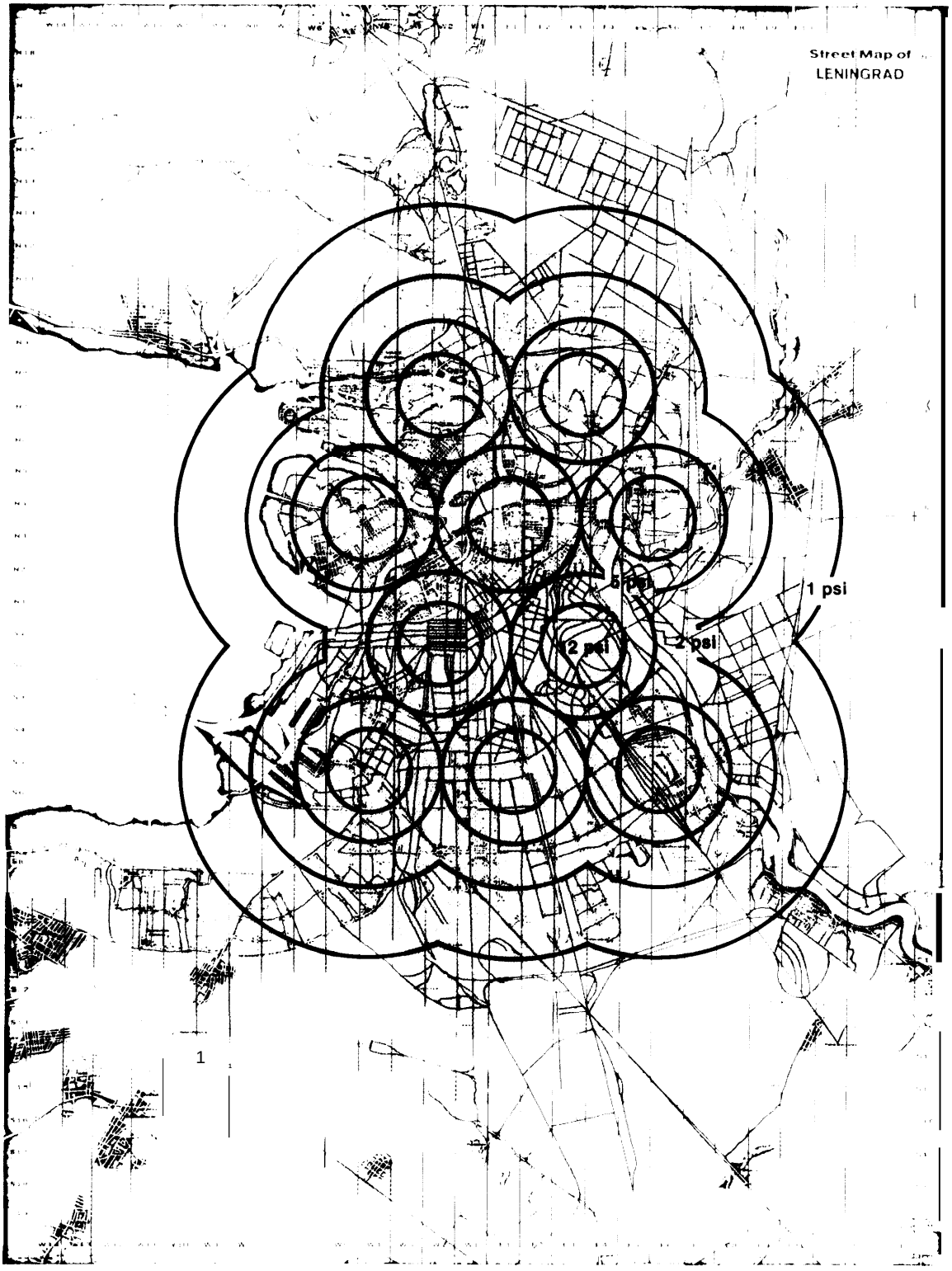


Figure 12.—Leningrad Ten 40-kt Air Burst



touching, and with only the envelope of the 2- and l-psi rings shown, Since this is an effects discussion only, it is assumed that this precise pattern can be achieved. The errors arising from neglecting the overlap of the 2- to 5-psi bands will be negligible compared to uncertainties in population distribution and structural design. Casualty estimates are shown in the right hand column of figure 6 (p. 37). Note that fatalities are only slightly greater than for the l-Mt case, which corresponds well to the equivalent megatonage (1.17 Mt) of the ten 40-kiloton (kt) weapons. However, the number of injured are considerably smaller because they primarily occur in the 2- to 5-psi band, which is much smaller for the 40-kt pattern than for the single 1-Mt case.

1-KT TERRORIST WEAPON AT GROUND LEVEL

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

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

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

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

*OTA report on “**Nuclear** Proliferation andi **Safeguards, ”** U S Government Printing **Office, June 1977, pp 111-12.2**

and down the street, while the majority of people will be protected by buildings. For the same reason directly initiated fires will be insignificant, but the problem of secondary fires starting from building damage will remain. The local fallout pattern also will be highly distorted by the presence of the buildings. The fireball, confined between the buildings, will be blown up to a higher altitude than otherwise expected, leading to reduced local fallout but causing broadly distributed long-term fallout.

In summary, the ranges of nuclear effects from a low-yield explosion in the confined space of an urban environment will differ significantly from large yield effects, but in ways that are very difficult to estimate. Thus the numbers of people and areas of buildings affected are very uncertain. However, it appears that, with the exception of streets directly exposed to the weapon, lethal ranges to people will be smaller than anticipated and dominated by the blast-induced CO I lapse of nearby buildings.

Chapter III

CIVIL DEFENSE

Chapter III.–CIVIL DEFENSE

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Chapter III

CIVIL DEFENSE

INTRODUCTION

Effective civil defense measures have the potential to reduce drastically casualties and economic damage in the short term, and to speed a nation's economic recovery in the long term. Civil defense seeks to preserve lives, economic capacity, postattack viability, and preattack institutions, authority, and values. The extent to which specific civil defense measures would succeed in doing so is controversial.

Some observers argue that U.S. **civil defense promotes deterrence by increasing the credibility of U.S. retaliation and by reducing any Soviet "destructive advantage" in a nuclear war. Others, however, argue that a vigorous civil defense program would induce people to believe that a nuclear war was "survivable" rather than "unthinkable," and that such a change in attitude would increase the risk of war.**

CIVIL DEFENSE MEASURES

Civil defense seeks to protect the population, protect industry, and improve the quality of postattack life, institutions, and values. This section considers several measures that support these goals.

Population Protection

People near potential targets must either seek protective shelter or evacuate from threatened areas to safer surroundings; if not at risk from immediate effects, they must still protect themselves from fallout. Both forms of protection depend on warning, shelter, supplies, life-support equipment (e. g., air filtration, toilets, communication devices), instruction, public health measures, and provision for rescue operations. I n addition, evacuation involves transportation, This section examines each form of protection.

Blast Shelters

Some structures, particularly those designed for the purpose, offer substantial protection against direct nuclear effects (blast, thermal radiation, ionizing radiation, and related effects such as induced fires). Since blast is usually the most difficult effect to protect against, such shelters are generally evaluated on blast resistance, and protection against other direct effects is assumed. Since most urban targets can be destroyed by an overpressure of 5 to 10 psi, a shelter providing protection against an overpressure of about 10 psi is called a blast shelter, although many blast shelters offer greater protection. Other shelters provide good protection against fallout, but little resistance to blast–such "fallout shelters" are disccused in the next section. Blast shelters generally protect against fallout, but best meet this purpose when they contain adequate life-support systems. (For example, a subway station without special provisions for water and ventilation would make a good blast shelter but a poor fallout shelter.)

Nuclear explosions produce "rings" of various overpressures. If the overpressure at a given spot is very low, a blast shelter is unnecessary; if the overpressure is *very* high (e. g., a direct hit with a surface burst), even the best blast shelters will fail. The "harder" the blast shelter (that is, the greater the overpressure it

can resist), the greater the area in which it could save its occupants' lives. Moreover, if the weapon height of burst (HOB) is chosen to maximize the area receiving 5 to 10 psi, only a very small area (or no area at all) receives more than 40 to 50 psi. Hence, to attack blast shelters of 40 to 50 psi (which is a reasonably attainable hardness), weapons must be detonated at a lower altitude, reducing the area over which buildings, factories, etc., are destroyed.

The costs of blast shelters depend on the degree of protection afforded and on whether the shelter is detached or is in a building constructed for other purposes. However, a large variation in costs occurs between shelters added to existing buildings and those built as part of new construction. The installation of shelters in new construction, or "slanting," is preferable, but it could take as long as 20 years for a national policy of slanting to provide adequate protection in cities.

An inexpensive way to protect population from blast is to use existing underground facilities such as subways, where people can be located for short periods for protection. If people must remain in shelters to escape fallout, then life-support measures requiring special preparation are needed.

Other lethal nuclear effects cannot be overlooked. Although, as noted above, blast shelters usually protect against prompt radiation, the shelters must be designed to ensure that this is the case.

Another problem is protection against fallout. If a sheltered population is to survive fallout, two things must be done. First, fallout must be prevented from infiltrating shelters through doors, ventilation, and other conduits. Other measures to prevent fallout from being tracked or carried into a shelter must also be taken. More important, the shelter must enable its occupants to stay inside as long as outside radiation remains dangerous; radiation doses are cumulative and a few brief exposures to outside fallout may be far more hazardous than constant exposure to a low level of radiation that might penetrate into a shelter.

Since radiation may remain dangerous for periods from a few days to several weeks, each shelter must be equipped to support its occupants for at least this time. Requirements include adequate stocks of food, water, and necessary medical supplies, sanitary facilities, and other appliances. Equipment for controlling tern perature, humidity, and "air quality" standards is also critical. With many people enclosed in an airtight shelter, temperatures, humidity, and carbon dioxide content increase, oxygen availability decreases, and fetid materials accumulate. Surface fires, naturally hot or humid weather, or crowded conditions may make things worse. If unregulated, slight increases in heat and humidity quickly lead to discomfort; substantial rises in temperature, humidity, and carbon dioxide over time could even cause death. Fires are also a threat to shelterers because of extreme tern peratures (possibly exceeding 2,000" F) and carbon monoxide and other noxious gases. A large fire might draw oxygen out of a shelter, suffocating shelterers. World War I I experience indicates that rubble heated by a firestorm may remain intolerably hot for several days after the fire is put out.

Fallout Shelters

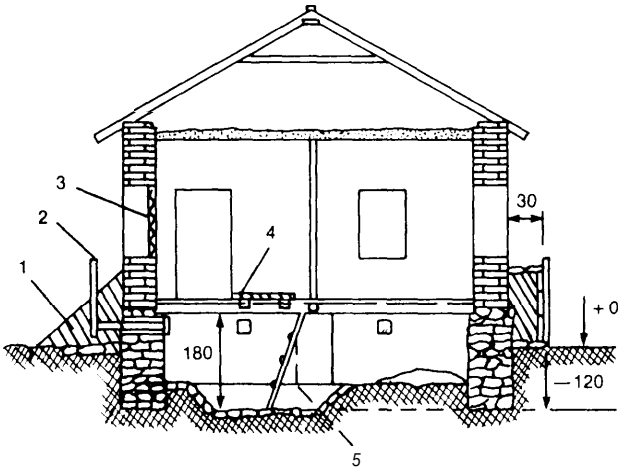
In the United States, fallout shelters have been identified predominantly in urban areas (by the Defense Civil Preparedness Agency (DCPA) shelter survey), to protect against fallout from distant explosions, e.g., a Soviet attack on U.S. intercontinental ballistic missiles (ICBMs). On the other hand, Soviet fallout shelters are primarily intended for the rural population and an evacuated urban population.

Fallout protection is relatively easy to achieve. Any shielding material reduces the radiation intensity. Different materials reduce the intensity by differing amounts. For example, the thickness (in inches) of various substances needed to reduce gamma radiation by a factor of 10 is: steel, 3.7; concrete, 12; earth, 18; water, 26; wood, 50. Consider an average home basement that provides a protection factor (PF) of 10 (reduces the inside level of radia-

tion to one-tenth of that outside). Without additional protection, a family sheltered here could still be exposed to dangerous levels of radiation over time. For example, after 7 days an accumulated dose of almost 400 reins inside the basement would occur if the radiation outside totaled 4,000 roentgens. This could be attenuated to a relatively safe accumulation of 40 reins, if about 18 inches of dirt could be piled against windows and exposed walls before the fallout begins. Thirty-six inches of dirt would reduce the dose to a negligible level of **4** reins **(400 - 100). Thus, as DCPA notes,** "fallout protection is as cheap as dirt. " Moving dry, unfrozen earth to increase the protection in a fallout shelter requires considerable time and effort, if done by hand. A cubic foot of earth weighs about 100 lbs; a cubic yard about 2,700 Ibs. Given time, adequate instructions, and the required materials, unskilled people can convert home basements into effective fallout shelters.

The overall effectiveness of fallout shelters, therefore, depends on: (a) having an adequate shelter—or enough time, information, and materials to build or improve an expedient shelter; (b) having sufficient food, water, and other supplies to enable shelterers to stay sheltered until the outside fallout decays to a safe level (they may need to remain in shelters for periods ranging from a few days to over 1 month, depending on fallout intensity); and (c) entering the shelter promptly before absorbing much radiation. (An individual caught by fallout before reaching shelter could have difficulty entering a shelter without contaminating it.)

Over the years, home fallout shelters have received considerable attention, with the Government distributing plans that could be used to make home basements better shelters. Such plans typically involve piling dirt against windows and (if possible) on floors above the shelter area, stocking provisions, obtaining radios and batteries, building makeshift toilets, and so forth. Such simple actions can substantially increase protection against radiation and may slightly improve protection against blast. However, few homes in the South and West have basements.



Basement of a stone house adapted for shelter: (1) earth embankment; (2) exhaust duct; (3) curtains on windows; (4) airtight hatch; (5) recessed pit. Material requirements: lumber, 0.5 m³; nails, 1 kg; earth, 3 to 5 m³; labor, 15 to 29 hours (man-hours).

With adequate time, instructions, and materials, an "expedient" shelter offering reasonable radiation protection can be constructed. This is a buried or semi buried structure, shielded from radiation by dirt and other common materials. Expedient shelter construction figures prominently in Soviet civil defense planning.

Evacuation

Evacuation is conceptually simple: people move from high-risk to low-risk areas. I n effect, evacuation (or crisis relocation) uses safe distances for protection from immediate nuclear effects. The effectiveness of crisis relocation is highly scenario-dependent. If relocated people have time to find or build shelters, if the areas into which people evacuate do not become new targets, and if evacuated targets are attacked, evacuation will save many lives.

Although evacuating is far less costly per capita than constructing blast shelters, planning and implementing an evacuation is difficult. First, people must be organized and transported to relocation areas. This is a staggering

logistics problem. Unless people are assigned to specific relocation areas, many areas could be overwhelmed with evacuees, causing severe health and safety problems. Unless private transportation is strictly controlled, monumental traffic jams could result. Unless adequate public transportation is provided, some people would be stranded in blast areas. Unless necessary supplies are at relocation areas, people might rebel against authority. Unless medical care is distributed among relocation areas, health problems would multiply.

Once evacuated, people must be sheltered. They might be assigned to existing public shelters or to private homes with basements suitable for shelter. If materials are available and time permits, new public shelters could be built. Evacuees require many of the same life-support functions described previously under fallout shelters; providing these in sufficient quantity would be difficult.

Evacuation entails many unknowns. The time available for evacuation is unknown, but extremely critical. People should be evacuated to areas that will receive little fallout, yet fallout deposition areas cannot be accurately predicted in advance. Crisis relocation could increase the perceived threat of nuclear war and this might destablize a crisis.

Whether people would obey an evacuation order depends on many factors, especially public perception of a deteriorating international crisis. If an evacuation were ordered and people were willing to comply with it, would time allow compliance? If the attack came while the evacuation is underway, more people might die than if evacuation had not been attempted. Sufficiency of warning depends on circumstances; a U.S. President might order an evacuation only if the Soviets had started one. In this case, the United States might have less evacuation time than the Soviets. The abundance of transportation in the United States could in theory permit faster evacuation, but panic, traffic jams, and inadequate planning could nullify this advantage. Disorder and panic, should they occur, would impede evacuation.

The success of evacuation in the United States would likely vary from region to region. Generally, evacuation requires little planning in sparsely populated areas. In some areas, especially the Midwest and South, evacuation is feasible but requires special planning because fallout from attacks on ICBMs might mean longer evacuation distances. Evacuation from the densely populated Boston-to-Washington and Sacramento-to-San Diego corridors, with their tens of millions of people and limited relocation areas, may prove impossible.

The Soviet Union reportedly has plans for large-scale evacuation of cities, and recent debate on its effectiveness has stimulated discussion of a similar plan, known as “crisis relocation”' for the United States. Some key considerations are:

- Tactical warning of a missile attack does not give enough time for an evacuation. Evacuation plans thus assume that an intense crisis will provide several days’ strategic warning of an attack, and that the leadership would make use of this warning.
- Unlike in-place blast sheltering, peacetime expenditures on evacuation are relatively small, since most expenditures occur only when a decision has been reached to implement plans.
- Evacuation involves considerably more preattack planning than a shelter-based civil defense plan, as logistical and other organizational requirements for moving millions of people in a few days are much more complex. Plans must be made to care for the relocated people. People must know where to go. Transportation or evacuation routes must be provided. A recent survey of the U.S. population revealed that many would spontaneously evacuate in a severe crisis, which could interfere with a planned evacuation.

Some U.S. analysts argue that detailed Soviet evacuation plans, together with evidence of practical evacuation preparations, indicate a reasonable evacuation capability, Others claim that actual Soviet capabilities

are far less than those suggested in official plans and that, in particular, an actual evacuation under crisis conditions would result in a mixture of evacuation according to plan for some, delay for others, and utter chaos in some places. In any case, a large evacuation has never been attempted by the United States. The extent of Soviet evacuation exercises is a matter of controversy.

Crisis relocation of large populations would have major economic impacts. These are the subject of a current DCPA study in which the Treasury, Federal Reserve Board, and Federal Preparedness Agency are participating. Results to date indicate that economic impacts of relocation, followed by crisis resolution and return of evacuees, could continue for 1 to 3 years, but that appropriate Government policies could significantly reduce such impacts. If blast shelters for key workers are built in risk areas, and if workers are willing to accept the risks, essential industries could be kept functioning while most people were in relocation areas. Such a program would substantially reduce the economic impacts of an extended crisis relocation.

Protection of Industry and Other Economic Resources

Efforts to preserve critical economic assets, and thereby accelerate postattack recovery, could take several forms. For example, if there is warning, railroad rolling stock might be moved from urban classification yards into rural locations, perhaps saving many cars and their cargo. Some industrial equipment and tooling might be protected by burial and sandbagging. Other industrial facilities, such as petroleum refineries and chemical plants, may be impossible to protect. Industrial defense measures include measures to make buildings or machinery more resistant to blast pressure (hardening), dispersal of individual sites and of mobile assets (e. g., transport, tools, equipment, fuel), proliferation of "redundant" and complementary capabilities, and plans to minimize disruption to an economy and its components in wartime by coordinated shutdown of industrial processes, speedy damage control, and plant repair.

There is no practicable way to protect an industrial facility that is targeted by a nuclear weapon with 1980's accuracy. Protective measures might, however, be helpful at industrial facilities that are not directly targeted, but that are near other targets.

Some equipment within structures can be protected against blast, fire, and debris with suitable measures. Other equipment, especially costly and critical equipment, and finished products, can be sheltered in semiburied structures and other protective facilities. A recent study' demonstrated that special hardening measures could save some machinery at blast overpressures higher than necessary to destroy the building in which the machinery is housed. However, it is unknown whether the amount of equipment that could actually be protected would make much difference in recovery.

Another method of protecting industrial capabilities is the maintenance of stock piles of critical equipment or of finished goods. Stockpiling will not provide a continuing output of the stockpiled goods, but could ensure the availability of critical items until their production could be restarted. Stockpiles can obviously be targeted if their locations are known, or might suffer damage if near other potential targets.

Finally, dispersal of industry, both within a given facility consisting of a number of buildings and between facilities, can decrease damage to buildings from weapons aimed at other buildings. A Soviet text on civil defense notes that:

> Measures may be taken nationally to limit the concentration of industry in certain regions. A rational and dispersed location of industries in the territories of our country is of great national economic importance, primarily from the standpoint of an accelerated economic development, but also from the stand-

'T. K. Jones, "Industrial Survival and Recovery After Nuclear Attack A Report to the Joint Committee on Defense Production, U S Congress" (Seattle, Wash The Boeing Aerospace Co , November 1976)

point of organizing protection from weapons of mass destruction.[2]

However, there is little evidence that the U.S.S.R. has adopted industrial dispersion as national policy. Despite reports of Soviet industrial decentralization over the last decade or so, Soviet industry appears more concentrated than ever. An excellent example is the Kama River truck and auto facility, a giant complex the size of Manhattan Island where about one-fifth of al I Soviet motor vehicles is produced. Clearly, Soviet planners have chosen industrial efficiency and economies of scale over civil defense considerations. Similarly, the United States has no directed policy of decentralization, and other facts suggest that nuclear war is not a significant civil planning determinant. There are those who reason that this "disregard" for many of the consequences of nuclear war indicates that policymakers betieve nuclear war is a very low possibility.

2P. T. E gorov, 1 A S hlyakov, and N. 1. A labin, *Civil Defense.* Translated by the Scientific Translation Service (Springfield, Va : Department of Commerce, National Technical Information Service, December 1973), p 101.

Planning for Postattack Activities

The economic and social problems following a nuclear attack cannot be foreseen clearly enough to permit drafting of detailed recovery plans. In contrast, plans can be made to preserve the continuity of government, and both the United States and the Soviet Union surely have such plans.

U.S. AND SOVIET CIVIL DEFENSE

U.S. Civil Defense

U.S. attitudes have been ambivalent toward civil defense ever since the Federal Civil Defense Act of 1950 responded to the first Soviet test of atomic bombs in 1949. Indeed, much of the U.S. civil defense was a reaction to external factors rather than part of a carefully-thought-through program. The "duck and cover" program and the evacuation route program, both of the early 1950's, responded to the threat of Soviet atomic bombs carried by manned bombers. Lack of suitable protection against fire and blast led to plans for rapid evacuation of cities during the several hours separating radar warning and the arrival of Soviet bombers.

The first Soviet test of thermonuclear weapons in 1953 necessitated changes in these plans. The much higher yield of these weapons meant that short-distance evacuations and modestly hard blast shelters in cities were ineffective for protecting people, and that simply "ducking" in school corridors, while perhaps better than nothing, was not part of a serious civil defense plan. H-bombs also raised the specter of radioactive fallout blanketing large areas of the country. Previously, civil defense could be conceptualized as moving people a short distance out of cities, while the rest of the country would be unscathed and able to help the target cities. Fallout meant that large areas of the country—the location of which was unpredictable— would become contaminated, people would be forced to take shelter in those areas, and their inhabitants, thus pinned down, would be unable to offer much help to attacked cities for several weeks.

The advent of ICBMs necessitated further changes. Their drastically reduced warning times precluded evacuations on radar warning of attack.

With previous plans made useless by advances in weapons technology, the United States cast around for alternative plans. One approach was to identify and stock fallout shelters, while recognizing the impracticability of protecting people from blast. After the Berlin crisis of 1961, the President initiated a program to provide fallout shelters for the entire population. The National Shelter Survey

Program was commenced on a crash basis. The President proposed:

1. the survey, identification, and stocking of existing shelters;
2. the subsidization of fallout shelter installation in new construction; and
3. the construction of single-purpose fallout shelters where these were needed.

Only the first step in this program was authorized. The Government also urged people to build home fallout shelters.

The civil defense program was broadened in the early 1970's to include preparedness for peacetime as well as wartime disasters. The 1970's also saw a new emphasis on operational capabilities of al I available assets, including warning systems, shelters, radiological detection instruments and trained personnel, police and fire-fighting forces, doctors and hospitals, and experienced management. This development program was called On-Site Assistance.

I n the mid-1970's, contingency planning to evacuate city and other high-risk populations during a period of severe crisis was initiated.

At present, U.S. civil defense has the following plans and capabilities:

Organization. – The Federal civil defense function has been repeatedly reorganized since the Federal **Civil** Defense **Act** of 1950. The most recent organization gave prime responsibility for civil defense to the Defense Civil Preparedness Agency (DCPA), housed in the Defense Department. The Federal Preparedness Agency (FPA) in the General Services Administration conducts some planning for peacetime nuclear emergencies, economic crises, continuity of Government following a nuclear attack, and other emergencies. The Federal Disaster Assistance Administration (FDAA), in the Department of Housing and Urban Development, is concerned with peacetime disaster response. In 1978, Congress assented to a Presidential proposal to reorganize civil defense and peacetime disaster functions into a single agency, the Federal Emergency Management Agency, which will incorporate DC PA, FPA, FDAA, and other agencies.

Civil Protection. -The United States is looking increasingly at crisis relocation (CR), under which city-dwellers would move to rural "host" areas when an attack appeared likely. CR would require several days of warning, so it would be carried out during a crisis rather than on radar warning of missile launch. The United States has conducted surveys to identify potential fallout shelters in host areas, and blast and fallout shelters in risk areas. Through FY 1971, about 118,000 buildings had been marked as shelters; about 95,000 other buildings have been identified as potential shelters but have not been marked. Marking would be done in crises. In the early 1960's, the Federal Government purchased austere survival supplies for shelters. The shelf life of these supplies has expired; shelter stocking is now to be accomplished during a crisis.

Direction and Control.–The Federal Government has several teletype, voice, and radio systems for communicating in crises between DCPA, FDAA, and FPA headquarters, regional offices, States, and Canada. State and local governments are planning to integrate communication systems into this net. DCPA has eight regions, each with emergency operating centers (EOCs). Six of these centers are hardened against nuclear blast. Forty-three States have EOCs, and EOCs with fallout protection are operational or under development in locales including about half the population.

Attack Warning.–Warning can be passed over the National Warning System to over 1,200 Federal, State, and local warning points, which operate 24 hours a day. Once warning has reached local levels, it is passed to the public by sirens or other means. Almost half of the U.S. population is in areas that could receive outdoor warning within 15 minutes of the issue of a national warning. Dissemination of warning to the public, however, is inadequate in many places.

Emergency Public Information.–Fallout protection, emergency power generators, and remote units have been provided for radio stations in the Emergency Broadcast System, to

permit broadcast of emergency information under fallout conditions. About a third of the stations are in high-risk areas and could be destroyed by blast. A program has been initiated to protect 180 stations from electromagnetic pulse (EM P). About one-third of the more than 5,000 localities participating in the civil defense program have reported development of plans to provide the public with information in emergencies.

Radiological Defense. — This function encompasses radiological detection instruments, communication, plans and procedures, and personnel trained to detect and evaluate radiological hazards. Between FY 1955-74, the Federal Government had procured about 1.4 million rate meters, 3.4 million dose meters, and related equipment. Effective radiological defense would require an estimated 2.4 million people to be trained as radiological monitors in a crisis.

Citizen Training.–The civil defense program once provided substantial training for the public via news media must now be relied on to educate citizens on hazards and survival actions. DCPA offers classroom and home study training for civil defense personnel.

Several points emerge from this discussion:

1. On paper, civil defense looks effective. The United States has more than enough identified fallout shelter spaces for the entire population, which include underground parking, subways, tunnels, and deep basement potential blast shelters. The United States has a vast network of highways and vehicles; every holiday weekend sees a substantial urban evacuation. CB and other radios can aid communication after an attack. The United States has enormous resources (food, medical supplies, electrical-generating capability, etc.) beyond the minimum needed for survival.
2. However, no one at all thinks that the United States has an effective civil defense.
3. U.S. civil defense capability is weakened because some elements are in place while others are not or have not been maintained. Shelters will not support life if their occupants have no water. Evacuation plans will save fewer people if host areas have inadequate shelter spaces and supplies, or if people are poorly distributed among towns.
4. Faced with drastic technological change, moral and philosophical questions about the desirability of civil defense, and budgetary constraints, Federal plans have been marked by vacillation, shifts in direction, and endless reorganization.

Soviet Civil Defense

Soviet civil defense has faced the same technical challenges as the United States — atomic bombs, hydrogen bombs fallout, ICBMs, limited warning, and so on. The Soviet Union has consistently devoted more resources to civil defense than has the United States, and has been more willing to make and follow long-term plans. However, it is not known how Soviet leaders evaluate the effectiveness of their civil defense.

The Soviet civil defense organization is a part of the Ministry of Defense and is headed by Deputy Minister Colonel-General A. Altunin. Permanent full-time staff of the organ i-zaiion is believed to number over 100,000. Some civil defense training is compulsory for all Soviet citizens, and many also study first aid. There has also been a large shelter-building program.

The Soviets reportedly have an extensive urban evacuation plan. Each urban resident is assigned to a specific evacuation area, located on COIlective farms; each farmer has instructions and a list of the people he is to receive. If fallout protection is not available, it is planned that simple expedient shelters would be constructed quickly. Soviet plans recommend that shelters be located at least 40 km [25 miles] from the city district to provide sufficient protection against the effects of a l-Mt weapon

exploding at a distance of 10 to 20 km [6 to 12 miles].

In July *1978,* the Central Intelligence Agency (CIA) released its unclassified study, "Soviet Civil Defense. "3 In brief, the report finds that Soviet civil defense is "an ongoing nationwide program under military control. " It notes several motivations for the Soviet program: the traditional Soviet emphasis on homeland defense, to convince potential adversaries they cannot defeat the Soviet Union, to increase Soviet strength should war occur, to help maintain the logistics base for continuing a war effort following nuclear attack, to save people and resources, and to promote postattack recovery. It observes that Sov'iet civil defense "is not a crash effort, but its pace increased beginning in the late 1960' s." It points to several difficulties with the Soviet program: bureaucratic problems, apathy, little protection of economic installations, and little dispersal of industry.

According to the report, the specific goals of Soviet civil defense are to protect the leadership, essential workers, and others, in that priority order; to protect productivity; and to sustain people and prepare for economic recovery following an attack. In assessing Soviet efforts to meet these goals, the CIA found:

> The Soviets probably have sufficient blast-shelter space in hardened command posts for virtually all the leadership elements at al l levels (about 110,000 people) Shelters at key economic installations could accommodate about 12 to 24 percent of the total work f o r c e
>
> A minimum of 10 to 20 percent of the total population in urban areas (including essential workers) could be accommodated at present in blast-resistant shelters
>
> The critical decision to be made by the Soviet leaders in terms of sparing the population would be whether or not to evacuate cities. Only by evacuating the bulk of the urban population could they hope to achieve a marked reduction in the number of urban casualties. An evacuation of urban areas could probably be accomplished in two or three days, with as much as a week required for full evacuation of the largest cities
>
> Soviet measures to protect the economy could not prevent massive industrial dam-a g e
>
> (Regarding postattack recovery), the coordination of requirements with available supplies and transportation is a complex problem for Soviet planners even in peacetime, let alone following a large-scale nuclear attack

Assessing the effectiveness of Soviet civil defense, the CIA study found that a worst case attack could kill or injure well over 100 mill ion people, but many leaders would survive; with a few days for evacuation and shelter, casualties could be reduced by more than 50 percent; and with a week for preattack planning, "Soviet civil defenses could reduce casualties to the low tens of millions. "

The U.S. Arms Control and Disarmament Agency (AC DA) released "An Analysis of Civil Defense in Nuclear War" in December 1978.[4] This study concluded that Soviet civil defense could do little to mitigate the effects of a major attack. Blast shelters might reduce fatalities to 80 percent of those in an unsheltered case, but this could be offset by targeting additional weapons (e. g., those on bombers and submarines that would be alerted during a crisis) against cities. Evacuation might reduce fatalities to a range of 25 million to 35 million, but if the United States were to target the evacuated population, some 50 million might be killed. Furthermore, civil defense could do little to protect the Soviet economy, so many evacuees and millions of injured could not be supported after the attack ended.

The sharp disagreement about Soviet civil defense capability revolves around several key issues:

Can **the Soviets follow their stated civil defense plans?** Some believe that the Soviets would fill their urban blast shelters to maximum occupancy rather than leave unevaluated people without protection and would evacuate all persons for whom no urban shelter spaces

[3] *Soviet* **Civil** *Defense* (Washington, D C Director **of Central Intelligence, July 1978), the text quotation below is from** pp *2-3*

[4] "An Analysis **of** Civil **Defense** in **Nuclear War"** (Washington, **D C U S. Arms Control and Disarmament Agency, December 1978)**

were available. Others believe that administrative confusion and other difficulties might render the Soviets far more vulnerable in practice.

How widely would evacuees be dispersed? It is obvious that the more widely dispersed an urban population is, the fewer casualties an attack on cities will produce. It is equally obvious that the more time there is for an evacuation, the more widely people can disperse. Nevertheless, there is great uncertainty over how well an evacuation would perform in practice. A Boeing study estimates that if urban dwellers walked for a day away from the cities, the population of cities would be more or less distributed over a circle of radius 30 miles [48.3 km].[5] If they did not dig shelters, a U.S. attack would kill about **27 percent of the Soviet population; if they dug expedient shelters, the attack would** kill about 4 percent. If the Soviets fully implemented their evacuation plans but the evacuees were not protected from fallout, then 8 percent of the total population would die; if they constructed hasty shelters, 2 percent would die. AC DA, however, argues that even if the Soviet Union is totally successful in implementing its evacuation, the United States could, if the objective is to kill people, use its reserve weapons against the evacuated population and ground burst its weapons, thus inflicting from **70 million to 85 million** fatalities.

How well would evacuees be protected from fallout? Some believe that Soviet evacuees could be fully protected against very high radiation levels if they are allowed a 1- to **2-week preattack** "surge" period. (Tests conducted by the Oak Ridge National Laboratory have shown, for example, that American families can construct adequate fallout shelters in 24 to 36 hours, if they are issued the necessary tools and instructions.)[6] The ACDA study assumes that from one-third to two-thirds of the evacuees would have little protection against fallout. The two cases are not necessarily exclusive, since the ability to dig in depends on assumptions, especially time available for preparations before an attack. Some assume a lengthy and deepening crisis would precede nuclear strikes. Others believe that error or miscalculation would lead to nuclear war, leaving the United States or the Soviet Union unprepared and not having ordered evacuation. I n addition, should an attack occur when the earth is frozen or muddy, construction of expedient shelters would be difficult.

How effective is Soviet industrial hardening? Soviet civil defense manuals provide instructions for the last-minute hardening of key industrial equipment in order to protect it from blast, falling debris, and fires. A considerable controversy has developed in the United States as to how effective such a program would be. The Boeing Company and the Defense Nuclear Agency carried out a number of tests that led them to conclude that "techniques similar to those described in Soviet Civil Defense manuals for protecting industrial equipment appear to hold great promise for permitting early repair of industrial machinery and its restoration to production.'" Others have challenged this conclusion: for example, the ACDA civil defense study concluded that "attempts to harden above-ground facilities are a futile exercise, and that even buried facilities which are targeted cannot survive. "

To understand this issue, one must recognize that it is virtually impossible to harden an economic asset so that it would survive if it were directly targeted. By lowering the height of burst, the maximum overpressure can be increased (at a small sacrifice to the area covered by moderate overpressures), and even missile silos can be destroyed by sufficiently accurate weapons. However, many economic targets are relatively close together (for example, separate buildings in a single factory), and it is possible and efficient to aim a single

5, K. Jones, "Effect of Evacuation and Sheltering on Potential Fatalities From a Nuclear Exchange" (Seattle, Wash.: The Boeing Aerospace Co., 1977),

6, J Condie, et al , "Feasibility of Citizen Construction of Expedient Fallout Shelters" (Oak Ridge, Term,: Oak Ridge National Laboratory, August 1978), See also R. W. Kindig, "Field Testing and Evaluation of Expedient Shelters" (Denver, Colo.: University of Colorado, February 1978)

7 Edwin N. York, *Industrial Survival/Recovery* (Seattle, Wash.: The Boeing Aerospace Co., undated).

weapon so that it destroys a number of targets at once. If each target is adequately hardened, then the attacker must either increase the number or yield of weapons used, or else accept less damage to the lower priority targets, However, the practicability of hardening entire installations to this extent is questionable, and the more likely measure would be to harden key pieces of machinery, The uncertainties about the Soviet program include the following:

- How much hardening could be done in the days before an attack?
- Would the United States target additional or larger weapons to overcome the effects of hardening?
- To what extent would the survival of the most important pieces of machinery in the less important Soviet factories contribute to economic recovery?

CONCLUDING NOTE

These pages have provided a brief description of civil defense as it might affect the impact of nuclear war. However, no effort has been made to answer the following key questions:

- Would a civil defense program on a large scale make a big difference, or only a marginal difference, in the impact of a nuclear war on civil society?
- What impact would various kinds of civil defense measures have on peacetime diplomacy or crisis stability?
- What civil defense measures would be appropriate if nuclear war were considered likely in the next few years?
- What kind and size of civil defense program might be worth the money it would cost?

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THREE ATTACK CASES

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Chapter IV

THREE ATTACK CASES

OVERVIEW

The following pages present descriptions of three '*cases" of nuclear attacks. (The tutorial on nuclear effects–chapter H-was the first of our four cases.) As mentioned in the *Executive Summary,* these cases do not necessarily represent "probable" kinds of nuclear attacks; they were chosen rather to shed light on the way in which different types of attacks could have differing effects on the civilian population, economy, and society. Moreover, each case is considered in isolation—events that could lead up to such an attack are deliberately ignored (because their prediction is impossible), and it is assumed (although that assumption is questionable at best) that the attack described is not followed by further nuclear attacks.

Each case considers first a Soviet attack on the United States, and then a U.S. attack on the Soviet Union. These attacks are similar in that they attack similar target sets, but different in detail because both the weapons available to the attacker and the geography of the victim are different. It should be emphasized that this discussion is not suggesting that in the real world an attack would be followed by a mirror-image retaliation; rather, it is looking at similar attacks so as to highlight the asymmetries in the ways in which the United States and the Soviet Union are vulnerable. To save space, it is assumed that the reader will read the Soviet attack on the United States in each case before turning to the U.S. attack on the Soviet Union, and repetition has been minimized.

The analyses that follow are much more like sketches than detailed portraits. Precise prediction of the future of the United States or the Soviet Union is impossible even without taking into account something as unprecedented as a nuclear attack. A detailed study would say more about the assumptions used than about the impact of nuclear war. What is possible, and what this report tries to do, is to indicate the kinds of effects that would probably be most significant, and to comment on the major uncertainties.

The following pages discuss the impact on civil i an societies of:

- A limited attack on industrial targets. For this case the hypothesis was an attack that would be limited to 10 strategic nuclear delivery vehicles (S NDVs) (i. e., 10 missiles or bombers, in this case Soviet SS-18 intercontinental ballistic missiles (I CBMs), and U.S. Poseidon submarine-launched ballistic missiles (SLBMs), and Minuteman Ill ICBMs), and that would be directed at the oil refining industry. Oil refining was chosen as the hypothetical target because it is vital, vulnerable, and concentrated in both countries. It is assumed that the attack would be planned without any effort either to minimize or to maximize civilian casualties.
- A large counterforce attack. The possibilities considered included both an attack on ICBM silos only (a case that has gained some notoriety as a result of assertions by some that the United States may become vulnerable to such an attack) and an attack on silos, missile submarine bases, and bomber bases (which some characterize

as the least irrational way to wage a strategic nuclear war). The analysis draws on several previous studies that made 'varying assumptions about attack design, weapon size, targets attacked, and vulnerability of the population; the ways in which variations in these assumptions affect the calculations of estimated fatalities are discussed.

- A large attack against a range of military and economic targets. This attack is intended to approximate "the ultimate deterrent''—the climax of an escalation process. The description of the results of this attack draws upon several previous studies that made differing assumptions about the number of weapons used and the precise choice of targets, but such variations are useful in indicating the range of possibilities. However, deliberate efforts to kill as many people as possible are not assumed, which would lead to more immediate deaths (perhaps 10 million to 20 million more) than targeting economic and military facilities.

CASE 2: A SOVIET ATTACK ON U.S. OIL REFINERIES

This case is representative of a kind of nuclear attack that, as far as we know, has not been studied elsewhere in recent years–a "limited" attack on economic targets. This section investigates what might happen if the Soviet Union attempted to inflict as much economic damage as possible with an attack limited to 10 SNDVs, in this case 10 SS-18 ICBMs carrying multiple independently targetable reentry vehicles (MlRVs). An OTA contractor designed such an attack, operating on instructions to limit the attack to 10 missiles, to create hypothetical economic damage that would take a very long time to repair, and to design the attack without any effort either to maximize or to minimize human casualties. (The contractor's report is available separately.) The Department of Defense then calculated the immediate results of this hypothetical attack, using the same data base, methodology, and assumptions as they use for their own studies. *

Given the limitation of 10 ICBMs, the most vulnerable element of the U.S. economy was judged to be the energy supply system. As table 6 indicates, the number of components in the U.S. energy system forces the selection of a system subset that is critical, vulnerable to a small attack, and would require a long time to repair or replace.

OTA and the contractor jointly determined that petroleum refining facilities most nearly met these criteria. The United States has about 300 major refineries. Moreover, refineries are relatively vulnerable to damage from nuclear blasts. The key production components are the distillation units, cracking units, cooling towers, power house, and boiler plant. Fractionating towers, the most vulnerable components of the distillation and cracking units, collapse and overturn at relatively low winds and overpressures. Storage tanks can be I if ted from their foundations by similar effects, suffering severe damage and loss of contents and raising the probabilities of secondary fires and explosions.

MlRVed missiles are used to maximize damage per missile. The attack uses eight l-megaton (Mt) warheads on each of 10 SS-18 ICBMs, which is believed to be a reasonable choice given the hypothetical objective of the attack. Like all MIRVed missiles, the SS-18 has limitations of "footprint"–the area within which the warheads from a single missile can be aimed. Thus, the Soviets could strike not any 80 refineries but only 8 targets in each of 10 footprints of roughly 125,000 mi^2 [32,375,000

***The Office of Technology Assessment wishes to thank the Defense Civil Preparedness Agency for their timely and responsive help in calculations related to this case, the Command and Control Technical Center performed similar calculations regarding a similar U S attack on the Soviet Union**

Table 6.—Energy Production and Distribution Components

Category	Prime sources	Numbers	Processing	Numbers	Distribution
Oil	Wells	Thousands	Refineries	Tens/hundreds (tend to be clustered)	Pipelines/rail/truck/barge/ship
	Ports (imports)	Tens			
	Pipelines (imports)				
Gas	Wells	Thousands	Gas plants	Tens/hundreds	Pipelines/rail/truck/barge/ship
	Oil refineries	Hundreds			
	Ports (imports)	Tens	Deliquification plants	Tens	
	Pipelines (imports)	Tens			
Coal	Mines	Hundreds	Usually at mines	Hundreds	Rail/truck/barge/coal slurry pipelines
Electric power production	Hydroelectric	Tens	Same as prime source		Powerlines/power grids
	Thermal	Hundreds			
	Nuclear power	Tens			
	Power grids (imports)	Units			

SOURCES: *Vulnerability of Total Petroleum Systems* (Washington, D.C.: Department of the Interior, Office of Oil and Gas), May 1973, prepared for the Defense Civil Preparedness Agency.
National Energy Outlook 1976 (Washington, D.C.: Federal Energy Administration, February 1976

hectares], The SS-18's footprint size, and the tendency of U.S. refineries to be located in clusters near major cities, however, make the SS-18 appropriate. The footprints are shown in figure 13. Table 7 lists U.S. refineries by capacity; and table 8 lists the percentage of U.S. refining capacity destroyed for each footprint.

The attack uses eighty l-Mt weapons; it strikes the 77 refineries having the largest capacity, and uses the 3 remaining warheads as second weapons on the largest refineries in the appropriate missile footprints, In performing these calculations, each weapon that detonates over a refinery is assumed to destroy its target. This assumption is reasonable in view of the vulnerability of refineries and the fact that a l-Mt weapon produces 5-psi overpressure out to about 4.3 miles [6.9 km]. Thus, damage to refineries is mainly a function of numbers of weapons, not their yield or accuracy; collateral damage, however, is affected by all three factors. it is also assumed that every warhead detonates over its target. In the real world, some weapons would not explode or would be off course. The Soviets could, however, compensate for failures of launch vehicles by readying more than 10 ICBMs for the attack and programming missiles to replace any failures in the initial 10. Finally, all weapons are assumed detonated at an altitude that would maximize the area receiving an overpressure of at least 5 psi. This overpressure was selected as reasonable to destroy refineries. Consequences of using ground bursts are noted where relevant.

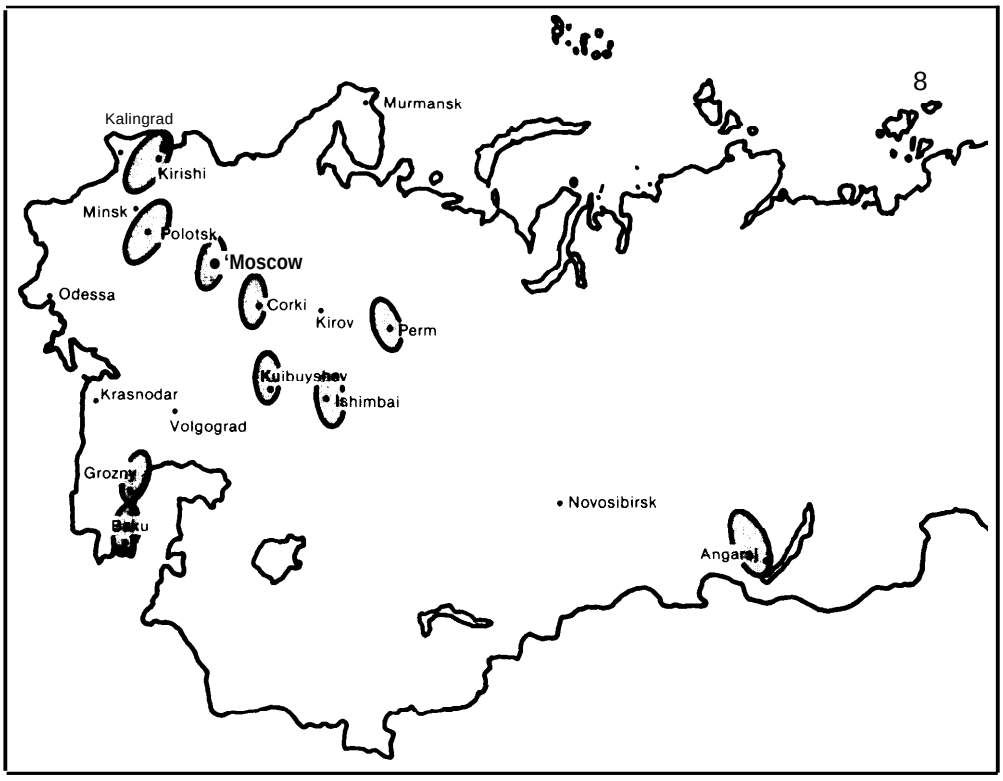
The First Hour: Immediate Effects

The attack succeeds. The 80 weapons destroy 64 percent of U.S. petroleum refining capacity.

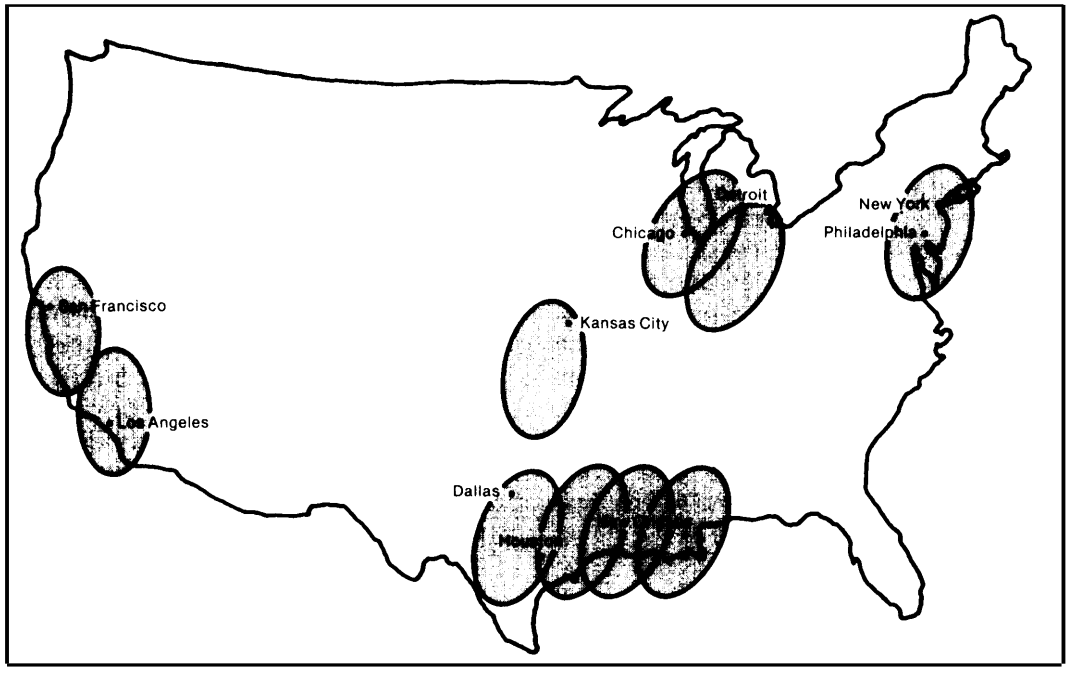
The attack causes much collateral (i. e., unintended) damage. Its only goal was to maximize economic recovery time. While it does not seek to kill people, it does not seek to avoid doing so. Because of the high-yield weapons and the proximity of the refineries to large cities, the attack kills over 5 million people if all weapons are air burst. Because no fireball would touch the ground, this attack would produce little fallout. If all weapons were ground burst, 2,883,000 fatalities and 312,000 fallout fatalities are calculated for a total of 3,195,000. Table 8 lists fatalities by footprint.

The Defense Civil Preparedness Agency (DC PA) provided fatality estimates for this attack. DCPA used the following assumptions re-

Figure 13



Approximate footprint coverage of U.S. attack



Approximate footprint coverage of Soviet attack

Table 7.–U.S. Refinery Locations and Refining Capacity by Rank Order

Rank order	Location	Percent capacity	Cumulative percent capacity	Rank order	Location	Percent capacity	Cumulative percent capacity
1	Baytown, Tex.	3.6	3,6	34		0 7	47,9
2	Baton Rouge, La.	2.9	6.4	35		0 7	48,6
3	El Segundo, Calif.	2.3	8.7	36		0 7	49.3
4	Whiting, Ind.	2,1	10.8	37		0 7	50.0
5	Port Arthur, Tex.	2.1	12,9	38		0.7	5 0 6
6	Richmond, Calif.	2,0	14,9	39		0 7	51.3
7	Texas City, Tex.	2,0	16,9	40		0.6	51.9
8	Beaumont, Tex.	1,9	18,8	41		0 6	52,5
9	Port Arthur, Tex.	1 9	20.7	42		0 6	531
10	Houston, Tex.	1.8	22.5	43		0.6	5 3 7
11	Linden, N.J.	1.6	24,1	44		0 6	5 4 3
12	Deer Park, Tex.	1.6	25.7	45		0 6	5 4 9
13	Wood River, Ill.	1,5	27,3	46		0 5	5 5 4
14	Pasagoula, Miss.	1.6	28,9	47		0.5	5 5 9
15	Norco, La.	1.3	30.1	48		0.5	56,5
16	Philadelphia, Pa.	1,2	31.3	49		0.5	57.0
17	Garyville, La.	1.1	32.4	50		0 5	57.5
18	Belle Chasse, La.	1.1	33.5	51		0 5	58.0
19	Robinson, Tex.	1.1	34.6	52		0 5	5 8 5
20	Corpus Christi, Tex.	1.0	3 5 7	53		0 5	59,0
21	Philadelphia, Pa.	1 0	36.7	54		0 5	5 9 5
22	Joliett, Ill.	1 0	37.7	55		0 5	6 0 0
23	Carson, Calif.	1 0	38.7	56		0.5	60.4
24	Lima, Ohio	0.9	39.6	57		0.5	6 0 9
25	Perth Amboy, N.J.	0.9	40,6	58		0 4	6 1 3
26	Marcus Hook, Pa.	0 9	41,5	59		0 4	61 7
27	Marcus Hook, Pa.	0 9	4 2 4	60		0.4	6 2 2
28	Corpus Christi, Tex.	0.9	4 3 3	61		4 1	66.3
29	Lemont, Tex.	0 8	44,1	62		1,6	6 7 9
30	Convent, La.	0.8	4 4 9	63		0 5	68.4
31	Delaware City, Del.	0 8	4 5 7	64		0 3	68.7
32	Cattletsburg, Ky.	0.8	46,5	65		3 1 3	1000
33	Ponca City, Okla.	0 7	47.2				

[a]Sum of all refineries m the indicated geographic area
[b]Foreign trade zone only
[c]Includes summary data from all refineries with capacity less than 75000 bbl/day 224 refineries included
SOURCE National Petroleum Refiners Association

Table 8. –Summary of U.S.S.R. Attack on the United States

Footprint number	Geographic area	EMT[a]	Percent national refining capacity	Percent national storage capacity	Air burst prompt fatalities (x 1,000)
1	Texas	8	14.9	NA[b]	472
2	Indiana, Illinois, Ohio	8	8.1	NA	365
3	New Jersey, Pennsylvania, Delaware	8	7.9	NA	845
4	California	8	7.8	NA	1,252
5	Louisiana, Texas, Mississippi	8	7.5	NA	377
6	Texas	8	4.5	NA	377
7	Illinois, Indiana, Michigan	8	3.6	NA	484
8	Louisiana	8	3.6	NA	278
9	Oklahoma, Kansas	8	3.3	NA	365
10	California	8	2.5	NA	357
	Totals ., ., .,	80	63.7	NA	5,031

[a]EMT=Equivalent megatons
[b]NA = Not applicable

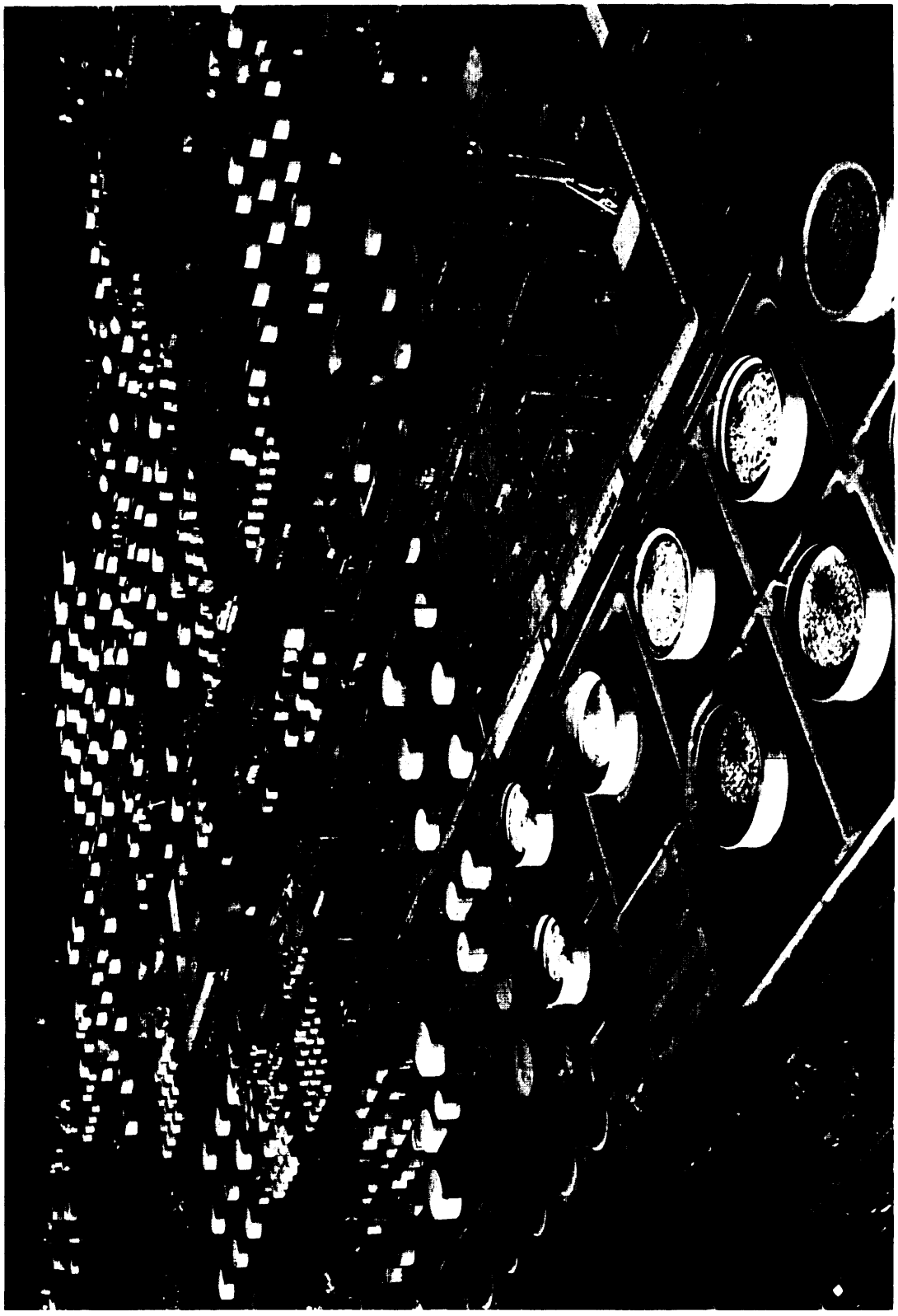


Photo credit: EXXON Corporation

Baytown refinery, Baytown, Tex.

garding the protective postures of the population in its calculations:

1. Ten percent of the population in large cities (above 50,000) spontaneously evacuated beforehand due to rising tensions and crisis development;
2. Home basements are used as fallout shelters as are such public shelters as subways;
3. People are distributed among fallout shelters of varying protection in proportion to the number of shelter spaces at each level of protection rather than occupying the best spaces first;
4. The remaining people are in buildings that offer the same blast protection as a single-story home (2 to 3 psi); radiation protection factors were commensurate with the type of structures occupied.

These assumptions affect the results for reasons noted in chapter III. Other uncertainties affect the casualties and damage. These include fires, panic, inaccurate reentry vehicles (RVs) detonating away from intended targets, time of day, season, local weather, etc. Such uncertainties were not incorporated into the calculations, but have consequences noted in chapters I I and I I 1.

The attack also causes much collateral economic damage. Because many U.S. refineries are located near cities and because the Soviets are assumed to use relatively large weapons, the attack would destroy many buildings and other structures typical of any large city. The attack would also destroy many economic facilities associated with refineries, such as railroads, pipelines, and petroleum storage tanks. While the attack would leave many U.S. ports unscathed, it would damage many that are equipped to handle oil, greatly reducing U.S. petroleum importing capability. Similarly, many petrochemical plants use feedstocks from refineries, so most plants producing complex petrochemicals are located near refineries; indeed, 60 percent of petrochemicals produced in the United States are made in Texas gulf coast plants.[1] Many of these plants would be destroyed by the attack, and many of therest would be for lack of feed stocks. III the attack aimed only at refineries would cause much damage to the entire petroleum industry, and to other assets as well.

All economic damage was not calculated from this attack, because no existing data base would support reasonably accurate calculations. Instead, the issue is approached by using Philadelphia to illustrate the effects of the attack on large cities. Philadelphia contains two major refineries that supply much of the Northeast corridor's refined petroleum. In the attack, each was struck with a l-Mt weapon. For reference, figure 14 is a map of Philadelphia. Since other major U.S. cities are near targeted refineries, similar damage could be expected for Houston, Los Angeles, and Chicago.

Fatalities and Injuries

The Defense Civil Preparedness Agency (DCPA) provided not only the number of people killed within each of the 2-minute grid cells in the Philadelphia region but also the original number of people within each cell. These results are summarized in the following table for distances of 2 and 5 miles [3 and 8 km] from the detonations:

Deaths From Philadelphia Attack

Distance from detonation	*Original population*	*Number killed*	*Percent killed*
2 ml	155,000	135,000	87
5 ml	5,785,000	410,000	52

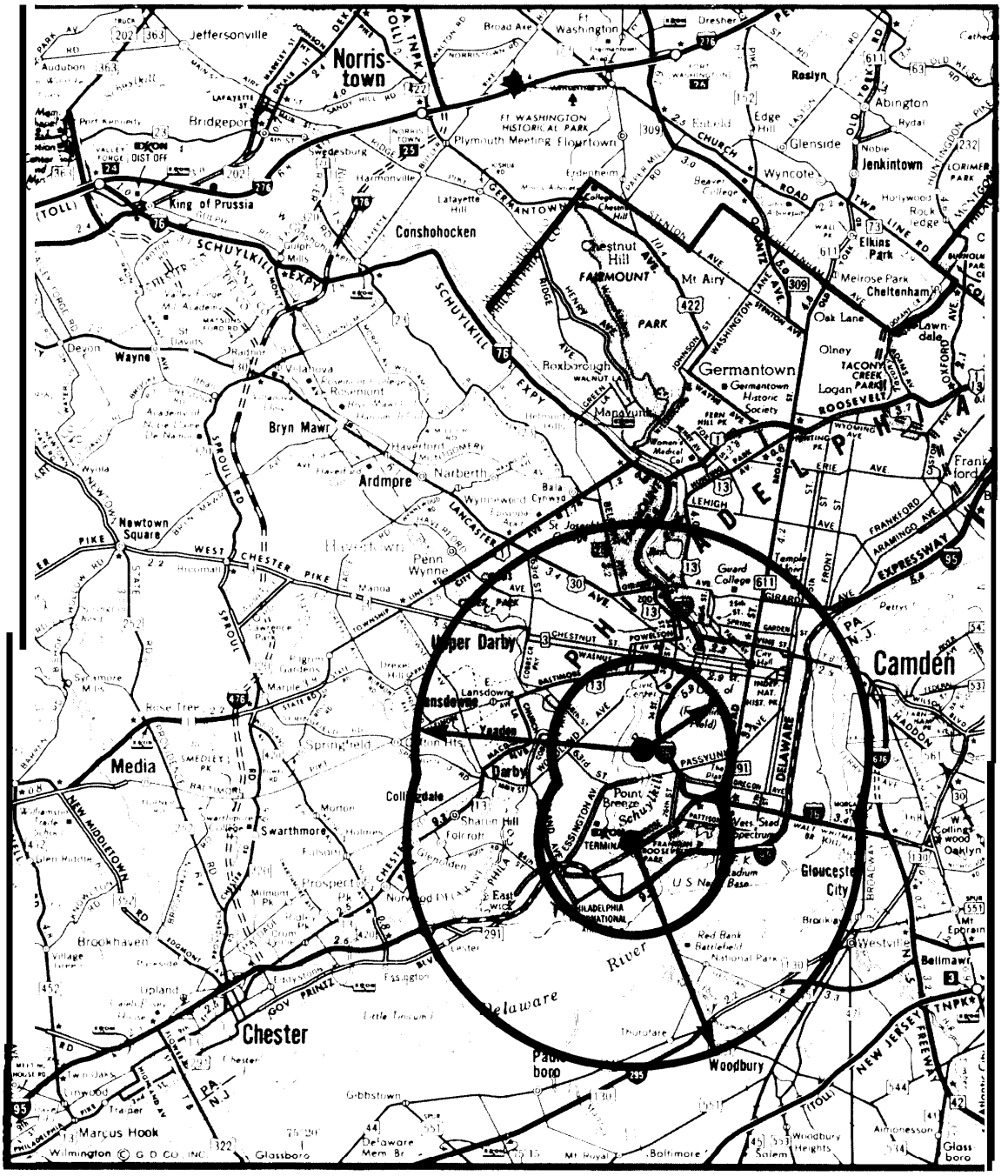
Detailed examination of the large-scale map also indicates the magnitude of the problems and the resources available to cope with them. These are briefly discussed by category.

Petroleum

Local production, storage, and distribution of petroleum are destroyed. 1 n addition to the two refineries, nearly all of the oil storage tanks are in the immediate target area. Presumably, reserve supplies can be brought to Philadelphia from other areas unless– as is likely– they are also attacked. While early overland shipment by rail or tank truck into north and northeast Philadelphia should be possible, water transport up the Delaware River may not

[1] Bill Curry, "Gulf Plants Combed for Carcinogens," *Washington Post*, Feb 19, 1979, page A3

Figure 14.— Philadelphia and Surrounding Counties



The two large dots represent the ground zeros of the two l-Mt Soviet weapons. Within 2 miles of these around zeros, there are approximately 155,000 people of which 135,000 were calculated to have been killed. Within 5 miles, there are 785,000 people of which 410,000 would have died.

be. This busy, narrow channel passes within about 1.3 miles [2.1 km] of one of the targets and could become blocked at least temporarily by a grounded heavily laden iron ore ship (bound upriver for the Fairless Works) or by sunken ships or barges.

Electric Power

There are four major electric powerplants in or near Philadelphia. Table 9 summarizes capacity, average usage (1976), and expected damage to these four installations.

While the usage figures in table 9 are average and do not reflect peak demand, it should be noted that a large percentage of this demand will disappear with destruction of the industrial areas along the Schuylkill River and of a large portion of the downtown business district. Thus, the plant in the Richmond section of Philadelphia, Pa., may be able to handle the emergency load. Assuming early recovery of the Delaware plant, there probably will be adequate emergency e ectric power for the surviving portion of the d stribution system.

Transportation

Air.– The major facilities of the Philadelphia International Airport are located about 1.5 nautical miles [2.8 km] from the nearest burst. These can be assumed to be severely damaged. The runways are 1.5 to 2.5 nautical miles [2.8 to 4.6 km] from the nearest burst and should experience little or no long-term damage. Alternate airfields in the northeast and near Camden, N. J., should be unaffected.

Rail.– The main Conrail lines from Washington to New York and New England pass about a mile from the nearest burst. I t can be expected that these will be sufficiently damaged to cause at least short-term interruption. Local rail connections to the port area pass within a few hundred yards of one of the refineries. This service suffers long-term disruption. An important consequence is the loss of rail connections to the massive food distribution center and the produce terminal in the southeast corner of the city.

Road.– Several major northeast-southwest highways are severed at the refineries and at bridge crossings over the Schuylkill River. While this poses serious problems for the immediate area, there are alternate routes through New Jersey and via the western suburbs of the city.

Ship.– Barring the possible blockage of the channel by grounded or sunken ships in the narrow reach near the naval shipyard, ship traf - fic to and from the port should experience only short-term interruption.

Casualty Handling

Perhaps the most serious immediate and continuing problem is the destruction of many of Philadelphia's hospitals. Hospitals, assuming a typical construction of multistory steel or

Table 9.—Electric Powerplants in Philadelphia

Name	Capacity (kW)	Average usage kW (1976)	Distance from blast	
Schuylkill	249,000 steam + 36,750 internal combustion (I.C.)	111,630	1.3	Electrical equipment destroyed. Plant heavily damaged.
Southwark	356,000 steam + 66,750 I.C.	71,605	2.6	Electrical equipment damaged or destroyed. Plant moderately damaged.
Delaware	250,000 steam + 68,750 I.C.	162,799	4.9	Electrical equipment moderately damaged. Plant intact.
Richmond	275,000 steam + 63,400 I.C.	29,247	6.6	Probably undamaged.
Totals	1,130,000 kW (steam) + 235,650 I.C.	375,281		

SOURCE: *Electrical World Directory of Electrical Utilities* (New York, N.Y.: McGraw Hill Inc., 1977)

reinforced concrete, would have a SO-percent probability of destruction at about 2.13 miles (1 .85 nautical miles [3.4 km]). A detailed 1967 map indicates eight major hospitals within this area; all are destroyed or severely damaged. Another nine hospitals are located from 2 to 3 miles [3 to 4 km] from the refineries. While most of the injured would be in this area, their access to these hospitals would be curtailed by rubble, fire, and so on. Thus, most of the seriously injured would have to be taken to more distant hospitals in north and northeast Philadelphia, which would quickly become overtaxed.

Military

Two important military facilities are located near the intended targets. The Defense Supply Agency complex is located within 0.5 miles [0.8 km] of one of the refineries and is completely destroyed. The U.S. Naval Shipyard is 1.0 to 1.8 miles [1.6 to 2.9 km] from the nearest target and can be expected to suffer severe damage. The large drydocks in this shipyard are within a mile of the refinery.

Other

Several educational, cultural, and historical facilities are in or near the area of heavy destruction. These include Independence Hall, the University of Pennsylvania, Drexel institute of Technology, Philadelphia Museum of Art, City Hall, the Convention Hall and Civic Center, Veterans Stadium, Kennedy Stadium, and the Spectrum.

Reaction: The First Week

During this period people would be in a state of shock, with their lives disrupted and further drastic changes inevitable. Many would have loved ones killed and homes destroyed. Factories and offices in the target areas would be destroyed, throwing people out of work. People would face many immediate tasks: care of the injured, burial of the dead, search and rescue, and fire fighting.

Fires at petroleum refineries, storage tanks, and petrochemical factories would rage for hours or days, adding to the damage caused by blast. Some oil tanks would rupture and the oil would leak onto rivers or harbors, where it would ignite and spread fire. Fires at refineries could not be extinguished because of intense heat, local fallout, an inadequate supply of chemicals to use on petroleum fires, and roads blocked by rubble and evacuees. Petrochemical plants, already damaged by blast, would be further damaged by fire and would leak toxic chemicals. As discussed in chapter 11, firestorms or conflagrations might begin, in this case supported by thousands of tons of gas-01 inc. Anyway, the plants would likely be damaged beyond repair. Finally, with fires threatening to burn, poison, or asphyxiate people in shelters, rescue crews would attach top priority to rescuing survivors.

Once it was clear that further attacks were unlikely, the undamaged areas of the country would supply aid. However, the available medical aid would be totally inadequate to treat burns this attack would cause. The radius of third-degree burns (5.2 nautical miles [9.6 km] for a l-Mt weapon air burst) is far greater than for any other life-threatenin$_g$ injury, and huge fires would cause more burns. But, even in peacetime, the entire United States has facilities to treat only a few thousand burn cases adequately at any one time.

If the attack used ground bursts exclusively, it would cause fewer prompt fatalities (2.9 million instead of 5.0 million for the air burst case), but much fallout. Given the extensive fallout sheltering described above, 312,000 people would die of fallout. Fallout casualties, however, would depend strongly on wind directions: would gulf coast fallout blow toward Atlanta, Miami, Cuba, or Venezuela? Would New Jersey fallout land on New York City on its way out to sea? The problems of shelterers are discussed under “Case 3: A Counterforce Attack Against the United States, ” in this chapter.

Beyond the physical damage, people would realize that a central assumption of their lives–that nuclear war could not occur—was wrong. Even people beyond target areas would know immediately that secondary effects

would irrevocably change their way of life; survivors traveling to undamaged areas would drive this point home. Most would fear further attacks, and would seek protection by evacuating or seeking shelter. While recovery plans could be made and damage assessed, little reconstruction could be done with many people away or in shelters. Thus, the reaction period would not end until most people acted as if they believed the war was over.

Recovery

Once people believed that the war was over, the Nation would face the task of restoring the economy. The human consequences would be severe, but most deaths would have occurred within 30 days of the attack. Economic disruption and the economic recovery process would last much longer.

Restoring an adequate supply of refined petroleum would take years. It is unlikely that any of the attacked refineries could be repaired, although enough infrastructure might survive to make it cost effective to clear and decontaminate the rubble and rebuild on the old sites, The attack would kill many people skilled in building or operating refineries. The attack would also destroy many ports with special facilities for handling large quantities of crude oil and refined petroleum, While intensive use of plant and equipment can substantially increase output for many industries, it can increase a typical refinery's output by only 4 percent. Thus, the attack would leave the United States with about a third of its prewar refining capacity and with little of its prewar oil importing capacity; this situation would persist until new refineries and ports could be built.

The survival of a third of the Nation's refining capacity does not mean that everyone would get a third of the petroleum they did before the war. The Government would surely impose rationing. Critical industries and services would have top priority— military forces, agriculture, railroads, police, firefighting, and so on. Heating oil could be supplied, but at austere levels. Uses of petroleum for which there were substitutes would receive little or no petroleum. For example, railroads could substitute for airlines, trucks, and buses on intercity routes; mass transit would probably substitute for private automobiles and taxis in local transportation.

The demise of the petroleum industry would shatter the American economy, as the attack intended. A huge number of jobs depend on refined petroleum: manufacture, sales, repair, and insurance of cars, trucks, buses, aircraft, and ships; industries that make materials used in vehicle manufacture, such as steel, glass, rubber, aluminum, and plastics; highway construct ion; much of the vacation industry; petrochemicals; heating oil; some electric power generation; airlines and some railroads; agriculture; and so on. Thus, many workers would be thrown out of work, and many industries would be forced to close.

The limited direct economic damage, already multiplied by thousands of secondary effects just enumerated, would be multiplied again by tertiary effects. Economic patterns that rest on the petroleum economy would be disrupted. Much of the American way of life is dependent on automobiles, from fast-food restaurants and shopping malls to suburban housing construction and industries located on major highways whose workers commute by car. The many people thrown out of work would have less money to consume things made by others. Service industries of all kinds would be especially hard hit.

These economic changes would lead to social changes that would have further economic consequences. Gasoline rationing would at best severely curtail use of private cars; mass transit would be used to its capacity, which would appear inadequate. Demand for real estate would plummet in some areas, especially suburbs, and skyrocket in others, notably cities, as people moved nearer to work and stores. Such mass movement, even within cities but especially between them, would upset the demographics underlying taxes, schools, and city services. With many people out of work, demand for unemployment com-

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pensation would rise at the same time taxes were falling. Vacation patterns would shift; cuts in air and car travel would force people to travel by train, which would lead people to vacation closer to home. The situation following the attack could lead the dollar to tumble, but whether or not that occurred, the curtailment of commercial air travel would prevent most people from traveling abroad. The economic system on which production depends would be radically different. To be sure, most workers and equipment would survive unscathed, and economic recovery would eventually take place.

Production depends, however, not only on the use of physical resources, but also on a wide range of understandings between producers and consumers. These underpinnings would be destroyed by the attack just as surely as if they were targeted. Prices would be uncertain, and various kinds of barter (trading favors as well as goods) would supplement the use of money. Credit and finance could not function normally in the absence of information about the markets for continuing production. Contracts would have uncertain meaning. Many businesses would go bankrupt as patterns of supply and demand changed overnight. Courts would be seriously overburdened with the task of trying to arbitrate among all of these competing claims. Corporations and individuals would be reluctant to make commitments or investments.

Given this disruption, the effort to resume production would require grappling with some basic organizational questions. To which tasks would surviving resources be applied? How would people be put back to work? What mix of goods would they produce? Which industries should be expanded, and which curtailed? Which decisions would Government make, and which would be left to the market?

This organizational task is unprecedented, but in principle it could be performed, Presumably the United States would follow the precedent of the mobilization for World Wars I and 11, in which extensive Government planning supplemented private enterprise, and key assets and key people from the private sector were borrowed by the Government for the duration of the emergency. Certain tasks, such as caring for the injured, decontamination, high-priority reconstruction, and serving as an employer of last resort (to say nothing of meeting military requirements), would obviously be handled by the Government. The difficulty would be in planning and facilitating the transformation of the private sector. The combination of unusable factories and service facilities with unemployed workers could easily create a situation analogous to that experienced in the United States between 1929-33.

Long-Term Effects

Postattack society would be permanently and irrevocably changed. People would live in different places, work at different jobs, and travel in different ways. They would buy different things and take different kinds of vacations. The Nation would tend to apply the lessons of the past to future policy by seeking to reduce its vulnerabilities to the last attack. Energy conservation, where not required by regulations, would be encouraged by prices, taxes, and subsidies. Railroads and mass transit would supplant travel by cars and planes; rail and ships would substitute for planes and trucks in hauling freight. Automobile production would drop sharply and would emphasize energy-efficient models; bicycles and motorcycles would be popular. While housing construction would not necessarily end in the suburbs, new homes there would probably be built closer together so that mass transit could serve them. Construction in cities would boom. All houses would be better insulated; more would use solar energy as fuel costs soared.

Farms would be able to obtain adequate supplies of petroleum and its derivatives. Agriculture uses only 4 or 5 percent of the Nation's petroleum, and its products are necessary. While gasoline and petrochemical-based fertilizers and pesticides would be much more expensive, they comprise only a small fraction of farm expenses and would be essential for large-scale efficient agriculture. Moreover

much fertilizer is made from natural gas rather than petroleum, so its price would not rise as dramatically as that of gasoline, Petroleum-related cost increases would be passed on to the consumer. The character of agriculture could change, however. I n particular, the livestock industry might be sharply curtailed. At every stage, livestock raising, slaughter, and distribution require much more energy than do crops. For example, rapid transportation and extensive refrigeration are required. Meat would become very much more costly in relation to other foods than it is now, and so would become a luxury. If livestock production dropped, a major source of demand for corn, soybeans, and other fodder would decline, possibly slowing price increases for other farm products.

Although refineries and oil importing facilities would be rebuilt, U.S. refining capacity after recovery would probably be less than pre-attack capacity. Increased prices for gasoline and heating oil would shift demand to other sources of energy, raising their prices and encouraging an acceleration of their development.

Patterns of industrial production would shift dramatically because of these changes, forcing massive shifts in demand for ski I Is and resources. Many people and factories would be oriented to the production of things no longer in demand; it would take many years for the economy to adjust to the sudden, massive changes imposed by the attack.

The attack would affect public health. Chapter V discusses the long-term effects of sublethal levels of radiation. Petrochemical plants damaged by the attack would leak carcinogenous petrochemicals, but numbers of cancer cases from this source, the time of their appearance, and the duration of the threat cannot be predicted. To the extent that contamination or destruction of housing, or economic collapse, force people to live in substandard housing, illness would increase. Not all changes, however, would be for the worse. Some new patterns of living would promote public health. There would be fewer auto, aircraft, and boating accidents. More people would walk or bicycle, increasing exercise. Reduced consumption of meat would reduce dietary fats, heart attacks, and strokes. At some point, Government-imposed controls necessitated by the attack could be lifted because societal changes and market forces (price increases, alternative energy sources, residential patterns, and numbers and efficiency of cars) would achieve the goals of controls without coercion. For example, gasoline rationing would certainly be imposed immediately after the attack, and might be lifted in stages as refining capacity was restored, or subsidies to expand and support mass transit could level off or decline as revenues made it self-supporting.

The Nation's adjustment to all these changes would be painful. The problems would be especially severe because of the speed of their onset. Many people say that the United States would be better off if it was less dependent on cars and petroleum. While changing to new patterns of living via nuclear attack would minimize political problems of deciding to change, it would maximize the difficulties of transition. Problems would appear all at once, while any advantages of new patterns of living would come slowly.

CASE 2: A U.S. ATTACK ON SOVIET OIL REFINERIES

This case investigates what might happen if the United States tried to inflict as much economic damage as possible on the Soviet Union with 10 SNDVs without seeking to maximize or minimize casualties. Petroleum refineries were selected as targets because of their small number and long construction time, and because of the severe economic consequences of doing without refined petroleum,

The Soviet refining industry is at least as vulnerable as its U.S. counterpart, though the

vulnerabilities differ slightly. The United States refines more petroleum than does the U. S. S. R., about 17.9 million barrels per day of crude (1978 figures) versus 11.0 million (1980 projection).[2] According to a 1977 source, the U.S.S.R. had 59 refineries, including at least 12 under construction, some of which are very large; the U.S. and its territories have at least 288.[3] All individual refineries in both nations are highly vulnerable to attacks with nuclear weapons. The U.S. attack destroys most of Soviet refining capacity because the U.S.S.R. has few refineries; the Soviet attack destroys most of U.S. refining capacity because U.S. refineries are clustered.

The hypothetical attack targets 24 refineries and 34 petroleum storage sites. Some major refineries are beyond range of Poseidon missiles, so the United States uses 7 Poseidons with a total of sixty-four 40-kiloton (kt) RVs and 3 Minuteman IIIs with a total of nine 170-kt RVs. Because of the dispersal of Soviet refineries and limits of footprint size, each footprint had fewer refineries than available RVs. The additional RVs were first allocated 2 on 1 against large refineries; remaining RVs were targeted against petroleum storage complexes. As in the U.S. case, every weapon is assumed to detonate over and destroy its target. It is assumed that all weapons are air burst, and the consequences of using ground bursts are noted where appropriate.

Immediate Effects: The First Hour

The attack destroys 73 percent of Soviet refining capacity and 16 percent of Soviet storage capacity, as table 10 shows. Collateral economic damage could not be calculated or collateral damage to a large Soviet city assessed because sufficient unclassified data could not be found.

If all weapons are air burst, the attack kills 1,458,000 people assuming everyone to be in single-story buildings, and 836,000 assuming everyone in multistory buildings; the latter assumption comes closer to reality. If all weapons were ground burst, the attack would kill 1,019,000 people, 722,000 promptly and 297,000 by fallout, assuming the worst case, everyone living in single-story buildings.

The estimated injuries from the attack are substantial under all conditions. Under the single-story assumption on housing, the air-

[2] "U S. Refining Capacity" (Washington, D.C National **Petroleum Refiners Association, July** 28, 1978), p 1 (U. S figures), and *International Petroleum Encyclopedia, 1976* **(Tulsa, Okla.: Petroleum Publishing Co , 1977), p. 323 (Soviet figures).**

[3] *International Petroleum Encyclopedia, 1976,* op. cit., p. 393 (Soviet figures); and **"U.S. Refining Capacity," op cit.;** *passim,* **(U.S. figures).**

Table 10.—Summary of U.S. Attack on U.S.S.R.

Footprint number	Geographic area (approx. center)	EMT[a]	Percent national refining capacity	Percent national storage capacity	Air burst prompt fatalities (x 1,000) SS[b]	MS[c]
1	Moscow	1.20	10.5	2.1	62	41
2	Baku	0.96	9.8	1.5	224	152
3	Ishimbai	1.20	8.7	2.8	25	12
4	Polotsk	0.92	7.5	0.3	52	32
5	Kuibuyshev	1.20	7.4	3.1	127	83
6	Angarsk	0 92	6.9	0.4	130	54
7	Grozny	0.96	6.7	1.6	56	37
8	Kirishi	0.92	6.2	0.3	493	230
9	Gorki	1.20	5.6	1.5	228	153
10	Perm	0.96	3.6	2.1	61	42
	Totals	10.44	72.9	15.7	1,458	836

[a] EMT = Equivalent megatons.
[b] SS = 100 percent of population in single-story buildings.
[c] MS = 100 percent of population in multistory buildings.

burst attack would produce 3.6 million injuries and a surface-burst attack about a million less. If in multistory buildings, the population would suffer 3.8 million injured from an air-burst attack and 2.5 million for the surface burst. (A protection factor of 5 was assumed against fallout from the surface bursts.)

The attack kills fewer Russians than Americans. The differences in fatalities do not mean that the United States is necessarily more vulnerable than the Soviet Union to nuclear attack; rather, the asymmetries occur from the design of the attack. Soviet refineries are farther from cities than are U.S. refineries and U.S. weapons are smaller, so fewer Russians are within the lethal radii of U.S. weapons. Sensitivity of fatalities and injuries to distance from ground zero is shown in table 11, Had either nation sought to kill people, it would have used different weapons and targeted them differently.

Reaction: The First Week

As in the United States, life for the surviving majority would be totally disrupted. Many would be directly affected by the attack: the injured, those with injured relatives, the homeless, people affected by shortages. Accommodation to a future with a sharply reduced petroleum supply would begin: gasoline and other products might be hoarded, by enterprises if not by individuals. Some less-important industries would probably be closed to save fuel or to allow their workers to shift to the military, agriculture, and essential industry. Until it became clear that the war was over, millions of reservists would be mobilized for military service, placing a heavy demand on the domestic economy to replace them. Because of the mobilization, hours worked and the mix of production would change dramatically and overnight; workers in essential industries might be on 12-hour shifts; other workers not drafted would be pressed into service in essential industries, and quite possibly moved to factories in distant areas. The speed and magnitude of disruption would cause much psychological shock.

How would the Soviet Union cope with the damage? Although a greater percentage of its refining capacity would be destroyed, it would suffer fewer fatalities than would the United States (1.0 million to 1.5 **million** versus **3.2 million to 5.0 million) and** fewer injuries **(2.5** million to **3.8 million versus 3.9 million to 4.9 mil-**

Table 11 .–Approximate Distance (Nautical Miles) of Various Effects From Selected Nuclear Air Bursts (personnel casualties)

Effect		Weapon yield		
		1 Mt	170 kt	40 kt
Overpressure (crushing)	Lethality—			
	Threshold	0.25	0.15	0.1
	Lung damage—			
	Threshold	2.1	1.1	0.7
	Severe	0.8	0.5	0.3
	Broken eardrums—			
	Threshold	3.5	2.0	1.2
	50%	1.0	0.6	0.4
Translation	Personnel in the open—1%	3.3	1.6	0.9
	Personnel near structures—			
	1%	3.8	1.9	1.0
	50%	2.1	1.0	0.6
Thermal	Third-degree burn—100%	5.2	2.6	1.5
	No burns—100%	8.7	4.8	2.8
	Flashblindness*	10	9	8
	Retinal burn*	25	23	20
Radiation	Lethal dose (1,000 rads)	0.9	0.8	0.7
	No immediate harm (100 rads)	1.2	1.1	1.0

Daytime safe distance.

lion) because of the lower yield of U.S. weapons and the location of Soviet refineries away from cities. If all weapons were air burst at optimum height of burst, there would be negligible fallout in both countries; if all weapons were ground burst, the Soviet Union would receive far less fallout because of the lower yield of the weapons. Because the Soviets have built many widely dispersed small dispensaries and first aid centers, rather than smaller numbers of modern full-service hospitals concentrated in cities, more of these facilities would survive than in the United States. In addition, many Russians have received first aid training, and people with injuries that could be treated by paramedics, dispensaries, and first aid would probably be better off than their American counterparts; others would be at least as bad off. Those who required treatment at major hospitals would suffer because of the small number of beds in nearby modern hospitals and the inability of the Soviet transportation system to move them elsewhere. Like the United States, the U.S.S.R. could not cope with large numbers (say, over 100) of severe burn cases. There would be many victims of severe burns in both nations who would die for lack of adequate treatment.

The damage, the emergency conditions, and the risk of further attacks would remind everyone of the special horror that the Soviets faced in World War II. The psychological trauma would be exacerbated in the first week by anticipation of crisis economic conditions. The Soviet Government in past crises has proved to be ruthless and efficient in moving people to parts of the country where labor was needed. Such action would be likely in this crisis as well, along with cutbacks in food, consumer goods, housing construction and maintenance, and transportation. Only regimentation would be likely to increase. Life would be grim, and would remain so for years.

Recovery

What course would Soviet recovery take? Economic viability would not be at issue following this attack, and the Government could be expected to remain firmly in control because of the limited scale of this attack. Assuming that there are no further attacks, most of the deaths would occur within 30 days of the attack. While the course of economic recovery cannot be predicted in detail, it is clear that:

- The attack would hurt. The recovery period would be marked by shortage and sacrifice, with particular problems stemming from agricultural shortfalls.
- Nevertheless, the Soviet economy and political system would survive, and would do so with less drastic changes than the United States would probably experience.
- The asymmetries between the two nations in effects for a given attack are greater for this case than for a very large attack.

The political and economic structure of the U.S.S.R. appears designed to cope with drastic emergencies like this attack. While almost all economic assets would be unscathed, resources would need to be shifted rapidly to produce a different mix of outputs. The attack would totally disrupt existing economic plans. The economic planning apparatus and Government control methods in place in the U.S.S.R. would permit the Government to shift plans and resources, but the speed with which such changes could be made is uncertain. To the extent that revisions in the economic plan were not made or were delayed, people and equipment would sit idle or would be producing according to less-efficient priorities, draining scarce resources from higher priority tasks and hindering recovery. Workers would be shifted to different industries as plants closed; some would be forced to move, share apartments with strangers, or work at new jobs (including manual labor in farms or factories).

Some insight into the economic consequences can be obtained by looking at four sectors of the economy— military, agriculture, transportation, and industry. Each of these sectors would have a strong claim on available petroleum, but their total demand would exceed the supply.

The military would have first call on fuel, especially if the war continued. It has adequate stocks to prosecute a war for several weeks. However, unless this attack led to a decisive Soviet victory or to a major relaxation of tensions, the military would need refined petroleum to rebuild its stocks and to carry out normal training.

Soviet agriculture is precarious even in peacetime because of its inefficiency. Agriculture engages about a third of the work force and consumes a third of Soviet gasoline and diesel fuel. (U.S. agriculture, in contrast, uses 2.7 percent of the work force (in 1978) and a small fraction of U.S. refined petroleum .)[4] The Soviet Union imports grain in most years. Nevertheless, the U.S.S.R. has maintained a large cattle industry at considerable expense to provide a consumer good much in demand. Farms use petroleum for tractors and trucks; petroleum and natural gas are feedstocks for fertilizer and pesticides. Agricultural use of petroleum is increasing. One small example is the Soviet use of light aircraft to spread fertilizer; while this task could be done by tractors or by hand, it is much more efficiently done by aircraft.

Cutbacks in petroleum would magnify agricultural inefficiency. Even if the Soviet Union allocated all the petroleum it produced to agriculture, it would not produce enough to sustain agriculture's prewar consumption, and other critical sectors would compete for petroleum. Drawing on inventory would sacrifice later agricultural production for earlier production. Following the attack, the main concern of agriculture would be planting, growing, or harvesting the year's crop; sacrifices and substitutions would be required in other agricultural subsectors to meet this goal with available petroleum. The U.S.S.R. would be likely to divert people from schools, factories, and (depending on the international situation) the military to work the fields, as it does in peacetime, but to a greater extent. The substitution of human labor for mechanical energy would be a poor but perhaps unavoidable trade. The most obvious cutback would be livestock; meat is a luxury, livestock consume much food that could otherwise be used for human consumption, and cattle raising, slaughter, and distribution require much energy. The Soviet Union might slaughter much of its livestock after the attack to free farmers, fields, trucks, and petroleum to produce crops. Russians might have a 3-month orgy of meat followed by two decades without.

Soviet transportation would be pinched. A few top leaders would still have cars; other cars would sit idle for years, monuments to the prewar standard of living. Air transportation would be sharply curtailed, and Soviet supersonic transports would be grounded. Truck transportation would be curtailed, with trucks used almost exclusively for intracity transportation and hauling goods between railroads and loading docks. By elimination, the transportation burden would fall to railroads because of their energy efficiency. Key trunklines are electrified, and might obtain electricity from sources other than petroleum. The Soviets have stored a number of steam locomotives, which would be hauled out, refurbished, and put to use.

The tempo of industrial production would slow. Even as it stands now, the Soviets have barely enough energy and occasional shortages. Electric power would continue, but would probably be cut back 10 to 15 percent,

[4] *Statistical Abstract of* the *United States, 1978* (Washington, D C U S Department of Commerce, Bureau of the Census, 1978), I ists 91,846,000 employed persons age 16 and over in the United States, of whom 2,469,000 were listed as farmworkers, for January-April 1978 (p. 418). *The Statistical Abstract* does not present the amount of petroleum consumed by American agriculture. Several statistics, however, indicate this number to be a small fraction of total U S petroleum consumption Preliminary 1977 data showed all U S prime movers (automotive and non-automotive) had 26,469,000,000 horsepower, whi le farms accounted for 328,000,000 horsepower, or 1 2 percent (p. 604) In 1976, industrial consumption of petroleum accounted for 18 percent of total U S petroleum consumption (p 764) And a National Academy of Sciences study found that agriculture accounted for 3.5 percent of total national energy consumption in 1968 *Agricultural Production* Efficiency (Washington, D C National Academy of Sciences, National Research Council Committee on Agricultural Production Efficiency, 1975), p 119)

forcing some industries to close and reducing heat and light at other industries and apartments. With transportation cut back, factories would have to wait longer for inputs, lowering productivity.

Some less-essential industries, especially energy- or petroleum-intensive ones, might shut down. Plastics use petroleum derivatives as feedstocks. Aluminum production uses great amounts of energy, though some Soviet aluminum plants, such as at Bratsk in Siberia, use hydroelectric power. Truck production would stop for lack of fuel for existing vehicles, idling the huge Kama River truck plant.

Construction consumes much petroleum, so it would be curtailed except for essential industries, hydroelectric powerplant construction, refining construction, and minimal housing for workers in those occupations.

These changes would disrupt workers' lives. Closing of some plants would idle many workers, forcing them to work in other industries; many could be moved long distances to other plants. Workers would not necessarily be forced to work long hours. While some plants would operate around the clock, others would be closed or cut back to enable the energy they consume to be diverted. At the same time, however, and within limits of substitutability, workers could likewise be diverted from closed to open plants, providing extra labor for factories that remained open extra time.

In sum, the reduction in the standard of living and the amount of disruption would probably be less than in the United States but there might well be more hardship and misery. Russians would have less food, especially protein, than they did before the attack, while American agriculture consumes so little petroleum that its output could probably be maintained, though some variety might be sacrificed. There would be less heat in both nations, but winters are shorter and milder in the United States, and U.S. indoor temperatures in winter could be reduced 50 or 10° F without ill effect. Therefore, heating could probably not be cut as much in the U.S.S.R. as in the United States without jeopardizing health. Cars would be sacrificed at least temporarily in both nations. Soviet industries producing consumer goods would be cut back more sharply than their U, S. counterparts after the attack, and would regain productivity more slowly.

Long-Term Effects

Destroying 73 percent of refining capacity would force the economy onto a crisis footing, curtailing choices and consumer goods, dropping the standard of living from austere to grim, and setting back Soviet economic progress by many years. Recovery might follow the post-World War II pattern, with a slow but steady improvement in the quality of life. But recovery would be slow, The desire to reduce vulnerability to future attacks would undoubtedly divert resources from recovery to such tasks as building some underground refineries. While the United States could possibly recover in a way that would use less petroleum than it did prewar, this course would be difficult for the U.S.S.R. because much of Soviet petroleum goes to necessities. Long-term health and genetic effects would be less than for the United States because of the smaller size of U.S. weapons and the location of Soviet refineries away from people. But the Soviet Government might accept greater radiation exposure for people in order to speed production, increasing such effects.

CASE 3: A COUNTERFORCE ATTACK AGAINST THE UNITED STATES

The case of a Soviet attack on U.S. strategic forces has received extensive public attention in recent years, since some observers believe it is the least irrational way of waging strategic war. For the purposes of this study, the military success of such an attack (i. e., how many U.S. forces would be destroyed) and the resulting U.S. responses are not important. It is sufficient to assume that such an attack is launched, and to examine the consequences for the civilian population, economy, and society. For this purpose, small variations in the attack design (e. g., whether control centers as well as silos are targeted) are immaterial. While there are many possible variations in the design of a counterforce attack, a question of particular interest is whether the attack would be delivered only against ICBM silos, or whether bomber bases and missile submarine bases would also be attacked. Some of the public discussion of such an attack suggests that an attack on ICBM silos alone could cause much less civilian damage than a full-scale counterforce attack because the silos are more isolated from population centers than are bomber bases. It is certainly true that, holding al l the other possible variables constant, an attack that included bomber bases and missile submarine bases would cause more civilian damage than one that did not. Nevertheless, the difference between the ICBM-only attack and a comprehensive counterforce attack was found to be no greater than the difference made by other variables, such as the size of weapons used, the proportion of surface bursts used, and the weather. Both cases are considered in this section; the countersilo attack is a subset of the counterforce attack, and available data is too coarse to support a believable differentiation between the civilian effects of each attack.

Prompt Effects

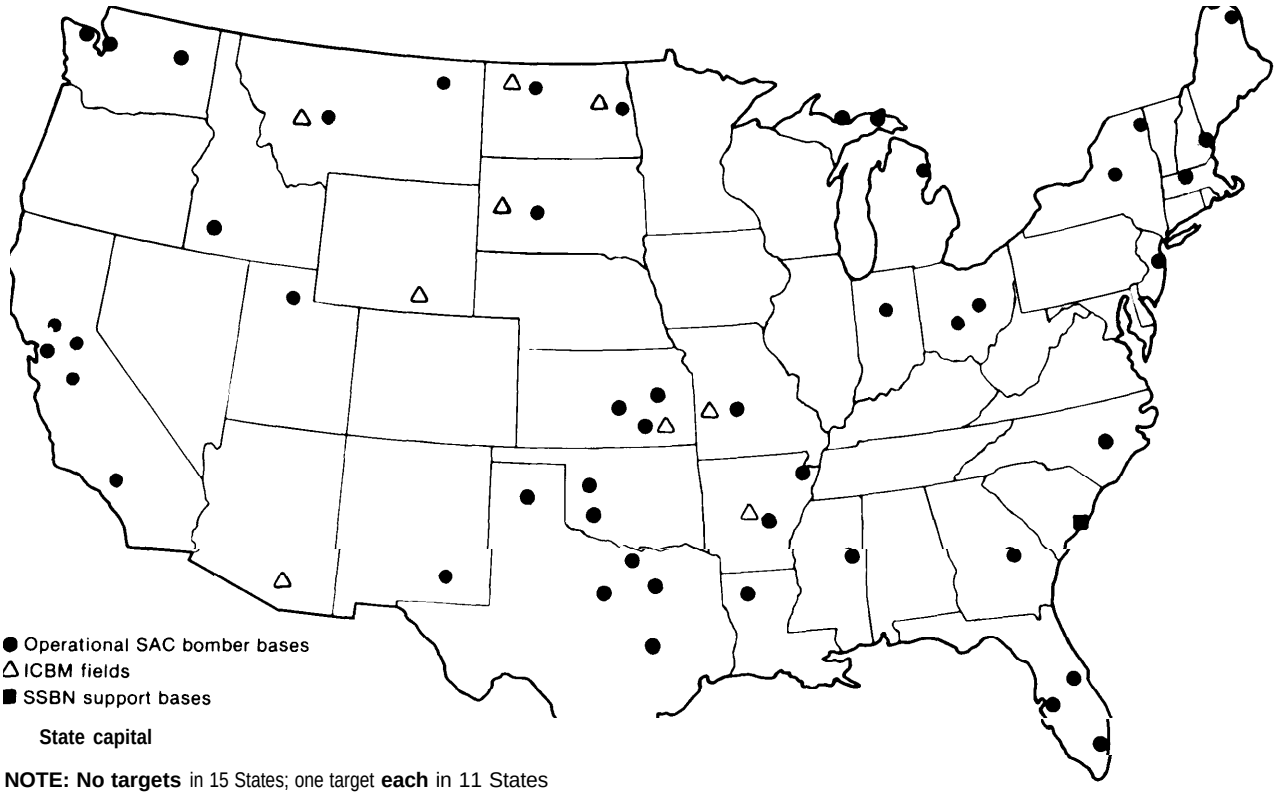
The blast damage from a counterforce attack is concentrated on military installations. Attacks on submarine bases and bomber bases would cause considerable blast damage to nearby populations and urban structures; attacks on silos would cause relatively little civilian blast damage. Unlike ICBM silos, many bomber bases and fleet ballistic missile submarine (SSBN) support facilities are near cities. (See figure 15.) For example, an attack on Griffiss Air Force Base, near Utica and Rome, N. Y., would place nearly **200,000 people at risk from prompt effects; attacking the** SSBN support facility near Charleston, S. C., would place more than 200,000 people at risk; attacking Mather Air Force Base, near Sacramento, Cal if., would place more than 600,000 people at risk. The additional attacks would simultaneously reduce the number of people able to provide aid and increase the number of injured or evacuees re quiring aid. The attacks would make it harder for people able to provide aid to sustain those needing it.

Countersilo attacks would probably detonate some weapons at or near the Earth's surface to maximize the likelihood of destroying ICBM silos. Surface bursts produce intense fallout, causing most of the damage to the civilian population, economy, and society. The principal civilian impact of adding attacks on bomber and SSBN bases is the large increase in urban destruction.

The Period Before Fallout Deposition

Fallout would begin to reach closer populated areas in a few hours; it would reach many others in a few days. As fallout arrives, radiation levels rise sharply and rapidly. People would therefore have to take any protective act ions —shelter or evacuation — before the fallout arrives. This prearrival period would thus be one of intense activity and intense confusion. How would people react? Training could help, but people trained in how to behave under fallout conditions would fare poorly if they could not get to shelters or if shelters were unstocked. To what extent would people

Figure 15.—Counterforce Targets in the United States



NOTE: No targets in 15 States; one target **each** in 11 States

panic, seek other family members, or evacuate spontaneously, and what would be the consequences of such actions?

Evacuation would probably be a poor choice, since it would be difficult or impossible to predict which would be the safe areas and which the hot spots, and since a car in a traffic jam would offer poor shelter indeed. The decision on whether or not to evacuate, however, is complicated because evacuation is a reasonable response for people who would be at risk from blast from further attacks even though evacuation is a poor strategy for people at risk from fallout alone.

Shelter would in theory be available to a majority of people, although the best available shelter might not be good enough in areas where the fallout proved to be very intense. However, the practical difficulties of fallout sheltering could be very great. The time to seek shelter could be very limited (and people would not know how long they had), and people would want to get their families together first. A shelter must have a sufficient protection factor. Fallout particles must be kept out of the shelter, which requires a ventilation system more complicated than an open window or door, and if anybody enters a shelter after fallout has fallen there must be some means of decontaminating the new arrival. Water is necessary; heat may be necessary depending on the time of year; sanitation is a problem. Finally, people could not tell how long it was necessary to stay in the shelter without radiation rate meters.

It is obvious that the time of day, the time of the year, and the degree of emergency preparations during the hours or days before the attack would all affect the level of deaths. Whatever the circumstances, the few hours after the attack would see a frantic effort to seek shelter on the part of most of the American popu-

lation. Then, in densities and locations determined by the attack parameters and the weather, the fallout would descend. Many Americans would be lucky enough to be in areas where the fallout level was low. Many others (between an estimated 2 million and 20 million), would be caught without shelter, or with inadequate shelter, and would die. Still others would suffer from a degree of radiation that would make them sick, or at least lower their life expectancy, but would not kill them. The trials of living in fallout shelters would be intensified by the fact that many people would not know which category they and their families were in.

A comprehensive counterforce attack would impose a greater burden than a countersi 10 attack. Many more people would be injured by prompt effects, and people near bomber and SSBN bases would have only a few minutes warning in which to seek shelter.

Cities in the blast area –those near SSBN or bomber bases–would be heavily damaged. A few cities, such as Charleston, SC., and Little Rock, Ark., could suffer consequences similar to Detroit in Case 1 (chapter 11) or Philadelphia in Case 2 (above in this chapter); most would not. People in blast areas would face hazards as noted in Case 1 — injuries from blast, initial nuclear radiation, and thermal radiation, and from such secondary effects as falling buildings and fires. As in other cases, rescue would be difficult, with streets blocked by rubble, water pressure gone, and emergency vehicles destroyed.

People in areas damaged by blast and in the path of fallout would be in greatest peril. injuries, damage to prospective shelters, damage to transportation, and damage to power and water could make them highly vulnerable. Little Rock, Ark., for example, the site of an ICBM base and a bomber base, would receive both blast damage from a pattern attack (designed to destroy bombers in flight) and intense fallout radiation from the attack on ICBMs.

People in areas neither damaged by blast nor threatened by fallout would believe themselves to be at risk from blast or, at a minimum, from fallout until it was clear that attacks had ended. To these people would fall the burdens of producing necessities and caring for the injured and evacuees. Yet people in these areas, believing themselves to be at risk, would feel compelled to seek shelter or, especially in unattached cities, to evacuate spontaneously. These actions would reduce the flow of aid to damaged areas. Indeed, the economy would probably shut down until people were certain that the war had ended and until most people could get back to work, probably until the end of the shelter period. Even if some people reported to work, production would be difficult with many absentees. There would be large credit, monetary, contractual, and legal problems. If production stopped even for a week, the loss would be tremendous. This attack would disrupt the economy less than Case 2, however, because most productive resources would remain intact.

Casualty Estimates

In seeking to estimate prompt damage from the attacks, fatalities are the most important component of damage and the most calculable. To estimate fatalities, the critical questions are which areas would be damaged by blast, and to what extent? How much fallout would there be, and where would it be deposited? These questions cannot be answered with great confidence because estimates of deaths from these attacks are highly sensitive to attack parameters and civilian shelter assumptions. However, reference can be made to several recent executive branch studies of counterforce attacks.

OTA drew on several executive branch studies, conducted between 1974 and 1978, of counterforce attacks. These studies differed widely in their results, primarily because of differences in the assumptions they made. OTA felt that it would be more useful to look at the ways in which these assumptions affect the results than to attempt to determine the “correct” assumption for each uncertainty. Consequently, a range of results is presented; it is believed that if OTA had done a new study of

this case the results would have fallen somewhere within this range. [5]

The executive branch countersilo studies that OTA drew on indicated that between 2 million and 20 million Americans would die within the first 30 days after an attack on U.S. ICBM silos. This range of results is so wide because of the extent of the uncertainties surrounding fallout. The key uncertainties are:

- Height of Burst.– If the fireball touches the ground, it vaporizes some dirt, irradiates it, and draws it up into the mushroom cloud. This material condenses to become fallout. The lower the height of burst, the more of the fireball touches the ground, and the more fallout that is produced. An air burst in which none of the fireball touches the ground creates negligible fallout. Because ICBM silos are very hard, a surface burst offers the greatest probability of destroying the silo with one explosion; it also maximizes fallout. The probability of destroying an ICBM silo is increased if two warheads are targeted against it; opinions differ as to whether the most effective tactic is to use two surface bursts, which doubles the amount of fallout, or one air burst and one surface burst.
- Weapon Design.— Some weapons derive a greater portion of their energy from fission (as opposed to fusion) than others; the more fission, the more fallout. The weapon yield affects the amount of fallout; the higher the yield of a given explosion, the greater the fallout.
- Wind.– The speed and direction of the wind at various altitudes determines the directions and distance from the explosion at which fallout is deposited, and influences fallout concentration. Winds typically vary with the season; indeed, this variance is so great that it can affect casualties by about a factor of three, as figure 16 shows. The hourly and daily variation of winds also affects casualties. It is important to bear in mind, when considering possible civil defense measures, that winds could not be accurately predicted even after an attack had taken place, much less in advance.
- Rain. – Raindrops collect fallout particles from the radioactive cloud, thereby creating areas of intense fallout where it is raining, and reducing fallout elsewhere.
- Terrain. — Hills, buildings, and ground temperature gradients (such as are caused by highways and small lakes) affect the exact pattern of fallout, creating hot spots in some places and relatively uncontaminated spots nearby.
- Distance.—Other things remaining constant, fallout decreases with distance from the explosion beyond roughly 50 miles [80 km].

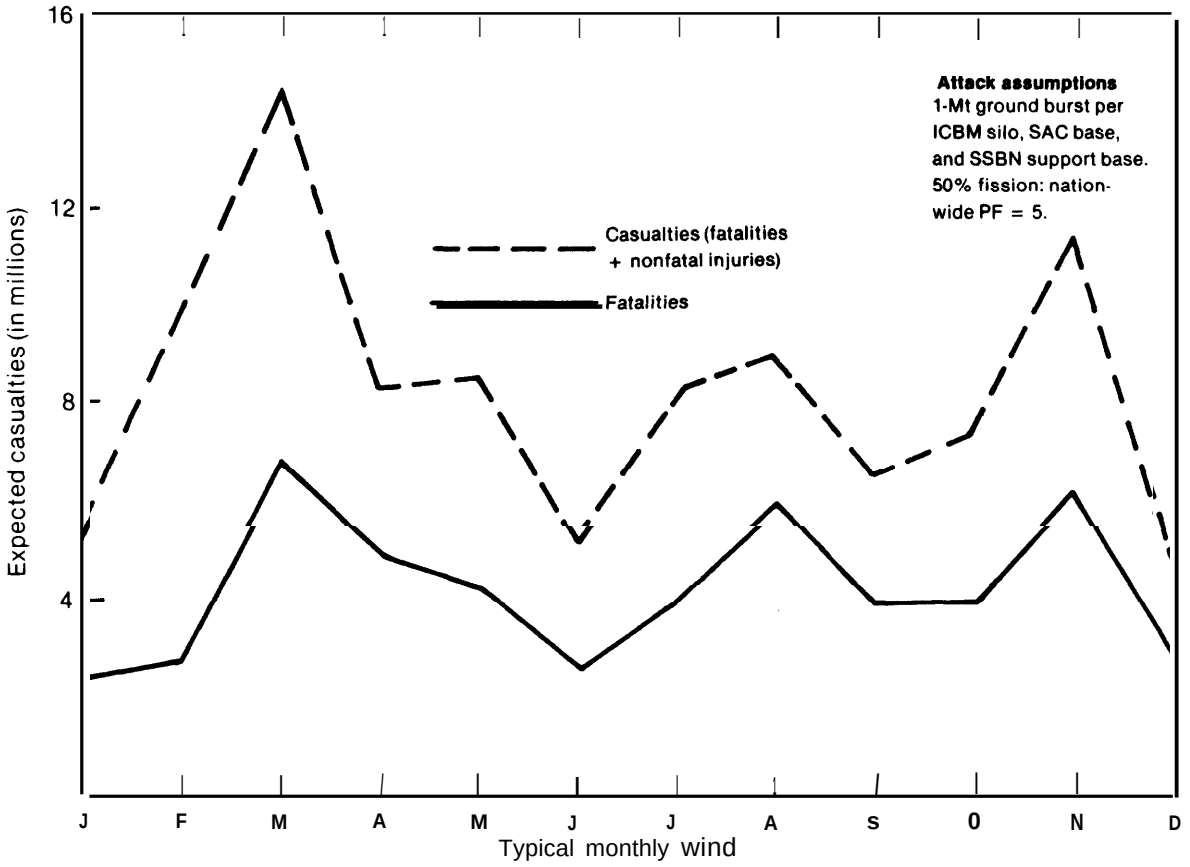
As chapter 11 explained, radiation from fallout in large doses causes death, in smaller doses causes illness, and in still smaller doses creates a probability of eventual illness or death (hence, .lowers life expectancy). As chapter I I I explained, protection can be obtained when matter is placed between the fallout and people— in general, the more matter (the greater the mass) between a source of radiation and a person, the greater the protection. The degree of protection offered by various materials is described as a protection factor (PF). The adequacy of a given PF depends on the intensity of the fallout. For example, a PF of 20 (typical of a home basement with earth piled over windows and against the walls) would reduce an outdoor radiation level of 60 rem per hour to an indoor level of 3 rem per hour. In this case, a person outdoors for 10 hours would almost certainly be killed by radiation, and a person in the basement shelter would have a good chance of survival. But if the outdoor level is not 60 reins per hour but 600 reins per hour, a PF of 20 is inadequate to save I ives.

Calculations of deaths from fallout are made by combining:

- an assumed distribution of fallout, with various intensities at various locations;

[5] For example, after the OTA analysis, was completed, a new study was completed showing fatalities from a counterforce attack with the current U S civil defense posture to be 8 to 12 million without warning, and 5 to 8 million with warning. See Roger Sullivan et al , "Civil Defense Needs of High-Risk Areas of the United States" (Arlington, Va System Planning Corporation, 1979), p. 22

Figure 16.—Expected Casualties as a Function of Typical Monthly Winds Resulting From an Attack on Selected Military Targets in the United States



- an assumed distribution of population within the areas where fallout is assumed to be deposited; and
- an assumed distribution of PFs for the population.

Some computer models use a grid (perhaps 4,000 yards on a side for a fine-grained model, but much larger in other cases) and assume that within each square of the grid the fallout intensity and population density are constant, with PFs mixed. Other calculations use regional or nationwide averages. In general, the calculations show lower numbers of deaths when they assume that the population is widely dispersed, and higher numbers when they take into account concentrations of population. The calculations also show lower numbers of deaths when they assume high PFs; in general, increasing PFs above 40 does not reduce casualties much in the calculations, but that does not mean that raising a PF above 40 might not save an individual's life in reality. The calculations also show lower numbers of deaths when the winds do not blow fallout into densely populated areas.

The studies mentioned previously made separate calculations for attacks including bomber and missile submarine bases, as well as silos. Assuming that there is no preattack evacuation, calculated deaths range from a low of 2 million to a high of 22 million. The differences result primarily from variations in assumptions regarding fallout protection: the high figure assumes approximately to degree of protection which people receive in their daily peacetime lives (PF of 3), and the low figure assumes that the entire population moves after the attack to fallout shelters with a PF of at least 25. A more reasonable assumption, that the fallout shelters which now exist

are utilized by people living near them, produces a calculation of **14 million dead. The same studies also assessed the effects of extensive preattack evacuation (crisis relocation), and found that it reduced the range of predicted deaths. However, the assumptions regarding fallout protection, both for those who are assumed to evacuate and for those who are assumed to remain near home dominate the results. Further detail** is in appendix D.

Given the threat U.S. bombers pose to the Soviet Union, a Soviet preemptive counterforce attack on bomber bases would probably seek to destroy the aircraft and supporting facilities rather than cratering the runways. To destroy airborne bombers launched on warning of attack, an attacker might detonate weapons in a spaced pattern over the base. Airbursting weapons rather than ground-bursting them could reduce the threat of fallout but increase casualties from blast and thermal effects; if the weapons were detonated much above the optimum height of burst for maximizing overpressure on the ground, fallout would be negligible and blast damage would be reduced. The attacks against missile submarine bases are much less complex. Ususally a single high-yield weapon with medium-to-good accuracy will destroy docks, piers, cranes, and other facilities — and nearby cities, factories, and people as well.

Accordingly, it is certain that if the only difference between two attacks is that one attacks only ICBM silos and the other attacks bomber and missile submarine bases as well, the latter attack would kill more people. However, the variations in assumptions made about attack design, weather, and fallout protection obscure this. Since these variations reflect genuine uncertainties, it is not possible to determine which set of assumptions and which fatality calculation is most probable. However, some of the extreme assumptions do appear implausible. One Defense Department study notes that its highest fatality figure assumed the use of Soviet weapons larger than those which U.S. intelligence estimates the Soviets possess. Very low fatality estimates assume abnormally low winds, an absence of surface bursts, and /or virtually perfect fallout protection. On balance, it does not appear possible to sustain greater precision than to say that "studies of hypothetical counterforce attacks show deaths ranging from 1 million to 20 million, depending on the assumptions used. " However, the low end of this range (deaths below the **8 to 10 million level) requires quite optimistic assumptions, while the high end of the range is plausible only on the assumption that the attack is not preceded by a crisis period during which civilians are educated about fallout protection.**

The data on injuries contained in the executive branch studies are quite limited; for the counterforce attacks, however, the results suggest that injuries would about equal fatalities.

The Contamination Period

For several days or weeks, radioactive contamination would be so intense that people in fallout areas would have to stay in shelters or evacuate. What might be called the "shelter period" begins at each location when fallout starts arriving and ends when people can leave their shelters long enough to do a day's work. The length varies from place to place; many places will receive no fallout, and some hot spots will be hazardous long after surrounding areas are safe. Note, however, that people could go outside for brief periods before an 8-hour day outside a shelter became safe, and could not live in houses with a low protection factor for weeks afterwards. After 2 or 3 months people would ignore the residual radiation, though it would be far higher than is considered "safe" in peacetime.

For the first 10 to 30 days, shelterers would have to remain in shelters almost all the time. Brief excursions outside, for example, to obtain water or food, would substantially reduce the effective protection factor. Life in a shelter would be difficult at best. People would not know if the shelter offered a sufficient PF, or whether further attacks were imminent. The shelter might be dark, as power could be out, and windows would be covered with dirt. Unless the shelter had a good air filtration system, the air would become clammy and smelly, and carbon dioxide concentration would increase. Supplies of food and water might or might not

be adequate, depending on what people brought and how many people were in a shelter. Unless the shelter were specially stocked, medical supplies would probably be inadequate. This would be a severe problem in light of unhealthy conditions in shelters. People who required special medicines would be threatened unless they could obtain an adequate supply. While most people would have radios to receive broadcasts, few would have two-way radios to transmit. While phones might or might not work, it would be difficult to obtain help, as anyone in a contaminated area who left shelter would be in jeopardy from radiation. In particular, medical care would probably be unavailable because of the radiation risk of going to a hospital and the tremendous number of patients seeking help at the few hospitals that remained open.

Radiation sickness would present special problems. Exposures too low to cause acute radiation sickness nevertheless weaken bodily resistance to infection. Resistance would also be weakened by a deterioration in sanitation, prolonged exposure to heat or cold, lack of medical care, psychological shock, and inadequate food, water, and medicine. Hence shelterers would be especially vulnerable to contagious diseases, ranging from colds and influenza to typhoid fever. There is a trend in the United States away from immunization; as a result, many would contract diseases they otherwise would not.

While many people would contract radiation sickness and live, it is very difficult for the layman to determine whether an individual showing pronounced symptoms of radiation sickness has received a moderate, severe, or lethal dose of radiation. Moreover, acute psychological shock induces symptoms similar to radiation sickness, and vomiting— a symptom of both— is contagious in small spaces. Thus, someone who vomited would not know if he had received a moderate, severe, or lethal dose of radiation; if he had severe psychological shock; if he had vomited because of contagion; or if he had some other illness. This uncertainty about one's own condition and that of one's loved ones, and nausea itself, would increase the tension in a shelter. Moreover, nausea weakens people.

Some people will be better off than others: people in adequately equipped shelters of good PF; people who are neither very young, very old, or ill; people who have received little or no radiation before entering the shelter; people in less-crowded shelters. Moderate ambient temperature would be better than hot, and hot would be better than cold. People in snow zones in the winter, however, would be more likely than others to have adequate provisions as a precaution against being stranded at home by snow. In addition, much would depend on how shelterers used their time before fallout arrived to prepare the shelter.

Even if the winds were perverse, there would be substantial areas of the country that would receive little or no fallout. **In some cases (e. g.,** Oregon), it would be evident that no fallout could be expected unless the war continued after the counterforce attack; in other cases it would be several days before people in an uncontaminated area were certain that they had been among the lucky ones. Once it became clear that a given area had been spared, the people living there could be expected to step up their normal pace of activity. To the extent possible, help would be offered to the contaminated areas. Depending on circumstances, there might be large numbers of evacuees to care for. The major task, however, would be to keep the country going until the other survivors could emerge from shelters. Intense but rather disorganized activity would be likely, and essential production would probably take place.

Most productive resources would survive unscathed, but would shut down until the threat of attack had ended; those in fallout areas would remain closed until radiation levels had diminished, with the possible exception of such critical services as radio stations, water pumping facilities, and sewage disposal units. Some plants, and some sectors of the economy, would use productive resources as intensively as possible to meet the demands of the damaged areas and the injured, and to compensate for loss of production elsewhere. The burden imposed on the economy by the

Armed Forces would depend on the international situation.

Economic Disruption

Most economic damage would occur from lost production, but there would be other losses as well: fires would burn unchallenged, and machinery would suffer damage from being shut down in haste or not at all, or from being left outside unprotected. The major damage to the economy, however, would result from deaths and long-lasting injuries (to consumers and producers), and persona I tragedies and other traumas making people less able to work. The magnitude of economic loss could be expected to vary with the number of deaths.

The attack would cause considerable economic disruption in the uncontaminated area. Facilities there would need to produce a vastly different mix of goods and cope with the absence of goods that normally come from contaminated areas. Until people acted as if they believed the war was over, it could prove difficult to organize production in the uncontaminated areas. Uncertainties about the legal and financial arrangements that support production (money, contracts, credit, etc.) following a nuclear attack might impede production in the uncontaminated areas. Some workers, fearing further attacks, would spontaneously evacuate. Public disorder could also impede production. The changes and uncertainties would cause some economic disruption; however, the greater effort put forth would probably more than compensate for it.

Recuperation

Economic viability would not be at issue following a counterforce attack. Because the attack seeks no economic damage, it would be far less likely than a deliberate strike on economic targets to create any bottlenecks that would greatly hinder recovery. The Nation would be able to restore production and maintain self-sufficiency. The attack would cause enormous economic loss, but the Nation's capacity for growth would be at worst only slightly impaired. The major task would be ending disruption and disorganization rather than rebuilding the economy — putting the pieces back together. Most likely these tasks would be accomplished by a mixture of individual, local, State, and Federal initiatives, with Federal intervention used as a last resort.

The main problem areas would be:

1. Agriculture. The attack could be expected to destroy a tiny fraction of farmland with blast and fire; of much greater significance, fallout would contaminate a substantial fraction of cropland because many ICBMs are in or near the Great Plains. Other cropland would escape with little or no fallout. It is unlikely that more than a fraction of the livestock in nearby fallout areas would be adequately protected. Fallout would affect agriculture in two ways: by killing livestock and crops, and by preventing farmers from working in the fields.

Damage from fallout contamination of crops would depend on the time of year. Most crops take up relatively little fallout and external irradiation does not contaminate them. Moreover, it is easy enough to remove fallout particles from food. However, the vulnerability of crops to fallout varies significantly with the type of crop and the stage of its growth. For example, yield of various crops can be reduced 50 percent by the following doses, in roentgens (R): peas, less than 1,000 R; rye, 1,000 to **2,000 R; wheat, corn, cucumber, 2,000 to 4,000 R; cotton,** melons, 6,000 to 8,000 R; soybeans, beets, **800 to 12,000 R; rice, strawberries, 12,000 to 16,000 R; and squash, 16,000 to 24,000 R. At the same time, young plants are most vulnerable to radiation, while those near maturity are least vulnerable.**

Knowledge about radiation effects on crops is, however, limited because much more is known about how gamma radiation affects crops than about beta radiation effects. Since fallout emits both types, and since beta doses to plants could be from 1 to **20 times the gamma dose, this is a major uncertainty.**

Fallout would prevent farmers from working in fields for a time. Fallout does decay, and

weathering would further reduce its effects on people. By a year after the attack, fallout would no longer be of consequence to farmworkers in most areas. How soon after the attack they could begin work would depend on the amount of fallout deposited on a field.

The effects would thus depend significantly on time of year. An attack between October and January would have little effect, as fallout would have decayed enough by planting time to permit farmers to work the fields and to avoid serious damage to crops. Radiation on fields could be substantially reduced by plowing the fallout under or by scraping off the top layer of dirt. An attack in February or March would delay planting, reducing crop yields or making it necessary to shift to crops that mature more quickly. An attack between April and June could kill the entire crop. An attack in July or August could conceivably have little effect, if the plants were undamaged by radiation. But the resulting crop should be safe for human consumption in an emergency. An attack during or just before the harvest could result in the loss of the whole crop, not by damaging the plants, but by preventing farmers from harvesting.

Fallout would be more damaging to livestock than to plants. Animals are only slightly more resistant to radiation than are people; for sheep, cattle, and pigs in barns, where they are protected from direct contact with the ingestion of fallout, a dose of 400, 500, and 600 R, respectively, will kill half these animals. The median lethal dose is considerably lower for animals in pastures, where they can eat fallout along with grass. Poultry are considered more resistant; a dose of 850 R will halve the poultry in a barn. Many animals in heavy fallout areas would probably be killed, as farmers generally have no fallout shelters for animals. Moreover, depending on the damage the attack wreaks on human food crops, it might be necessary to use animal feed as human food. The consequence could be that it would take many years to rebuild the national livestock supply, and until then meat would become a scarce luxury.

2. Decontamination. Cities, farms, and factories in contaminated areas would require decontamination in order to reopen for human use. Decontamination involves moving fallout to areas where it can do less harm in order to reduce the dose rate to people in certain places. It can be done with bulldozers, street sweepers, firehoses, brooms, etc. It does, however, require people to place themselves at risk. Would enough people be willing to run these risks? Training is required for people to know that certain doses are tolerable and other doses are not; this training would make people less unwilling to face these risks, but will enough people have received this training?

3. Public health standards would have to be lowered following the attack. in peacetime, standards are often set cautiously; when acceptable exposure risk is unknown, it is preferable to err on the side of safety. Following the attack, that luxury would not be possible. Fields would be farmed while low-level radioactivity persisted; the risks, quite unacceptable in peacetime, would be preferable to starvation. The cost-benefit ratio would change: the benefits of individual safety would need to be weighed against the costs of foregoing critical production. Moreover, how applicable would our knowledge be for setting standards for the entire population after an attack? Could enough instruments be made available to enable everyone to know what dose they were receiving? And what role would politics play in setting standards when “acceptable risk” rather than “negligible risk” was at issue? Society would be running greater risks without knowing just how great the risks were; so doing would increase low-level radiation sickness, cancers, genetic damage, and so on.

4. Burdens on society would increase, removing people from production while increasing demand on production. Many people would suffer long-lasting, permanent, or debilitating injuries. Demands for more military force could well increase. Inefficiencies stemming from economic dislocation would reduce the outputs from any given set of inputs. Decontamination and civil defense would draw resources.

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5. Economic disorganization would be a problem, possibly a severe one. Once people were confident that the war had ended, money would retain its value, and so would property in uncontaminated areas. But the marketplace that organizes the American economy would be severely disrupted by abrupt shifts in demand, abrupt changes in supply, questions about the validity of contracts involving people or things in contaminated areas, etc. In addition, a major question would develop over how to share the losses from the attack in an equitable way.

Long-Term Effects

The main long-term damage would be caused by countersilo strikes, which release the great bulk of radiation even if bomber and missile submarine bases are also attacked. Radiation has long-term health consequences, such as cancers, other illnesses, deaths, and genetic damage, that blast does not.

Similarly, ecological damage would be caused mainly by countersilo attacks; this topic is dealt with in chapter V.

In the long run, the economy would recover, although it would be some decades before the people killed would be "replaced" in either a demographic or an economic sense. There would undoubtedly be permanent shifts in demand (e. g., there might be little market for houses without basements or fallout shelters), and supply of some goods (notably meat) might be scarce for some time.

An imponderable is the psychological impact. The United States has never suffered the loss of millions of people, and it is unlikely that the survivors would simply take it in stride. The suffering experienced by the South in the decade after 1860 **provides the nearest analogy, and a case can be made that these effects took a century to wear off.**

CASE 3: A COUNTERFORCE ATTACK AGAINST THE SOVIET UNION

As in the case of the Soviet counterforce attack on the United States (described in the previous section), the main threat to the civilian population, economy, and society is derived from fallout, while the damage done to the strategic forces is outside the scope of this study. Here too OTA drew on the executive branch for calculations, and here too the uncertainties are very great.

The First Day

Each of the parameters mentioned in the previous section as affecting the damage to the United States would also affect the damage to the Soviet Union. An additional source of variation is pertinent: the U.S. missiles mostly carry smaller warheads than their Soviet counterparts, but U.S. bombers carry weapons with quite high yields. Ground bursts of bomber-carried weapons (which are especially likely in an attack on Soviet bomber bases) would create very large amounts of fallout.

As in the case of a counterforce attack on the United States, sheltering is preferable to evacuation for protection provided there are no subsequent attacks. Depending on the time of year, the Soviets might have more difficulty than the United States in improvising fallout protection (both frozen earth and mud would create problems); on the other hand, Soviet preparations for such sheltering in peacetime are more extensive than their U.S. counterparts.

The executive branch has performed several calculations of fatalities resulting from counterforce attacks, and variations in the assumptions produce a range of estimates. All these studies except one assume a Soviet first strike and a U.S. retaliatory strike. As a result, estimates of Soviet fatalities are lower than they would be for a U.S. counterforce first strike,

partly because the United States would have fewer ICBMS available for a second strike, and partly because the Soviets are more likely to take precautionary civil defense measures before a Soviet first strike than before a U.S. first strike. All of these studies consider only fatalities in the so days following the attack; they exclude later deaths resulting from relatively less intense radiation or the effects of economic disruption.

For both counterforce and countersilo attacks, with an in-place Soviet population, the fatality estimates are very similar: for the former, from less than 1 to 5 percent of the population; for the latter, from less than 1 to 4 percent. The low end results from using smaller weapons air burst, while the high end results from using larger weapons ground burst. A comprehensive counterforce attack can logically be expected to kill more people than the countersilo attack because the latter is a subset of the former. However, other factors have a greater influnce on numbers of fatalities: A full counterforce attack in which the United States deliberately tried to minimize Soviet fatalities by using small weapons air burst, in which winds were favorable, and in which the Soviets had tactical or strategic warning, would kill far fewer people than a counters ilo-only attack in which the United States used one large weapon ground burst against each ICBM silo.

An unpublished Arms Control and Disarmament Agency (AC DA) analysis highlights the importance of sheltering and attack characteristics for fatal ities from a U.S. countersilo attack. One estimate is that, with the urban population 90-percent sheltered and the rural population given a PF of 6, Soviet fatalities would range from 3.7 million to 13.5 million, depending on attack parameters. With a degraded shelter posture (urban population 10-percent sheltered and rural population given a PF of 6), fatality estimates for the same set of attacks range from 6.0 m i l l ion to 27.7 million.

The Shelter Period

If bomber bases (or airfields with long runways that were attacked even though r-to bombers were present) are attacked, tactical warning could be of great importance to people living nearby. There would be an area near each base (roughly, the area more than 1 mile [2 km] but less than 10 miles [16 km] from a surface burst) in which people who were sheltered at the moment of the blast would have a much greater chance of survival than those who were unsheltered. Soviet civil defense plans envisage that civilians in such high-threat areas would receive some warning, but it cannot be said to what extent this would actually be the case.

Many millions of Soviet citizens live in areas that would receive substantial amounts of fallout from such an attack. Those far enough away from the explosions to be safe from blast darnage would have some time (a range from 30 minutes to more than a day) to shelter themselves from fallout, but evacuation from high-faliout areas after the attack would probably not be feasible. The Soviet civil defense program gives attention to blast shelters rather than fallout shelters in urban areas (see chapter I I l), and while such blast shelters would offer good protection against fallout, some of them may not be habitable for the necessary number of days or weeks for which protection would be required.

The sheltering process would be much more tightly organized than in the United States. The Soviet Government has extensive civil defense plans, and while Americans would expect to try to save themselves under general guidance (informational in character) from the Federal authorities, Soviet citizens would expect the Government to tell them what to do. This introduces a further uncertainty: efficient and timely action by the authorities would be very effective, but it is also possible that Soviet citizens would receive fatal radiation doses while waiting for instructions or following mixed-up instructions. In any event, some hours after the attack would see a situation in which a large number of people in contaminated areas were in fallout shelters, others were receiving dangerous doses of radiation, and those outside the fallout areas were congratulating themselves on their good luck

while hoping that no further attacks would take place.

Would Soviet shelterers be better off than their American counterparts? They have several advantages. They are more accustomed to crowding and austerity than are Americans, so would probably suffer less "shelter shock. " They would be more accustomed to following Government orders, so to the extent that orders proved correct and were correctly implemented, they would be more evenly distributed among shelters. Training in first aid and civil defense is widespread, which would improve people's ability to survive in shelters. If the U.S. attack used low-yield warheads, fallout would be less widespread and less intense.

Soviet shelterers face some problems that Americans would not. They would be more vulnerable than Americans to an attack in winter. The Soviet economy has less "fat," so other things being equal, Soviet citizens could bring less food and supplies into shelters than could Americans.

Public health is a major uncertainty. To the extent that shelters are well stocked, provided with adequate medications and safe ventilation, have necessary sanitary facilities, are warm and uncrowded, and have some people with first aid knowledge, health would be less of a problem. If Soviet citizens receive less fallout than Americans, they would be less weakened by radiation sickness and more resistant to disease. If conditions were austere but reasonably healthy, public health in shelters would be mainly a matter of isolating ill people and practicing preventive medicine for the others. Doctors would be unnecessary for most such tasks; people trained in first aid, especially if they have some access (by phone or radio) to doctors, could perform most tasks. To be sure, some people would die from being untreated, but the number would be relatively small if preventive care worked. However, isolating the ill would not be easy. It is likely that many people would be moderately ill (from flu, etc.) when they entered their shelter, and radiation would make the others more susceptible to contamination. The Soviet Government might send medical teams to contaminated areas, especially to shelters containing workers with key skills. The Soviet Army has built tanks and some other military vehicles with protection against fallout, and has trained its soldiers for operations in areas contaminated with fallout. In addition, as in the United States, military helicopters could ferry people and supplies into contaminated areas with limited exposure to crews. Using such resources would obviously improve health of shelterers, but priority military tasks might make these military resources unavailable.

People in hasty shelters, if they could be built, would face worse health problems, despite the legendary ability of Russians to endure hardships. Presumably these shelters would have inadequate supplies, heat, air filtration, sanitary facilities, waterproofing, and so on. Placing people in a cold, damp hole in the ground for 2 weeks with little food and makeshift toilets would make many people sick even in peacetime; how well would such problems be overcome in war?

Soviet civil defense presents a large question mark. Some believe that the Soviets have massive food stockpiles, meticulous plans detailing where each person should go, ample shelter spaces, subways and buildings convertible to shelters, and so on that would be valuable in the shelter period. Others contend that these claims are vastly overstated and confuse speculation about a plan with its existence and the existence of a plan with its operational effectiveness. (See chapter III on civil defense.) If Soviet civil defense works well, it would save many lives; if it doesn't, Soviet shelterers would face conditions at least as hazardous as their American counterparts.

Agricultural losses would, as in the United States, depend on the time of the year when the attack came and on the precise patterns of fallout. In general, Soviet agriculture appears more vulnerable because it borders on inadequacy even in peacetime–even relatively minor damage would hurt, and major crop losses could be catastrophic. On the other hand, for this very reason the Soviets would

know how to handle agricultural shortages: surviving production and stockpiles (the extent of Soviet food stockpiles is a matter of controversy, apart from the fact that they are lowest just before each harvest) would probably be used efficiently.

The economy outside the contaminated area would continue to function. There would be more than enough industrial facilities in uncontaminated areas to keep necessary production going. The key task facing Government planners, however, would be using available workers and resources to best advantage. How fast could planners generate new economic plans that were detailed enough for that task? Because the Soviet economy operates closer to the margin than does that of the United States, the Soviets could tolerate less loss of production than could the United States. This would make superproduction the norm, with key factories working all the time. It would lead to suspending production of many consumer goods. It would probably lead the Covernment to begin decontamination earlier and to take more risks with radiation exposure than would the United States. These actions to increase production would be aided in general by the Government's control of the economy, and in particular by keeping work groups together in shelters and host areas.

Recuperation

As in the United States, economic viability would not be threatened. The key question, which would begin to be answered in the shelter period, is how appropriate Soviet emergency plans are and how rapidly planning mistakes could be corrected. Major shifts, and the inefficiencies that accompany them, would be inevitable. To what extent could planning minimize them? Could a command economy do better under the circumstances than a mixed economy? The Soviet Union's long experience with central planning would mean that the changes would involve details within the existing system rather than changing from one economic system to another.

In the U. S. S. R., as in the United States, the crop loss caused by the attack would depend on season, fallout deposition, which crops were hit by fallout, and so on. Similarly, the amount of food reserves would vary with the season. The immediate goal for agriculture would be to send adequate food supplies to cities. Presumably, the Government would try to meet this goal by tightening controls rather than by giving farmers more capitalistic incentives. For a moderate attack like this one, with little physical damage, controls would probably work.

It is questionable whether adequate labor would be available for agriculture. Depending on the situation, millions of men might be mobilized into the Army. On the other hand the Soviets have well-established procedures for getting military personnel, factory workers, and others to help with harvests; moreover, following a nuclear attack, some workers in nonessential industries would be out of work, and could be sent to farms. The large number of farmers (perhaps 35 to 40 percent of the Soviet work force is in agriculture, compared to 2 or 3 percent in the United States), the fallout contaminating some farmland, and accepting more exposure to radiation would increase the Soviet population's exposure to radiation.

If a year's crop were lost, would there be austerity, short rations, or starvation? How much surplus food is there? In particular, would there be enough to maintain a livestock industry, or would meat be seen as a nonessential consumer good and feed grains diverted for human use?

As in the United States, the attack would create many burdens for the Soviet economy. Military expenditures would probably increase; people injured by the attack would need care, and fewer people would be alive and well to care for them; major changes in the economy would cause inefficiencies; lowered public health standards would increase early production at the expense of later health burdens.

The Soviet Union would not face certain problems that a market economy faces. The legal and financial devices supporting production – money, credit, contracts, and ownership of productive resources — would be far less important than in the United States. Instead, Soviet production would be guided by a central plan. There are reports that contingency planning has been done for postwar recuperation; such contingency plans (or the peacetime plan if there are no applicable contingency plans) would have to be adjusted to take account of the actual availability of surviving workers and economic assets. Without doubt such adjustments would be made, though there would be some waste and inefficiency.

Long-Term Effects

Chapter V discusses the likely long-term health hazards from such an attack.

All things considered, an attack of this nature could be somewhat less damaging than World War II was to the Soviet Union, and Soviet recovery from that conflict was complete. However, it helped that in 1945 the Soviets were victorious and able to draw on resources from Eastern Europe. Much would depend on whether the aftermath of this attack found the Soviet people pleased or appalled at the results of the war and on the relative power and attitudes of the Soviets' neighbors.

CASE 4: A LARGE SOVIET ATTACK ON U.S. MILITARY AND ECONOMIC TARGETS

This case discusses a massive attack that one normally associates with all-out nuclear war. The attack uses thousands of warheads to attack urban-industrial targets, strategic targets, and other military targets. The number of deaths and the damage and destruction inflicted on the U.S. society and economy by the sheer magnitude of such an attack would place in question whether the United States would ever recover its position as an organized, industrial, and powerful country.

OTA favored examining purely retaliatory strikes for both sides, but all of the available executive branch studies involved Soviet pre emption and U.S. retaliation. However, the differences between a Soviet first strike and a retaliation do not appear to be appreciably large in terms of damage to the civilian structure. Like the United States, the Soviets have a secure second-strike force in their SLBMs and are assumed to target them generally against the softer urban-industrial targets. Moreover, a U.S. first strike would be unlikely to destroy the bulk of Soviet ICBMs before they could be launched in retaliation.

The effects of a large Soviet attack against the United States would be devastating. The most immediate effects would be the loss of millions of human lives, accompanied by similar incomprehensible levels of injuries, and the physical destruction of a high percentage of U.S. economic and industrial capacity. The full range of effects resulting from several thousand warheads — most having yields of a megaton or greater— impacting on or near U.S. cities can only be discussed in terms of uncertainty and speculation. The executive branch studies that addressed this level of attack report a wide range of fatality levels reflecting various assumptions about the size of the attack, the protective posture of the population, and the proportion of air bursts to ground burst weapons.

The DOD 1977 study estimated that 155 million to 165 million Americans would be killed by this attack if no civil defense measures were taken and all weapons were ground burst. DCPA looked at a similar attack in 1978 where only half the weapons were ground burst; it reduced the fatality estimate to 122 million. ACDA's analysis of a similar case estimated that 105 million to 131 million would die.

If people made use of existing shelters near their homes, the 155 million to 165 million

fatality estimate would be reduced to 110 million to 14s million, and the 122 million fatalities to 100 million. The comparable ACDA fatality estimate drops to 76 million to 85 million. Again ACDA gets a lower figure through assuming air bursts for about 60 percent of the incoming weapons. Finally, if urban populations were evacuated from risk areas, the estimated prompt fatality levels would be substantially reduced. The DOD study showed fatalities of 40 million to 55 million, with DCPA showing a very large drop to 20 million from the 100 mill ion level. The primary reason for the 2-to-1 differential is the degree of protection from fallout assumed for the evacuated population.

In summary, U.S. fatality estimates range from a high of 155 million to 165 million to a low of 20 million to 55 million. Fatalities of this magnitude beg the question of injuries to the survivors. None of the analyses attempted to estimate injuries with the same precision used in estimated fatalities. However, DCPA did provide injury estimates ranging from 33 million to 12 million, depending on circumstances. An additional point worth noting is that al I of the fatality figures just discussed are for the first 30 days following the attack; they do not account for subsequent deaths among the injured or from economic disruption and deprivation.

The First Few Hours

The devastation caused by a single l-Mt weapon over Detroit (chapter I I), and of two similar weapons denoted near Philadelphia, have been described. In this attack the same destruction would take place in 30 or so other major cities (with populations of a million or greater). Many cities with smaller populations would also be destroyed. The effects on U.S. society would be catastrophic.

The majority of urban deaths will be blast induced, e.g., victims of collapsing buildings, flying debris, being blown into objects, etc. Except for administering to the injured, the next most pressing thing (probably ahead of handling the dead) for most survivors would be to get reliable information about what has occurred, what is taking place, and what is expected. Experience has shown that in a disaster Situation, timely and relevant information is critical to avoiding panic, helpful in organizing and directing productive recovery efforts, and therapeutic to the overall psychological and physical well being of those involved. Presumably, the civil preparedness functions would be operating well enough to meet some of this need.

Rescuing and treating the injured will have to be done against near insurmountable odds. Fire and rescue vehicles and equipment not destroyed wil I find it impossible to move about in any direction. Fires will be raging, water mains will be flooding, powerlines will be down, bridges will be gone, freeway overpasses will be collapsed, and debris will be everywhere. People will be buried under heavy debris and structures, and without proper equipment capable of lifting such loads, the injured cannot be reached and will not survive. The fortunate ones that rescuers can reach will then be faced with the unavailability of treatment facilities. Hospitals and clinics in downtown areas would likely have been destroyed along with most of their stocks of medical supplies. Doctors, nurses, and technicians needed to man makeshift treatment centers are likely to have been among the casualties. The entire area of holocaust will be further numbed by either the real or imagined danger of fallout. People will not know whether they should try to evacuate their damaged city, or attempt to seek shelter from fallout in local areas and hope there will be no new attacks. No doubt some of both would be done.

If this situation were an isolated incident or even part of a small number of destroyed cities in an otherwise healthy United States, outside help would certainly be available. But if 250 U.S. cities are struck and damaged to similar levels, then one must ask, “Who is able to help?” Smaller towns are limited in the amount of assistance they can provide their metropolitan neighbors. It is doubtful that there would be a strong urge to buck the tide of evacuation

in order to reach a place where most of the natives are trying to leave. Additionally, the smaller cities and towns would have their own preparedness problems of coping with the anticipated arrival of fallout plus the influx of refugees. In light of these and other considerations, it appears that in an attack of this magnitude, there is likely not to be substantial outside assistance for the targeted areas until prospective helpers are convinced of two things: the attack is over, and fallout intensity has reached safe levels. Neither of these conditions is likely to be met in the first few hours.

The First Few Days

Survivors will continue to be faced with the decision whether to evacuate or seek shelter in place during this interval. The competence and credibility of authority will be under continuous question. Will survivors be told the facts, or what is best for them to know, and who decides? Deaths will have climbed due to untreated injuries, sickness, shock, and poor judgement. Many people will decide to attempt evacuation simply to escape the reality of the environment. For those staying, it likely means the beginning of an extended period of shelter survival. Ideally, shelters must protect from radiation while meeting the minimums of comfort, subsistence, and personal hygiene. Convincing people to remain in shelters until radiation levels are safely low will be difficult, but probably no more so than convincing them that it is safe to leave on the basis of a radiation-rate meter reading. There will be unanswerable questions on long-term effects.

Sheltering the survivors in the populous Boston to Norfolk corridor will present unprecedented problems. Almost one-fifth of the U.S. population lives in this small, 150- by 550-mile [250 by 900 km] area. Aside from the threat of destruction from direct attack, these populations are in the path of fallout from attacks on missile silos and many industrial targets in the Pittsburgh, St. Louis, and Duluth triangle. Depending on the winds at altitude, the fallout from the Midwest will begin arriving 12 to 30 hours after the attack.

At the time when fallout radiation first becomes intense, only a fraction of the surviving urban population will be in adequate fallout shelters. Those that are sheltered will face a variety of problems: making do with existing stocks of food, water, and other necessities or else minimizing exposure while leaving the shelter for supplies; dealing with problems of sanitation, which will not only create health hazards but also exacerbate the social tensions of crowds of frightened people in a small space; dealing with additional people wanting to enter the shelter, who would not only want to share scarce supplies but might bring contamination in with them; dealing with disease, which would be exacerbated not only by the effects of radiation but by psychosomatic factors; and finally judging when it is safe to venture out. Boredom will gradually replace panic, but will be no easier to cope with. Those with inadequate shelters or no shelters at all will die in large numbers, either from lethal doses of radiation or from the combination of other hazards with weakness induced by radiation sickness.

The conditions cited above are generally more applicable to urbanites who are trying to survive. The problems of rural survivors are somewhat different, some being simpler—others more complex. With warning, people living in rural areas could readily fabricate adequate fallout shelters. However, it might be more diifficult for a rural shelteree to have current and accurate information regarding fallout intensity and location. The farm family is likely not to have suffered the traumatic exposure to death and destruction, and consequently is probably better prepared psychologically to spend the required time in a shelter. (Possible consequences to livestock and crops are addressed later in this section.)

Outdoor activity in or near major cities that were struck would likely be limited to emergency crews attempting to control fires or continuing to rescue the injured. Crews would wear protective clothing but it would be necessary to severely limit the total work hours of any one crew member, so as not to risk dangerous accumulations of radiation. Areas not

threatened by fallout could begin more deliberate fire control and rescue operations. Whether a national facility would survive to identify weapons impact points and predict fallout patterns is doubtful.

The extent of death and destruction to the Nation would still be unknown. For the most part, the agencies responsible for assembling such information would not be functioning. This task would have to wait until the numbing effect of the attack had worn off, and the Government could once again begin to function, however precariously.

The Shelter Period (Up to a Month)

As noted earlier, after the initial shock period, including locating and getting settled in shelters, the problem of sheltering large masses of people will be compounded as the shelter time extends. Survival will remain the key concern. People will experience or witness radiation death and sickness for the first time. Many previously untreated injuries will require medical attention, if permanent damage or death to the individual is to be avoided. Stockpiles of medical, food, and water supplies are sure to become items of utmost concern. Whether some people can safely venture outside the shelter for short periods to forage for uncontaminated supplies will depend on fallout intensity, and the availability of reliable means of measuring it.

This period will continue to be marked by more inactivity than activity. Many areas will have been freed from the fallout threat either by rain, shifting winds, or distance from the detonations. But economic activity will not resume immediately. Workers will remain concerned about their immediate families and may not want to risk leaving them. Information and instruction may not be forthcoming, and if it is, it may be confusing and misleading, and of little use. Uncertainty and frustration will plague the survivors, and even the most minor tasks will require efforts far out of proportion to their difficulty. Many will interpret this as symptomatic of radiation effects and become further confused and depressed. The overall psychological effects will likely worsen until they become a major national concern, perhaps on the same level with other incapacitating injuries.

Deaths occurring within the first 30 days of an attack are categorized as prompt fatalities. This duration is a computation standard more than it is related to specific death-producing effects, and is the basis for most fatality estimates. However, deaths from burns, injuries, and radiation sickness can be expected to continue far beyond this particular interval.

The Recuperation Period

Whether economic recovery would take place, and if so what form it would take, would depend both on the physical survival of enough people and resources to sustain recovery, and on the question of whether these survivors could adequately organize themselves.

Physical survival of some people is quite probable, and even a population of a few million can sustain a reasonably modern economy under favorable circumstances. The survivors would not be a cross-section of prewar America, since people who had lived in rural areas would be more likely to survive than the inhabitants of cities and suburbs. The surviving population would lack some key industrial and technical skills; on the other hand, rural people and those urban people who would survive are generally hardier than the American average.

While the absolute level of surviving stocks of materials and products would seem low by prewar standards, there would be a much smaller population to use these stocks. Apart from medicines (which tend to have a short shelf life and which are manufactured exclusively in urban areas), there would probably not be any essential commodity of which supplies were desperately short at first. A lack of medicines would accentuate the smallness and hardiness of the surviving population.

Restoring production would be a much more difficult task than finding interim stockpiles. Production in the United States is extremely complex, involving many intermediate stages.

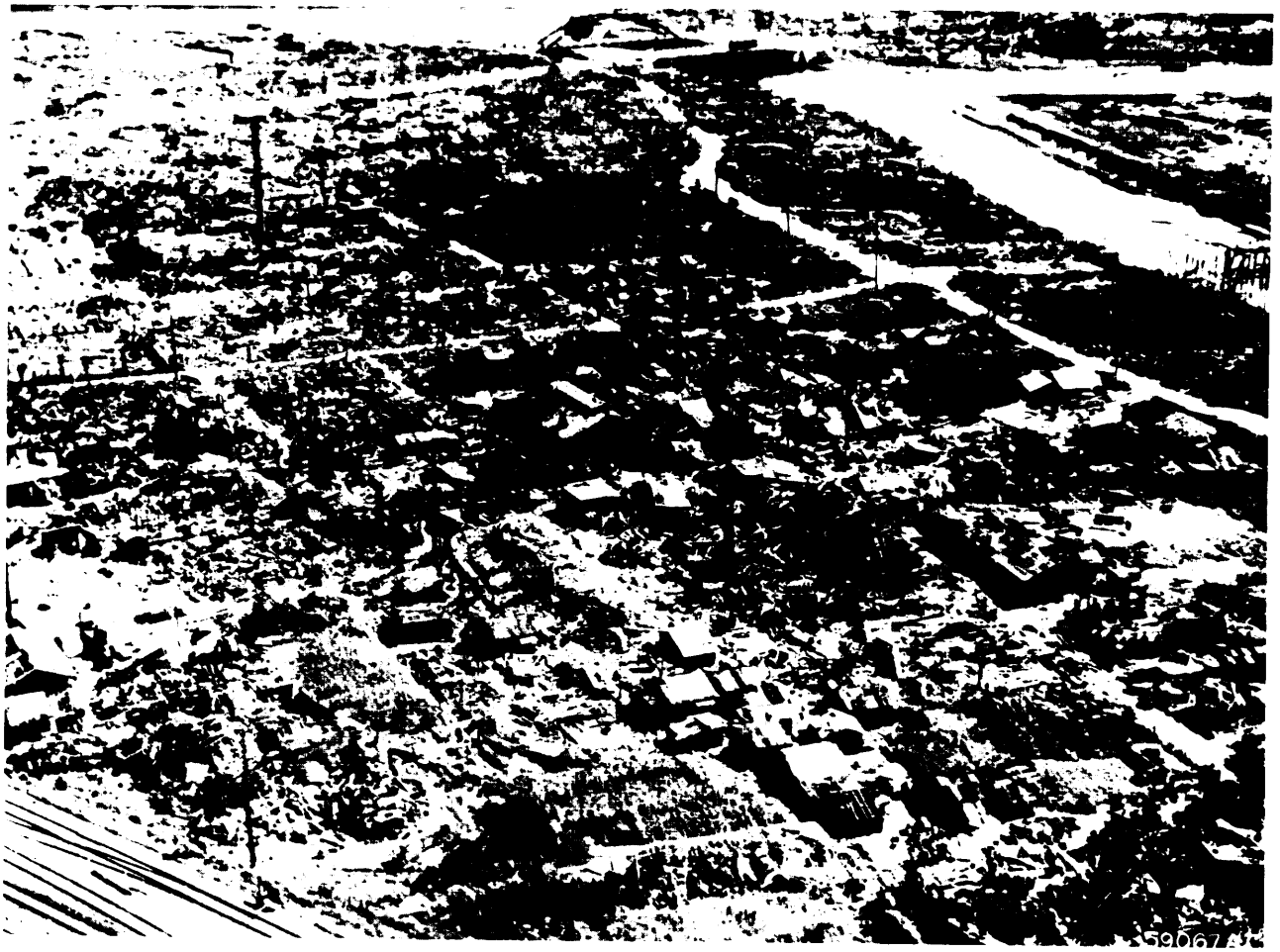

Photo credit: U.S. Air Force

A part of Hiroshima after atomic blast

New patterns of production, which did not rely on facilities that have been destroyed, would have to be established.

It cannot be said whether the productive facilities that physically survived (undamaged or repairable with available supplies and skills) would be adequate to sustain recovery. It seems probable that there would be enough equipment and that scavenging among the ruins could provide adequate "raw materials" where natural resources were no longer accessible with surviving technology.

The most serious problems would be organizational. Industrial society depends on the division of labor, and the division of labor depends on certain governmental functions, Physical security comes first—a person is reluctant to leave home to go to work without some assurance that the home will not be looted. While some degree of law and order could probably be maintained in localities where a fairly dense population survived, the remaining highways might become quite unsafe, which would reduce trade over substantial distances. The second requirement is some form of payment for work. Barter is notoriously inefficient. Payment by fiat (for example, those who work get Government ration cards) is inefficient as well, and requires a Government stronger than a postwar United States would be likely to inherit. A strong Government might grow up, but most survivin, citizens would be reluctant to support a dictator-

ship by whatever name. The best solution is a viable monetary system, but it would not be easy to establish. Regions or localities might develop their own monies, with "foreign" trade among regions.

The surviving resources might not be used very efficiently. Ideally one would want to conduct a national survey of surviving assets, but the surviving Government would probably not be capable of doing so, especially since people would fear that to acknowledge a surviving stock was to invite its confiscation. To make use of surviving factories, workers would have to live nearby, and they might be unwilling to do so in the absence of minimally adequate housing for their families. Ownership of some assets would be hopelessly confused, which would diminish the incentives for investment or even temporary repairs.

There is a possibility that the country might break up into several regional entities. If these came into conflict with each other there would be further waste and destruction.

In effect, the country would enter a race, with economic viability as the prize. The country would try to restore production to the point where consumption of stocks and the wearing out of surviving goods and tools was matched by new production. If this was achieved before stocks ran out, then viability would be attained. Otherwise, consumption would necessarily sink to the level of new production and in so doing would probably depress production further, creating a downward spiral. At some point this spiral would stop, but by the time it did so the United States might have returned to the economic equivalent of the Middle Ages.

The effect of an all-out attack would be equally devastating to the U.S. social structure. Heavy fatalities in the major urban areas would deprive the country of a high percentage of its top business executives, Government officials, medical specialists, scientists, educators, and performers. There is no measure for estimating the impact of such lasting losses on our society. In addition to the irreplaceable loss of genius and talents, the destruction of their associated institutions is still another compounding of effects that is overlooked by some recovery estimates. Who could calculate how long to *get over the loss* of Wall Street, an MIT, a Mayo Clinic, and the Smithsonian?

The American way of life is characterized by material possessions, with private ownership of items representing substantial long-term investments (such as homes, businesses, and automobiles) being the rule rather than exception. Widespread loss of individual assets such as these could have a strong, lasting effect on our social structure. Similarly, the question of whether individual right to ownership of surviving assets would remain unchanged in a postattack environment would arise. For example, the Government might find it necessary to force persons having homes to house families who had lost their homes.

The family group would be particularly hard hit by the effects of general nuclear war. Deaths, severe injuries, forced separation, and loss of contact could place inordinate strains on the family structure.

Finally, major changes should be anticipated in the societal structure, as survivors attempt to adapt to a severe and desponding environment never before experienced. The loss of a hundred million people, mostly in the larger cities, could raise a question on the advisability of rebuilding the cities. (Why reconstruct obvious targets for a nuclear Armageddon of the future?) The surviving population could seek to alter the social and geopolitical structure of the rebuilding nation in hopes of minimizing the effects of any future conflicts.

How well the U.S. political structure might recover from a large-scale nuclear attack depends on a number of uncertainties. First, with warning, national level officials are presumed to evacuate to outlying shelter areas; State and local authorities will take similar precautions, but probably with less success, especially at the lower levels. The confidence and credibility of the system will come under severe strains as relief and recovery programs are imple mented. Changes in an already weakened

structure are sure to result as many normal practices and routines are set aside to facilitate recovery. Survivors may demand more immediate expressions of their likes, dislikes, and needs. Widespread dissatisfaction could result in a weakening of the Federal process, leading to a new emphasis on local government. An alternative possibility is martial law, which might be controlled in theory but decentralized in practice.

All of this assumes that there would be no significant ecological damage, a possibility discussed in chapter V. Chapter V also discusses long-term health hazards.

CASE 4: A LARGE U.S. ATTACK ON SOVIET MILITARY AND ECONOMIC TARGETS

A U.S. retaliatory attack against the Soviet Union would destroy 70 to 80 percent of its economic worth. The attacking force would consist primarily of U.S. strategic bombers and Poseidon/Polaris SLBMs, since most U.S. land-based ICBMs are assumed lost to a Soviet first strike. Bombers carry gravity bombs and short-range attack missiles having yields of about 1 Mt and 200 kt respectively. Poseidon SLBMs nominally carry up to 10 RVs of 40 kt each.

The attack would strike the full set of Soviet targets —strategic offensive forces, other military targets, economic targets, and cities. Population would in fact be struck, although killing people would not be an attack objective in itself. The objectives would be to cause as much industrial damage as possible and to make economic recovery as difficult as possible. The attacks might not be limited in time. Concentrations of evacuees would probably not be struck, but industries that recovered very quickly after the attack could be.

The immediate effects of the attack would be death and injury to millions of Soviet citizens, plus the destruction of a large percentage of Soviet economic and industrial capacity. As with the all-out Soviet attack, the executive branch studies provided a wide range of casualty estimates. Since the thrust of those analyses was to look at the potential effectiveness of Soviet civil defense, casualties were estimated under various assumptions re lated to the posture of the population.

If the Soviet population remained in-place, fatality estimates range from a high of 64 million to 100 million (26 to 40 percent of the Soviet population) to a low of 50 million to 80 million (20 to 32 percent). The high-value range is due to the different data bases used by DOD and ACDA and the higher protection levels assumed by AC DA. The low-value range results from the use of day-to-day alert status by the interagency intelligence study as compared to ACDA's use of generated forces, and the types of weapons used against the economic target base in the two studies. With evacuation, the ACDA study estimated that fatalities would be reduced to 23 million to 34 million. It is difficult to judge whether these figures represent a high or low estimate. They could be considered as representing the low side because of the coarseness of Soviet data as used by ACDA. On the other hand, some would say that the evacuation scheme assumed by ACDA was unrealistic, and the results should be considered a high estimate. Nevertheless, Soviet fatalities are lower than the United States for both in-place and evacuated population postures. The lower Soviet fatalities are again primarily due to major differences in the yields of the weapons detonating in each country, and to the greater proportion of Soviet population that lives in rural areas.

As to the cause of fatalities (blast, thermal radiation, and direct nuclear radiation versus fallout radiation), DCPA data suggests that, in large attacks, that is, attacks that include economic or economic and population targets, fatalities are primarily due to prompt effects as opposed to fallout. Prompt effects account for at least 80 percent of the fatalities for all population postures when economic targets or population are included in the attack. ACDA

notes a similar result in its study for attacks that include counterforce and other military targets. The reason for this is that in attacks on targets near urban areas, that is, attacks involving economic targets or population, those protected enough to survive the blast effects also have enough protection to survive the fallout. Conversely, those who do not have enough protection against fallout in urban areas near targets will not have enough protection against prompt effects and will already be dead before fallout has an effect.

Estimates of Soviet injuries were generally not included in the analyses. However, one study suggested that injuries might be roughly equal to fatalities under certain attack and exposure assumptions.

The First Few Hours

As chapter **11** I notes, Soviet civil defense can have substantial impact on the full range of effects. Fallout shelters, blast shelters, and industrial hardening can reduce the overall damage from nuclear attack. First aid and civil defense training can ameliorate health problems. Storing supplies in shelters lengthens shelter stay time. Thus, the issue is how well Soviet civil defense would in fact work. Many unknowns— numbers of shelters, amount of food and medicine stock piles, small er amounts of surplus resources than the United States–prevent a judgment in detail. It seems safe to assume, however, that Soviet civil defense measures would be at least as effective as U.S. measures and probably better.

Preattack preparations would have a decided influence on damage caused. Since a U.S. retaliatory attack is by definition preceded by a Soviet first strike, it would seem logical that some evacuation would have occurred. However, there are reasons why evacuation might not have taken place. These include the following Soviet concerns: an evacuation could increase the risk of a U.S. attack; the U.S. attack might be so close at hand that an evacuation could increase casualties; a prolonged evacuation might be such an economic disruption that it would be better to wait until war appeared certain; or war through miscalculation. In any event, a Soviet decision to strike first would allow the Soviets to make preparations—distribute supplies, improve and stock shelters, increase production of essential goods, harvest grain, protect livestock, conduct civil defense training, harden industrial facilities, and so on. These actions would also make Soviet citizens more responsive to civil defense instructions, especially to a warning that an attack was underway. While these actions would be observed by the United States, they would be more ambiguous than an evacuation, so the United States could see them as safeguarding against an attack rather than preparing for one.

The effects of evacuation in reducing casualties could be diluted to some extent by varying U.S. attack strategy. Spreading the attack over a period of time could extend shelter periods, enhance economic disruption, and delay rescue and emergency operations.

The Soviet Union, despite its vast geographical size, is vulnerable to an urban/industrial attack in many of the same ways as the United States. Although there has been extensive publicity on their reported dispersal of industry, indications are that population and industry are becoming more and more concentrated. While some industries may have been moved away from cities, many others have been built near cities. Indeed, some of the industries recently built away from cities are themselves so concentrated that they form new targets of their own. Hedrick Smith describes

> the Kama River Truck Plant as an archetype of the gigantomania of Soviet planners, as a symbol of the Soviet faith that bigger means better and the Soviet determination to have the biggest at any cost.
>
> Kama is the kind of massive crash project that appeals to Russians. It emanates brute strength. In 1971, Soviet construction brigades started from scratch to build the world's largest truck plant in the open, rolling, windswept plains about **600** miles east **of** Moscow Kama was not just one factory but six, all huge The production complex, costing **in** the **billions,** occupies 23 square miles, an area larger than the entire island of Manhat-

tan. At full capacity, Kama is slated to produce 150,000 heavy trucks and 250,000 diesel engines a year, dwarfing anything in Detroit or the German Ruhr.[6]

The attack could cause "derussification. " The U.S.S.R. is a nation of nationalities, of which Great Russians — who dominate politics, industry, and much else— comprise about 48.5 percent of the population. Most Great Russians live in cities, so an attack would reduce their numbers and influence. Derussification could weaken Great Russians' control of the U. S. S. R., with unforeseeable consequences.

Timing makes a critical difference in destruction. An attack at night would have people with their families and more dispersed; they would seek shelter in apartment buildings. An attack during the day would strike people at factories and offices; to the extent they left to find family members, chaos would result as in the United States, but to the extent they sought shelter at work, they would be organized by economic task. Such organization would be useful for postattack recovery.

An attack in winter would expose more people to bitter cold and impede evacuation; an attack in spring or fall, when many roads are made impassable by mud, would hinder evacuation by motor vehicle. An attack near harvest time could result in the loss of an entire year's crop, thus leaving food reserves at a low point. This effect could be magnified if the United States attacked agricultural targets, such as storage silos, dams, and drainage facilities.

Even time of month makes a difference because of the Soviet practice of "storming." The Soviet factory month in practice divides into three periods: "sleeping," the first 10 days; "hot" work, the second 10; and "feverish" work, the third. This division occurs because the economic plan calls for a specified output from each plant by the end of the month, but the inputs needed often arrive only after the 15th or 20th of the month. Thus, perhaps 80 percent of a factory's output is produced in the last 10 or 15 days of the month. (This 80 percent is typically of such reduced quality that Soviet consumers often refuse to buy merchandise made after the 20th of a month.) Hypothetically, an attack around the 15th or 20th of a month would cause the loss of most of a month's production, and would destroy the large inventory in factories of partially completed goods and of inputs that cannot be used until other inputs arrive.

On the other hand, the U.S.S.R. has several strengths. Cities are in general less flammable than U.S. cities, as there are more large apartment buildings and fewer wood frame houses. These buildings would also provide better shelter, especially those that have shelters built in. People would expect to follow instructions and would be less likely to evacuate spontaneously. The Party apparatus would probably survive with a far lower casualty rate than the population at large because it is well distributed and because blast shelters have been constructed for party members. Russians are likely to be less traumatized by shelter conditions, as they are more accustomed to austerity and crowding. The nation is larger, which in theory provides more land area over which people could relocate, but much of the area is mountain, desert, or arctic.

The First Few Days

Actions in this period would greatly affect the number of casualties and the amount of economic damage. Obviously, much damage would have been caused in the first hour. Many people trapped in the rubble could be rescued, would be seriously injured but could survive with medical care or first aid, would be able to seek shelter or evacuate, could prepare hasty fallout shelters, could improve existing shelters, and so on. Some industries would be damaged but not destroyed; if small fires were extinguished, undamaged equipment hardened against blast, exposed equipment protected from rust, and so on, more resources would be available for recovery. Likewise, farms could harvest crops, shelter livestock,

[6] Hedrick Smith, *The Russians* (New York: Ballantine Books, 1977), p. 241.

and protect harvested crops in the few days before fallout deposition.

The issue is not what could be done but what would be done. Proper use of time— organization and prioritization to get the most important tasks done with the least wasted effort and resources—would be critical. The Soviet system offers a major advantage in this period. As we noted in the case of a counterforce attack, the Government's role in this crisis would be more clearly defined, and its control over individual action and the economy would be much stronger than that of the U.S. Government in a comparable situation. Its experience with central planning and a command economy would be good preparation for the actions needed —decisions involving large shifts in behavior and resources, obeyed without argument. Its decisions would save some people and industries and condemn others, but delay in order to make better decisions could easily condemn more. Evacuation would have to be ordered in this period, or else would-be evacuees would have to wait until radiation had reached safe levels. For cities damaged only slightly, evacuation would prove difficult but not impossible. With many rail yards and some key bridges out, it would be difficult to get trains to smaller cities. Destruction of petroleum refineries, some petroleum storage capacity (especially that located in rail marshaling yards that were attacked), and some electric power generators, would further impede evacuation by train. Fallout contours would be difficult to predict, so it would be hard to select the best evacuation routes and relocation centers. An attack in winter would add other problems.

Survivors in Soviet cities would face the same severe problems as those in U.S. cities. Many would be injured, trapped in rubble, irradiated with initial nuclear radiation, etc. Many shelters would be destroyed or damaged. Power would be out, so water pressure would be too low for fighting fires. Rubble would impede rescue.

Undamaged areas, especially those not threatened by heavy fallout, would face severe burdens. They would receive many evacuees in the first few days, would send rescue teams and resources to devastated areas, and would strive to produce as much as possible. Evacuees in undamaged areas would be pressed into work in fields and factories, and would be sheltered in public buildings or private homes. The performance of undamaged areas would thus largely determine the nation's ability to prosecute the war and to achieve economic viability. The Government would, however, face a dilemma in how to use resources surviving in undamaged areas: it could maximize current production, leaving workers and resources vulnerable to further attacks, or it could seek to protect workers and resources, thus reducing current production. The specific choices would depend on the likelihood of further attacks, criticality of various products, and so forth, but the dilemma would stand.

An all-out attack would exacerbate the inefficiencies that Soviet industry has in peacetime. The Government would have to decide what it needed to have produced, and whether the factories existed to have them produced. The Government would have far more difficulty correlating inputs and outputs and arranging for their transportation. It would have to assign people to jobs, and arrange to transport, shelter, and care for workers. Many workers would be sick, in shelters, killed, traumatized, or debilitated by radiation sickness. However, the Government would probably be able to control what movement of people did take place. Even in peacetime, the Government has very high control over mobility. People are not in the habit of going anywhere without permission, and everyone's actions must be justified and accounted for. There is little independent travel. The internal passport system strengthens these controls. I n wartime, the Government would presumably strengthen its control of transportation. People would have nowhere to go where they could be sure of shelter from fallout unless the Government arranged their transportation and shelter. This control would

help the Government maintain economic organization following attack.

The Shelter Period

By all reports, the Soviets are better prepared than Americans to spend extended periods of time in shelters. In their literature well-conceived protective structures are seen that should afford good survivability. Life in shelters and evacuation areas would in some ways be similar to that described in earlier cases. Actions taken before fallout deposition would affect casualties. Public health, number and quality of shelters, and amount of food and medicine stockpiled are uncertainties. Civil defense and first aid training would mitigate deaths, but to an unpredictable extent. People in uncontaminated areas would be best off, followed by those in fallout shelters in contaminated areas, those in secure fallout shelters in blast areas, and those in hasty shelters in contaminated areas.

One public health problem would be especially acute in this case. Antibiotics, which are invaluable in fighting many diseases, are in short supply in the U.S.S.R. even in peacetime. Antibiotics have a short shelf life and cannot be frozen. Large doses of radiation destroy most of the body's antibodies, which fight diseases. Antibiotics are typically used to compensate for the drastic decrease in antibodies in radiation victims, as it takes the body a long time to rebuild its antibodies after large radiation doses. Because of the U.S.S.R. 'S limited supply of antibiotics, many people could be expected to die from diseases.

In areas contaminated by fallout but undamaged by blast, shelter life would be less intolerable. Utilities might be working, buildings would be undamaged so would offer better shelter, people would be uninjured, there would be time to prepare and provision shelters, there would be less inclination to evacuate, and there would be less pressure to leave shelters prematurely.

Fallout deposition patterns would become clear in this period, and would largely determine the damage to agriculture and which industries would need to remain closed. Harvesting crops uncontaminated by fallout would be impeded by fuel shortages, but evacuees would be plentiful and could harvest crops by hand. Similarly, evacuees could work in surviving industries in uncontaminated areas.

The key issue that the Government would face would be successful organization. Production would be far below prewar levels. It would take some time before the Government could take inventory, set priorities, arrange for inputs of workers, resources, and power, and transport the outputs. Most needs in this period would be met from inventory. The Covernment would thus need to establish strict controls over inventory; it could be necessary to implement severe rationing of food, as was done in Leningrad in World War 11.

Problems of organization would be especially critical in light of the intense struggle for resources and the need to use resources as widely as possible. The competition for petroleum, discussed previously in Case 2, would be minimal compared to the competition here. The military, agriculture, industry, transportation, and life support systems would all have urgent claims on resources. Everything would be in short supply; there would be hundreds of bottlenecks instead of one. How would the Government mediate among these claims? There would be far less margin for error than in peacetime, and a decision to use resources for one purpose would almost automatically pre elude other courses of action. Viability would be at issue, and deaths would increase because of delays in achieving it.

What sacrifices would the Government demand? Obviously, each critical sector would be called on to make some, and consumer goods would probably be sacrificed completely. Public health would be sacrificed to some extent by starting production in contaminated areas early and by giving people contaminated food rather than nothing.

The Government would probably be able to maintain control. Food rationing, control of transportation and shelters, and internal

passports would help the Government restart the economy. Its economic plans would be the only alternative to chaos, and people would expect to obey them and their demands even without controls. Many party members would survive. Contenders for resources would struggle inside the Government, but external threats, the specter of chaos, the urgency of decisions, and the recognized impossibility of getting everything needed would dampen the debate. All sectors would make sacrifices. The military, for example, might be forced to forego fuel-intensive training. In agriculture and industry, manual labor—which would be plentiful – would substitute for machinery. People would use wood for fuel where possible; many would go cold. Coal-burning locomotives woud likely be taken from storage. Decisions would be taken quickly and set rigidly, Productivity would decrease before it increased. The standard of living would be far lower, and some would die in this period and the next as a result. The question is— how many?

Recuperation

Production– and with it, standard of living and the number of people production could support —would go down before it went up. Industries would use inventories of supplies for production, then would have to close until supply could be reestablished. Transportation would wind down as petroleum refining was cut off, and petroleum supplies became exhausted or requisitioned by the military. People would be diverted from production by being sick or injured, caring for the sick or injured, or being drafted for military service. What production took place would be far less efficient. Many workers would be debilitated by minor cases of radiation sickness, other illness, malnutrition, psychological shock, and so on. Many would be called on to do tasks for which they lacked the training or the physical strength. Factories would be damaged or could not obtain necessary parts, so industrial processes would have to substitute labor for capital or use shortcuts that would reduce the quality of the product or the efficiency of the process.

If things went well, production would stabilize at a level that made good use of surviving resources, and would recover from there. The Government would increase its control over people and the economy, production of consumer goods would be delayed, many resources would flow to the military, public health would be lower, but sacrifices would pay off. Soviet engineers and plant managers reputedly are skilIful at improvising solutions to mechanical problems. Such skills, Government organization and control, and brute force could overcome bottlenecks, use production to expand capacity, and give people austere but adequate food, housing, medical care, and other necessities.

The recovery could go poorly, however. A great many people could require medical care that could not be provided, and would die. The harvest could be lost, and more would die. Starving people would find and eat grain to be planted next year, reducing that crop and causing others to starve. Transportation could collapse, preventing factories from obtaining inputs and making it impossible for their products to be distributed, forcing them to close. Hardening might save key machine tools, but these tools might be buried under tons of rubble or be in intensely radioactive areas, pre eluding their use. The Government might be unable to conduct a detailed resource inventory that could integrate these tools into the economy, or there might be no way of transporting them to a factory that could use them. A war or threat of war, from NATO, China, or both, might divert surviving industry and materials into producing for the war effort and away from the economy. Which way the economy would go is unpredictable, for there are far too many unknowns. But should economic productivity fall precipitously, for whatever reason, the economy could support fewer people, and more would die. Indeed a failure to achieve viability could cause as many Soviet deaths as the attack itself.

I n summary, the effects of a large-scale nuclear attack against Soviet military and urban-industrial targets would remove that nation from a position of power and influence for the

remainder of this century. Soviet fatalities, due to asymmetries in weapons yields and population densities, would be lower than those for the United States. However, there is no evidence that the Soviet economy and its supporting industry would be less severely damaged than their U.S. counterparts. Nor is there any evidence that the Soviets face a lower risk of finding themselves unable to rebuild an industrial society at all.

Chapter V

OTHER LONG-TERM EFFECTS

Chapter V.—OTHER LONG-TERM EFFECTS

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Chapter V

OTHER LONG-TERM EFFECTS

The preceding chapter has made it clear that even the immediate effects of a nuclear attack would have a long-term impact. Structures and resources that would be destroyed in seconds (by blast) or hours (by fire) might not be rebuilt or replaced for years, or even decades. People who would die in seconds or in weeks (from fallout radiation) might not be repiaced in a demographic sense for several generations. Political social, and economic changes arising from the immediate postattack disruption would probably prove in some significant respects to be irreversible.

There is another category of effects of nuclear war, however, which are "long term" in the sense that they would probably not be noticeable for some months, or even years, after the attack took place. Such effects include long-term somatic and genetic damage from radiation, possible changes in the physical environment (including the possibility of damage to the ozone layer of the upper atmosphere), and possible changes in the ecological system of which humans area part. These are effects that conventional weapons cannot produce. They are discussed under three rubrics:

- Effects from low-level ionizing radiation, which are reasonably certain to take place, whose magnitude would depend on the scope of the attack, and which can to some extent be calculated on the basis of existing data and theory.
- Damage to the ozone layer in the atmosphere. Such damage could injure human and animal health, and possibly lead to changes in the Earth's climate. At the present time it is not known how to calculate the likelihood of its occurrence, but ongoing research into the chemistry of the upper atmosphere offers promise of greater understanding in the future.
- Other effects whose magnitude and likelihood are incalculable, but whose possibility should not be ignored.

CALCULABLE EFFECTS: IONIZING RADIATION

A large body of scientific literature addresses itself to the issue of long-term effects from low levels of ionizing radiation, There has been an intensive study over the years of the health of the survivors of Hiroshima and Nagasaki, and of some of those who were subjected to radioactive fallout as a result of nuclear weapons testing. There has been considerable research into the question of how large a quantity of radioactive particles of various kinds are produced by nuclear weapon explosions. There is a body of theory regarding the effects of ionizing radiation on the human body. But there are also formidable uncertainties. New information is coming to light regarding some of the effects of past weapons testing, and there are unresolved scientific controversies over matters as basic as whether a small dose of radiation does more damage to the human body (or, from a statistical point of view, is more likely to do a given amount of damage to a human body) if it is absorbed during a brief period of time than if it is absorbed over a longer period. There are pertinent questions whose answers are only known to within a factor of 10.

Previous chapters have discussed the effects of very intensive ionizing radiation: 1,000 reins will almost certainly be lethal if absorbed

within a matter of days; 450 reins will kill 50 percent of a healthy adult population, and a slightly higher percentage of the young, the old, and those without adequate medical care; 250 reins will cause acute radiation sickness, from which "recovery" is probable; and even lower doses may lower the body's resistance to infectious diseases of various kinds. It is generally assumed that because of the rate at which fallout radiation decays, doses of this magnitude are likely to be received during the first so days after an attack if they are received at all. The preceding chapter, and appendix D, include calculations on the numbers of people who might die from radiation effects during the first 30 days after various kinds of nuclear attack.

However, doses of ionizing radiation that are too small or too slowly accumulated to produce prompt death or radiation sickness nevertheless have harmful effects in the long run. These effects can only be discussed statistically, for it appears that if a large population is exposed to a given (small) dose of radiation, some will suffer harmful effects while others will not. The larger the dose, the greater the percentage of the population that is harmed, and the greater the risk to any one individual.

There are a number of ways in which a nuclear attack would lead to radiation exposures which, although too low to cause death within the first 30 days, nevertheless pose an appreciable long-term hazard:

- Prompt radiation from the nuclear explosions could inflict sublethal doses on some survivors, especially if the weapons are small ones. Most of the radiation absorbed by survivors of the Hiroshima and Nagasaki attack was direct radiation. A substantial number of U.S. weapons have yields in the tens of kilotons, and might inflict radiation on people far enough away from the explosion to survive the blast effects. Few Soviet weapons are of such low yields and high-yield weapons are expected to kill those within radiation range by blast. A terrorist weapon would almost certainly inflict direct radiation on survivors. There is a particular area of uncertainty regarding the effects on humans of low levels of neutron radiation.
- Local fallout will inflict small doses of radiation on people who are on the fringe of "fallout zones, " or on people who are in fallout shelters in zones of heavier fallout. It is important to realize that even the best fallout shelters attenuate fallout rather than block it completely, and the whole theory of fallout shelters is to see to it that people who would, if unsheltered, receive a lethal dose would instead receive a sublethal dose. However, this sublethal dose will produce harmful long-term effects for some percentage of those exposed.
- After a period of time, local fallout radiation levels decay to the point where the area would be considered "safe," and survivors in fallout shelters would emerge. Nevertheless, low levels of radiation would persist for some time— indeed, low levels of radiation have persisted for years at some sites of nuclear weapons tests. The question of safety here is a relative one. By the standards of peacetime, many such areas would be considered unsafe, because living in them would expose a population to a significant risk of long-term hazards— cancer, genetic damage, etc. However, in the aftermath of a nucle ar attack, there may be few habitable areas that do not have a measurable (though low) level of additional radiation, and the survivors would simply have to accept the hazards.
- Some fallout is deposited in the troposphere, and then is brought down to Earth (largely by rain) over a period of weeks. Such fallout reaches areas quite far from the blast. While the doses inflicted would be relatively small, they would add to the risk.
- Some fallout is deposited in the stratosphere. It returns to Earth over a period **of** years (through the effects of gravity), and consequently only very long-lived radioactive isotopes pose a significant hazard. If the attacks are confined to the territory

of the United States and the Soviet Union (and, for that matter, to Europe and China as well), then stratospheric fallout will be confined mostly to the Northern Hemisphere, and the region between 300 and 600 north latitude will receive the bulk of it.

In quantifying the radiation dose received by individuals, radiation from external and internal (ingested) sources must be distinguished. External radiation passes through the skin. Ingested radioactivity derives its effects from particular radioactive isotopes becoming concentrated in specific organs. For example, radioactive iodine (I-1 31), which may enter the body through breathing, eating, and drinking, is concentrated in the thyroid, and radioactive strontium (Sr 89 and Sr 90) is concentrated in bone.

An OTA contractor performed a series of calculations to estimate the magnitude of the long-term health hazards that would be created by the long-term, low-level radiation that each of the OTA cases might produce. The basic method was to calculate the total amount of radiation that all the survivors of each hypothetical nuclear attack might absorb during the 40 years following the attack, and then calculate the numbers of adverse health effects that this much radiation could be expected to produce. (Tables 12 and 13 present the risk factors used for these calculations.) The difficulties in such a procedure are formidable, and precise results are manifestly impossible to obtain.

The major uncertainties, which result in a wide range of answers, are the following:

- All of the uncertainties discussed in previous chapters about the size and nature of the attack, and the distribution of the population.
- How much of the population benefits from what degree of fallout sheltering? It has been noted that there is no necessary relation between civil defense plans and actual shelter received.
- How many people die in the immediate aftermath of the attack?

Table 12.—Assumed Effects of Radiation Exposures

Effect	Number per million person-rems[a]
Somatic effects †	
Cancer deaths (DEF = 1)*	194.3[b c]
Cancer deaths (DEF = 0.2)	38.9[d]
Thyroid cancers	131.4[e]
Thyroid nodules	197.4[e]
Genetic effects †	
Abortions due to chromosomal damage	21-210[f]
Other genetic effects	66-660[f]

†These effects are in addition to those expected from natural or background causes.
*DEF = Dose effectiveness factor.
[a] This assumes that total exposure is governing—that is, that 1 rem each to a million people produce the same effects as 10 rems each to 100,000 people.
[b] This figure is modified from values presented in table VI. 9-4 of the Nuclear Regulatory Commission Reactor Safety Study (WASH 1400). The rationale for the modification was that although the latent period for cancer induction used by WASH 1400 was deemed appropriate, there is insufficient evidence that the plateau periods are limited to 30 years. Using the latent periods in WASH 1400 and the remaining lifespan as the plateau period along with the population age distribution, the cancer risk coefficients in the WASH 1400 study were converted to those in this table.
[c] See table 12 for the sources of these cancer deaths.
[d] Arrived at by multiplying the DEF = 1 figure by 0.2.
[e] Taken from table VI. 9-8 of the WASH 1400 report.
[f] These figures were derived from tables VI. 9-11 and VI. 9-12 of the WASH 1400 report. The range is based on a range of possible doubling dose from 20 to 200 rems, as suggested by the BEIR report (Washington, D.C.: National Academy of Sciences, 1972), p. 53.

Table 13.—Assumed Sources of Cancer Deaths[a]

Cancer type	Cancer deaths per million organ-rems
Leukemia	45.4
Lung	35.5
Digestive tract	27.1
Bone	11
Others	75.3

[a] See footnotes a and b to table 12.

- Does radiation that is part of a low exposure or a very slow exposure do as much damage per rem absorbed as radiation received as part of a high and rapid exposure? One theory holds that, given time, the body can repair the damage done by radiation, and that hence the same dose spread over years does less damage than it would if received within a few days. Another theory is that radiation damages the body in ways that are essentially irreparable. The contractor calculated the effects both ways (DEF = 1 and DEF = 0.2), which accounts for some of the range in the answers.
- Is there a threshold dose below which radiation exposure does no harm at all? If there is, then the methodology used produces somewhat exaggerated results,

since it attributes damage to radiation absorbed by people whose total dose is below the threshold.

- How to deal with the distribution of ages of the population at the time of the attack, since susceptibility to cancer, etc., from causes other than radiation varies with age.
- How great are the genetic effects from a given level of radiation? Extensive experimental results permit an approximate calculation of the number of mutations that would be produced, although one source notes that the doubling dose for genetic disorders might be anywhere from 20 to 200 reins. However, it is far more difficult to predict exactly how these mutations would manifest themselves in future generations.

The results of these calculations are summarized in table 14. [The full report of the contractor is available separately.) The ranges result from the uncertainties noted above, and it is expected that the "actual" results if a war took place would be some distance from either extreme. It is observed that:

- Cancer deaths in the m i l l ions could be expected during the 40 years following a large nuclear attack, even if that attack avoided targets in population centers. These millions of deaths would, however, be far less than the immediate deaths caused by a large attack on a full range of targets.
- A large nuclear war could cause deaths in the low millions outside the combatant countries, although this would represent only a modest increase in the peacetime cancer death rate.
- These results might not apply if an attacker set out deliberately to create very high radiation levels.

Just as this study was going to press, the results of the new report of the Committee on the Biological Effects of Ionizing Radiations ("BEIR II") of the National Academy of Sciences (NAS) became available. (The full report, entitled "The Effects on Populations of Exposure to Low Levels of Ionizing Radiations," will be published by NAS during the second half of 1979.) In general, the new report suggests a slightly narrower range of uncertainty than the OTA calculations, but generally confirms their assumptions. OTA used assumptions of cancer deaths per million person-reins which appear to be about 10 percent higher at the high end of the range and about 40 percent lower at the low end of the range than the findings of the new BEIR report. OTA calculated genetic effects on the basis of a doubling dose of 20 to 200 reins, compared with a range of 50 to 250 reins suggested by the new BE I R report, which may mean that the OTA estimates are too high at the high end of the range. The new BEIR report also notes that the incidence of radiation-induced cancer would be higher for women than for men.

EFFECTS ON THE OZONE LAYER

Large nuclear explosions would, among other things, inject a variety of particles into the upper atmosphere. In recent years, considerable attention has focused on the possibility that the injection of a substantial quantity of nitrogen oxide (NO_x) into the stratosphere by a large number of high-yield nuclear weapons might cause a depletion or thinning of the ozone layer. Such a depletion might produce changes in the Earth's climate, and would allow more ultraviolet radiation from the Sun through the atmosphere to the surface of the Earth, where it could produce dangerous burns and a variety of potentially dangerous ecological effects.

As of 1975, a report by the National Academy of Sciences (discussed more fully below)

Table 14.–Long-Term Radiation Effects From Nuclear Attacks[a]

A. Air Bursts

Estimated worldwide[b] effects from 1-Mt air burst over a city (OTA Case 1):

Somatic effects	
Cancer deaths	200 - 2,000
Thyroid cancers	about 700
Thyroid nodules	about 1,000
Genetic effects	
Abortions due to chromosomal damage	100 - 1,000
Other genetic effects	350 - 3,500

Estimated worldwide[b] effects from an attack using 78 air bursts of 1 Mt each (OTA Case 2 attack on the United States) are 78 times as great, that is:

Somatic effects	
Cancer deaths	16,000 - 160,000
Thyroid cancers	about 55,000
Thyroid nodules	about 78,000
Genetic effects	
Abortions due to chromosomal damage	8,000 - 80,000
Other genetic effects	27,000 - 270,000

Estimated total[c] effects from an attack using 72 air bursts of 40 kt each (OTA Case 2 attack on U.S.S.R.):

Somatic effects	
Cancer deaths	6,000 - 60,000
Thyroid cancers	about 50,000
Thyroid nodules	about 80,000
Genetic effects	
Abortions due to chromosomal damage	2,500 - 25,000
Other genetic effects	5,000 - 50,000

B. Limited Surface Bursts

Estimated total[c] effects of an attack on U.S. oil refineries using surface bursts, with fallout sheltering treated parametrically

Somatic effects	PF* = 5	PF* = 10	PF* =40
Cancer deaths	2,000.000-5.500,000	1,000,000-3,000>000	300,000-1 ,000! 000
Thyroid cancers	about 2,000,000	about 1,000,000	about 300,000
Thryold nodules	about 2,500,000	about 1,500,000	about 500,000
Genetic effects			
Abortions due to chromosomal damage	250,000-2,500,000	150,000-1,500,000	50,000-500,000
Other genetic effects	900,000-9,000,000	500,000-5,000,000	150,000-1,500,000

Estimated effects outside he United States from this attack

Somatic effects	
Cancer deaths	8,000-80,000
Thyroid cancers	about 30,000
Thyroid nodules	about 50,000
Genetic effects	
Abortions due to chromosomal damage	4,000- 40,000
Other genetic ffects	13,000-130,000

C. Counterforce Attacks (Mixed air and surface bursts—Case 3)

Estimated total[c] effects of an attack on U.S. ICBM silos, using one air burst and one surface burst (each 1 Mt) against 1,054 silos. A case in which bomber and submarine bases are also attacked with air bursts gives similar results. Fallout sheltering is treated parametrically:

Somatic effects	PF = 5	PF = 10	PF = 40
Cancer deaths	1,000,000-6,000,000	700,000-5,000,000	500,000-4,500,000
Thyroid cancers	about 2,000,000	about 2,000,000	about 1,500,000
Thyroid nodules	about 3,000,000	about 3,000,000	about 2,500,000
Genetic effects			
Abortions due to chromosomal damage	300,000-3,000,000	250,000-2,500,000	200,000-2,000,000
Other genetic effects	900,000-9,000,000	750,000-7,500,000	650,000-6,500,000

Estimated effects outside the United States from this attack:

Somatic effects	
Cancer deaths	400,000 - 3,800,000
Thyroid cancers	about 1,400,000
Thyroid nodules	about 2,000,000
Genetic effects	
Abortions due to chromosomal damage	170,000 - 1,700,000
Other genetic effects	600,000 - 6,000,000

Estimated total[c] effects of an attack on Soviet ICBM silos, using one air burst and one surface burst (each 100 kt) against 1,477 silos. The overwhelming bulk of deaths are from "worldwide" (between 30° and 60° north latitude) fallout, and hence fallout sheltering in the Soviet Union makes little difference:

Somatic effects	
Cancer deaths	300,000 - 3,300,000
Thyroid cancers	about 2,500,000
Thyroid nodules	about 3,600,000
Genetic effects	
Abortions due to chromosomal damage	120,000 - 2,500,000
Other genetic effects	400,000 - 4,000,000

D. Comprehensive Attacks (Case 4)

Estimated effects inside the United States of an attack on military and economic targets in the United States consisting of 3,325 weapons with a total yield of 6,500 Mt. A mixture of air bursts and surface bursts was assumed, and the ranges include variations in fallout protection available:

Somatic effects	
Cancer deaths	1,000,000 - 5,500,000
Thyroid cancers	1,000,000 - 2,000,000
Thyroid nodules	1,500,000 - 2,500,000
Genetic effects	
Abortions due to chromosomal damage	150,000 - 6,000,000
Other genetic effects	400,000 - 9,000,000

Estimated effects outside the United States:

Somatic effects	
Cancer deaths	900,000 - 9,000,000
Thyroid cancers	about 3,200,000
Thyroid nodules	about 4,500,000
Genetic effects	
Abortions due to chromosomal damage	500,000 - 5,000,000
Other genetic effects	1,500,000 - 15,000,000

Estimated total[c] effects of an attack on military and economic targets in the Soviet Union consisting of 5,660 weapons with a total yield of 1,300 Mt. A mixture of air bursts and surface bursts was assumed, and the ranges include variations fallout protection

Somatic effects	
Cancer deaths	1,200,000-9,300,000
Thyroid cancers	about 5,500,000
Thyroid nodules	7,700,000-8,400,000
Genetic effects	
Abortins due to chromosomal damage	320,000-8,000,000
Other genetic effects	1,000,000-12,500,000

*PF = Protection factor. [a]Assumptions and sources are those used for tables 12 and 13. [b]Most worldwide fallout would be in the Northern Hemisphere, and it would be concentrated between 30° and 60° N Latitude. [c]Includes worldwide totals (note b above), but effects are greater in the target country than elsewhere

called attention to this danger as a serious one, estimating that a 30- to 70-percent reduction in the ozone column was a possibility.

Since that time, however, there have been two changes which bear on the question of the degree of risk of ozone depletion:

1. Further research into the chemistry of the upper atmosphere has modified the model calculations used in 1975. The results of past nuclear tests do not, however, provide data adequate for the complete validation of any chemistry model. There are also indications that the chemistry concerned is much more complex than was formerly believed. The state of knowledge in early 1979 is roughly this: injections of NO. could deplete the ozone layer if they occur at very high altitudes (80,000 ft [24 km] and upwards), which would result from very high-yield explosions (i.e., substantially more than 1 Mt) in large numbers (1 ,000 or more), or possibly from high-altitude explosions. Otherwise, ozone depletion is not believed to be likely. However, further changes in the theory of what would happen are likely in the future.
2. The development of MIRVs has reduced the number-of very high-yield warheads in the arsenals of the superpowers, as they are replaced by multiple weapons of lower yield.

These changes cast doubt on the likelihood of serious ozone depletion as a consequence of nuclear war. However, they by no means demonstrate that ozone depletion is impossible, and even slight depletion could cause an increase in the incidence of skin cancer.

This is an area where research continues, and further changes should not be surprising.

INCALCULABLE EFFECTS

In 1975, the National Academy of Sciences published a report, Long-Term Worldwide *Effects of Mu/tip/e Nuclear-Weapons Detonations,* which addressed the question of whether a large-scale nuclear war would be likely to produce significant, irreversible effects on the world environment.

This document may be summarized as follows:

- It is possible that a large nuclear war would produce irreversible adverse effects on the environment and the ecological system.
- In particular, it would not require very large changes to greatly diminish the production of food. The report notes that it would be difficult to adapt to such changes in view of the likelihood that much of the world's expertise in agricultural technology might perish in the war.
- The physical and biological processes involved are not understood well enough to say just how such irreversible damage, if it occurred, would take place.

d w h d pp m h h
p N g p h h

. Therefore, it is not possible to estimate the probability or the probable magnitude of such damage.

With the exception of the discussion of possible damage to the ozone layer, where there has been some advance in knowledge since 1975, these conclusions still hold in 1979.

Moreover, there are at least two other respects in which there are hazards whose magnitude cannot be calculated. It is certain that the radiation derived from a nuclear war would cause mutations in surviving plants and animals; it is possible that some of these mutations might change the ecosystem in unpredictable ways, but this seems unlikely. Furthermore, the possibility cannot be excluded of major changes in human behavior as a result of the unprecedented trauma. Science fiction writers have speculated, for example, that in the aftermath of a nuclear war, the survivors would place the blame on "science" or on "scientists," and through a combination of lynching and book-burning eliminate scientific knowledge altogether. There are cases in history (or rather archeology) of high civilizations that simply stopped functioning (though people survived biologically) after some shattering experience.

FINDINGS

The calculations for long-term radiation hazards, with all their uncertainties, permit an order-of-magnitude conclusion:

- There would be a substantial number of deaths and illness due to radiation among those who were lucky enough to escape a lethal dose during the first weeks after the attack.
- The number of deaths would be very large by peacetime standards, and the hazards much greater than what is considered tolerable today.
- The number of deaths would be rather small compared to the number of deaths resulting from the immediate effects of the attack — millions compared to tens or hundreds of millions.

In contrast, the incalculable effects of damage to the Earth's ecological system might be on the same order of magnitude as the immediate effects, but it is not known how to calculate or even estimate their likelihood.

APPENDIXES

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United States Senate

COMMIITEE ON FOREIGN RELATIONS

WASHINGTON, D.C. 20510

September 8, 1978

The Honorable Edward M. Kennedy
Chairman, Technology Assessment Board
Office of Technology Assessment
United States Congress
Washington, D. C. 20510

Dear Mr. Chairman:

Several years ago, a study conducted under the auspices of the Office of Technology Assessment at the requestof t Committee on Foreign Relations provided guidance which led to substantially improved analyses by the Department of Defense of the effects of limited nuclear war.

The resulting study was released by the Committee and has become an invaluable aid in the study of nuclear conflict. However, the OTA panel, under the chairmanship of Dr. Jerome M. Wiesner, President of the Massachusetts Institute of Technology, which was convened to oversee the study, went on to point out the need for a more thorough and comprehensive study of the effects of nuclear warfare and recommended that such a study be undertaken.

On behalf of the Committee on Foreign Relations, we are writing to request that the Office of Technology Assessment organize and conduct such a study on the effects of nuclear warfare, which would put what have been abstract measures of strategic power into more comprehensible terms. The study should concentrate on the impact which various levels of attack would have on the populations and economies of the United States and the Soviet Union. In the case of larger levels of attack, the study should address impact upon other nations. The earlier Department of Defense analyses concentrated upon short-term effects. In this more comprehensive study, intermediate and long-term, direct and indirect effects should be addressed as well. In the original study, the panel cited in its appendix a list of effects which should be detailed in a comprehensive and systematic way. The list is attached.

We believe that this study would be valuable to the Commit tee, and to the Congress and the general public. It would become a basic reference work in this area of inquiry. We hope that the Office of Technology Assessment will be able to embark upon this project promptly, so that a finished product can be provided the Committee at the outset of the new Congress to assist the Committee in its oversight of strategic arms limitation issues. The earlier effort was conducted with the full support of the executive branch. We stand ready again to seek the assistance of appropriate government agencies in carrying out the necessary supporting work.

Sincerely,

Clifford P. Case
Ranking Member

John Sparkman
Chairman

Attachment

1975 OTA Panel's List of Damage Effects Requiring Examination

1. Damage effects should be detailed in a comprehensive and systematic way. At a minimum, each case examined should include the following information:

   a. Fatalities and injuries resulting from:
   -Direct and indirect blast effects;
   -Indirect effects resulting from fires, disruption of transportation, communications, medical facilities, etc.;
   -Acute radiation deaths from fallout;
   -Cancers, genetic defects, life shortening and other direct effects of radiation exposure resulting from: external exposure~ inhalation of radioactive particles, ingestion of material from the food chain or the water supplies;
   -Infections and diseases aggravated by the loss of resistance resulting from exposure to radiation.
   Analysis of exposure should include both people exposed initially and people who have been sent to the area to assist in recovery. There should also be a discussion of world-wide effects with particular attention paid to Canada because of that nation's proximity to many U.S. targets which may be of strategic interest.

   b. The average integrated REM per survivor from all sources (prompt and fallout) should be indicated along with the geographic distribution of these dosages and a discussion of the disabilities resulting from each exposure level.

   CO A detailed analysis should be made" of the impact of the attacks on the local areas most heavily affected. The discussion should include a discussion of the feasibility of restoring the area to a viable economy, the land lost to agriculture, manufacturing assets lost, skilled manpower lost, and the impact on local ecologies (permanent altering of watersheds, pollution of streams and rivers with radioactivity, bursting of dams, etc.) . The effect of these local losses and problems on the national economy and environment should also be indicated.

   d. An attempt should be made to indicate the magnitude of the effort which would be required to clean up the contaminated area and restore it to its pre-attack condition. It should be possible to draw on the experience which we have had in attempting to restore the Bikini and Eniwetok atolls.

2. An attempt should be made to determine the amount of radioactive material which would be released by U.S. sites damaged by the effects of the enemy attack. Such material might be found in power or research reactors, nuclear material reprocessing facilities, waste disposal areas for radioactive materials, military installations where some nuclear weapons are not in hardened storage areas, weapons carried by aircraft which are on the bases attacked, and possibly on the ICBM's which may be destroyed in their silos. The added fallout from these sources should be included in the assessment of overall radiation exposure.

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APPENDIX B—STRATEGIC FORCES ASSUMED

The strategic forces assumed to be available for an early to mid-1980's conflict between the United States and the Soviet Union are derived from open-source estimates of weapons characteristics and force levels. Generally, the forces are assumed to be within SALT I I established limits and assume the completion of ongoing intercontinental ballistic missile (ICBM) modernization programs of both superpowers. For the United States this means that yield and accuracy improvements for the MM I I I force are carried out. On the Soviet side, it means completing the deployment of their fourth-generation ICBMS, the SS-17, SS-18, and SS-19.

A recent study conducted by the Congressional Budget Office, entitled, "Counterforce Issues for the U.S. Strategic Nuclear Forces, " provided table B-1, which shows Soviet forces and their capabilities for the early to mid-1980's.

Western estimates differ as to the exact attributes and capabilities of Soviet strategic systems, As a result some of the assumptions used in the studies drawn on for this report are mutually inconsistent. This would be an important factor in an analysis of relative U.S. and Soviet military effectiveness, where the outcomes of a study would be very sensitive to the exact technical data used. In a study of the impacts of nuclear war on civilian population, however, a slight difference in the estimated yield or accuracy of a Soviet weapon will have no corresponding effect on the computation of the consequences of a given attack, relative to the degree of uncertainty that already exists in the prediction of those consequences.

U.S. estimates, on the other hand, are not subject to such great uncertainties. The Congressional Budget Office summary of U.S. forces is shown in table B-2.

It is useful to bear in mind that Soviet ICBM warheads are much higher in yield than their U.S. counterparts. While this has only a marginal impact on relative capabilities to destroy civil ian targets on purpose, it means that Soviet attacks on U.S. targets will produce much more collateral damage (i.e. population casualties from attacks on economic targets, or economic and population damage from attacks on military targets) than will U.S. attacks on Soviet targets.

Table B-1 .–Estimated Soviet Strategic Nuclear Forces, 1985

Launcher	Number[a]	Warheads per launcher[b]	Total warheads	Yield in megatons[c]	Total megatons	Equivalent megatons
SS-11	330	1	330	1.5	495	432
SS-17	200	4	800	0.6	480	560
SS-18	308	8	2,464	1.5	3,696	3,228
SS-19	500	6	3,000	0.8	2,400	2,580
SS-16	60	1	60	1.0	60	60
Total ICBMs	1,398		6,654		7,131	6,860
SS-N-6, SS-N-8	600	1	600	1.0	600	600
SS-N-17, SS-N-18	300	3	900	0.2	180	306
Total SLBMs	900		1,500		780	906
Bear	100	1	100	20	2,000	740
Bison					200	116
(Backfire)	(250)	(2)	(500)	(0.2)	(loo)	(170)
Total bombers	140 (390)		140 (640)		2,200 (2,300)	856 (1,026)
Grand total	2,438 (2,688)		8,294 (8,794)		10,111 (10,211)	8,622 (8,792)

SOURCE. *Counterforce Issues for the U.S. Strategic Nuclear Forces*. Congressional Budget Office, January 1978

Table B-2.–Estimated U.S. Strategic Nuclear Forces, 1985

Launcher	Number	Warheads per launcher	(Mid-1980's force) Total warheads	Yield in megatons	Total megatons	Equivalent megatons
Minuteman II	450	1	450	1,0	450,0	450
Minuteman III	550	3	1,650	0.17	280.5	512
(with MK-12A)	(550)	3)	(1 ,650)	(0.35)	(572.5)	(825)
Titan II	54	1	54	9.0	486,0	232
Total ICBMs.	1,054		2,154		1,216.5	1,194
					(1 ,508,5)	1 ,507)
Poseidon .,	336	0	3,360	0.04	134	403
Poseidon C-4	160	8	1,280	0.10	*128*	282
Trident I .,	240	8	1,920	0.10	*192*	422
Total SLBMs .,	736		6,560		454	1,107
B-52 G/H .,	165	6 SRAM	990	0.2	198	337
		4 bombs	660	1.0	660	660
B-52CM .,	165	20 ALCM	3,300	0.2	660	1,122
FB-111, ., .,	60	2 SRAM	120	0.2	24	41
		2 bombs	120	1.0	120	120
Total bombers	390		5,190		*1,662*	2,280
Grand total.	2,180		13,904		3,332.5	4,581
					(3,629.5)	(4,894)

SOURCE: *Counterforce Issues for the U.S. Strategic Nuclear Forces*, Congressional Budget Office, January 1978.

Which weapons would be used in our attack cases? In Case 1, Detroit is targeted with a single warhead similar to those deployed on the multiple independently targetable reentry vehicle (MIRVed) SS-18 ICBM or with a large single weapon such as those carried by SS-9 or SS-18 Soviet ICBMs. Leningrad is targeted with yields approximately those of a Minuteman II warhead, a Titan II warhead, and all 10 reentry vehicles (RVs) from a Poseidon submarine-launched ballistic missiles (SLBM). In Case 2, the U.S.S.R. attacks U.S. refinery targets with 10 MIRVed SS-18, warheads, and the United States attacks Soviet targets with a mix of Poseidons and Minuteman III, numbering 73 warheads. In Case 3, each side uses its most accurate MIRVed ICBMs against the other side's silos, and a mix of ICBMs, SLBMs, and bombers against bomber and missile submarine bases.

APPENDIX C—CHARLOTTESVILLE: A FICTIONAL ACCOUNT BY NAN RANDALL

/n an effort to provide a more concrete understanding of the situation which survivors of a nuclear war would face, OTA commissioned the following work of fiction. It presents one among many possibilities, and in particular it does not consider the situation if martial law were imposed or *if the* social *fabric disintegrated into anarchy. It does provide detail which adds a dimension to the more abstract ana/ysis presented in the body of the report.*

At first, it seemed like a miracle. No fireball had seared the city, no blast wave had crumbled buildings and buried the inhabitants, no dark mushroom cloud had spread over the sky. Much of the country had been devastated by massive nuclear attack, but the small, gracious city of Charlottesville, Va., had escaped unharmed.

* * *

The nuclear attack on the Nation did not come as a complete surprise. For some weeks, there had been a mounting anxiety as the media reported deteriorating relations between the superpowers. The threat of possible nuclear war hung heavy in the world's consciousness. As evidence reached the U.S. President's desk that a sizable number of Americans were deserting the major cities for what they perceived to be safety in the rural areas, he considered ordering a general evacuation. But, with the concurrence of his advisors, he decided that an evacuation call from the Federal Government would be premature, and possibly provocative. There was no hard evidence that the Soviets were evacuating and there was a good chance that the crisis would pass.

Spontaneous evacuation, without official sanction or direction, grew and spread. A week before the attack, Charlottesville had no free hotel or motel rooms. A few evacuees found lodgings with private families, at great expense, but most were forced to camp by their cars in their trailers next to the fast-food chains on Route 29. The governing bodies of Charlottesville and surrounding Albemarle County were rumored to be concerned about the drain on the area resources, without really having any way of turning back newcomers. "If this keeps up, " remarked a member of the Al bemarle Board of Supervisors, "we're going to be overrun without any war. "

A few of the students at the University of Virginia left Charlottesville to join their families. But the majority of the students stayed, believing that they could go home easily if it were necessary.

Refugees came from Washington, 130 miles to the north, and they came from Richmond, 70 miles to the east. A few of the hardier types continued on into the mountains and caverns near Skyline Drive; the majority sought the reassurances of civilization that the small city could provide.

The population of Charlottesville normally stood a little above 40,000, while Albemarle County which surrounds the city like a donut boasted an additional 40,000 to 50,000. With the arrival of the city evacuees, the combined population was well over 120,000.

In the week before the nuclear attack, much of the population familiarized itself with the location of fallout shelters. Little hoarding took place as retailers limited sales of food and other necessities. Transistor radios accompanied both adults and children when they were away from home. However, most of the residents of Charlottesville continued to live as

they always had, although they were particularly alert for sirens or bulletin broadcasts on the radio. Many children stayed out of school.

* * *

At the sound of the sirens and the emergency radio alerts, most of Charlottesville and Albemarle County hurried to shelter. Fortunate ly, Charlottesville had a surplus of shelter space for its own population, though the refugees easily took up the slack. Many headed for the University grounds and the basements of the old neoclassical buildings designed by Thomas Jefferson; others headed downtown for the office building parking garages. Carrying a few personal effects, blankets, cans and bottles of food, and transistor radios, they converged in a quiet if unordered mass, For most people, the obvious emotional crises —grief at leaving behind a pet, anxiety at being unable to locate a family member or relative—were suppressed by the overwhelming fear of the impending attack.

Some residents chose not to join the group shelters. Many suburbanites had ample, sturdy basements and food stocks. They preferred not to crowd themselves. In the event, those who had taken the precaution of piling dirt against the windows and doors of their basements found that they provided adequate shelter. Among the rural poor, there was a reluctance to desert the small farms that represented the sum of their life's work. They wondered whether, if they left, they would return to find their means of livelihood gone. Further, many lived far from an adequate public shelter. So they stayed.

* * *

Most did not see the attacks on Richmond and on Washington as they huddled in their shelters. But the sky to the east and north of Charlottesville glowed brilliant in the noonday sun. At first no one knew how extensive the damage was.

Communication nationwide was interrupted as the Earth's atmosphere shivered with the assault of the explosions. Each town, city, village, or farm was an island, forced to suffer its selected fate of death or salvation alone. (Some time later it was learned that more than 4,000 megatons (Mt) had destroyed military and industrial targets, killing close to 100 million people in the United States. The U.S. counterattack on the Soviet Union had had a similar, devastating effect. Destruction ranged from the large industrial centers on the coasts and Great Lakes to small farming communities that had the misfortune to be close to the great missile silos and military bases.)

Areas of the country such as the northeast corridor were reduced to a swath of burning rubble from north of Boston to south of Norfolk. Still, there were some sections of the Nation that were spared the direct effects of blast and fire. ınland in Virginia, only the town of Radford, west of Roanoke, received a direct hit. The farming and orchard land of the rural counties were not targets.

Charlottesville, the small but elegant center of learning, culture, and trade in central Virginia, was not hit either. This monument to the mind and manner of Jefferson retained its status as a kind of genteel sanctuary, momentarily immune to the disaster that had leveled the cities of the Nation.

* * *

An hour after nothing fell on Charlottesville, rescue squads and police were dispatched to scour the countryside for stragglers to get them to shelters. Because, even if the population was safe from the direct effects of the nuclear warheads, another danger was imminent. Fallout, the deadly cloud of radioactive particles sucked up by the nuclear fireballs, could easily blanket the town of Charlottesville in a matter of hours. And no one could predict how much, and where it would go. Fallout could poison many of those idyllic rural towns and villages that seemed light-years away from the problems of international power and politics. While a few places, such as Roseberg, Ore., would receive no fallout at all, the rest of the Nation would have to constantly monitor to know the level of radiation and where it *was* located. Fortunately for Charlottesville, the University and the hospitals had

sophisticated radiological monitoring equipment, and the training to use it. Many other towns were not so lucky.

Two and one-half hours after the warnings had sounded, the nuclear engineering staff from the University picked up the first fallout. Starting at a moderate level of about 40 reins an hour — a cumulative dose of 450 reins received in a l-week period would be fatal to one-half of those exposed —the intensity rose to 50 reins before starting the decline to a level of about four-tenths of a rem an hour after 2 weeks. (The total dose in the first 4 days was 2,000 reins, which killed those who refused to believe shelter was necessary, and increased the risk of eventually dying of cancer for those who were properly sheltered.) For the immediate period, it was essential to stay as protected as possible.

For several days, Charlottesville remained immobile, suspended in time. It was unclear just what had happened or would happen. The President had been able to deliver a message of encouragement, which was carried by those emergency radio stations that could broadcast. As the atmosphere had cleared, radio station WCHV was able to transmit sporadically on its backup transmitter and emergency generator in the basement. However, the message from the President posed more questions than it answered — the damage assessment was incomplete. Nevertheless, he said that there was a tentative cease-fire.

In the first days of sheltering, only those with some particular expertise had much to do. Nuclear engineers and technicians from the University were able to monitor radiation in the shelters they occupied, and CB radios broadcast results to other shelters. The doctors were busy attempting to treat physical and psychological ailments — the symptoms of radiation sickness, flu, and acute anxiety being unnervingly similar — while the police and government officials attempted to keep order. The rest waited.

For the time being, the food stocks brought to the shelter were adequate if not appetizing. The only problem was the water supply which, though it kept running because of its gravity system, was contaminated with lodine 131. Potassium iodide pills, which were available in some shelters, provided protection; elsewhere people drank bottled water, or as little water as possible.

Not all of the shelters had enough food and other necessities. Most shelters had no toilets. The use of trash cans for human waste was an imperfect system, and several days into the shelter period, the atmosphere was often oppressive. As many suffered from diarrhea –the result either of anxiety, flu, or radiation sickness — the lack of toilet facilities was especially cliff i cult.

Shelter life was bearable in the beginning. Communications by CB radio allowed some shelters to communicate with one another, to locate missing family members and friends. A genuine altruism or community spirit of cooperation was present in almost all the shelters — though some of them were fairly primitive. Even those refugees who were crowded into halls and basements with the local residents were welcomed. Parents watched out for one another's children or shared scarce baby food. Most people willingly accepted direction from whomever took charge. Among the majority of the shelter residents, the out-of-town refugees being an exception, there was a sense of relief, a sense that they had been among the lucky ones of this world. They had survived.

Within a few days, the emergency radio was able to broadcast quite regularly. (As the ionosphere does not clear all at once, occasional interruptions were expected.) The station had had no protection from the electromagnetic pulse that can travel down the antenna and shatter the inner workings of electronic equipment during a nuclear explosion. However, by detaching the back-up transmitter at the sound of the warning, the station engineer had protected equipment. Intermittent communications from Emergency Operations Centers got through to Charlottesville officials, though the main communications center at Olney, Md., was silent. Telephone switching facilities were almost entirely out, although the

small, independent phone company could expect to be operational fairly quickly. The complex, coast-to-coast trunk lines of Ma Bell might take a year or more to reconnect.

Lifeline of the sheltered community was the CB radio. Rural Virginians had been CB fans long before it became a national craze, and they put their equipment to imaginative use. Prodded by anxious refugees, as well as by local residents who had relatives and friends in other parts of the world, CBers tried to set up a relay system on the lines of an electronic pony express. Though less than perfect, the CB relay was able to bring limited news from outside, most of that news being acutely distressing. From the limited reports, it was clear that there was little left in the coastal cities; those who had abandoned family or friends to come to Charlottesville understood that probably they would never see them again.

The first surge of grief swept over the refugees and those Charlottesville residents who were affected. In time, the sorrow of loss would affect almost everyone. Although they had survived themselves, still they had lost.

* * *

Three days after the attacks, the next large influx of refugees poured into Charlottesville, many of them suffering with the early symptoms of radiation sickness. They had been caught poorly sheltered or too close to the nuclear targets themselves. A few showed the effects of blast and fire, bringing home to Charlottesville the tangible evidence of the war's destruction. Some refugees had driven, while others had hitchhiked or even walked to reach what they hoped was safety and medical help. On the way, many were forced to abandon those who were too weak to continue.

The hospitals were completely overwhelmed. Up to now, the hospitals had managed to treat the ill with some modicum of order. The hospitals themselves were fallout shelters of a kind; patients' beds had been moved to interior corridors for fallout protection; emergency surgery was feasible with the emergency generators, hospital staff slept in the most protected areas. Some borderline cases in intensive care were released to nature's devices while any elective medical procedures were eliminated, Still, hospitals were able to cope, even with the increasing number of common ailments caused by the shelter crowding.

Suddenly, this changed. Fallout levels were too high for anyone to be out in the open for any length of time, but the people came anyway. The carefully laid plans of the University of Virginia Emergency Room, devised for the possibility of peacetime accidents, were hurriedly modified. No longer was the careful showering and decontaminating of victims possible with the single shower and uncertain water pressure. Instead, patients were stripped of their clothes and issued hospital gowns. With no time for studied decision, doctors segregated the very sick from the moderately sick — the latter to be treated, the former given medication and allowed to die.

Nevertheless, the day came when the hospitals were full. The University Hospital, Martha Jefferson Hospital, the Blue Ridge Sanatorium, and the others were forced to lock their doors to protect those patients they had already accepted.

After being turned away, the sick had no specific destination. Many still clustered around the middle of town near the two major hospitals, taking up residence in the houses abandoned by local residents several days before. With minimal protection from fallout and no medical treatment for other trauma, many died, their bodies left unburied for several weeks.

The combined populations of Charlottesville and Albemarle County rose to 150,000 in the 7 days after the nuclear attack. Slowly, hostility and resentment wedged a gap between residents and refugees who attempted to join the group shelters, The refugees, still in a daze from their experience, believed that they had priority rights after all they had suffered. The local residents viewed the outsiders as a threat to their own survival, particularly as the extent of the war damage was becoming evident.

In fact, the supply of food was not a problem in the short run. Like most other towns and cities, Charlottesville and Albemarle had some 3 weeks worth of food on hand, on home shelves, in supermarkets and wholesale outlets. The Morton Frozen Food plant could be expected to supply a rich diet of convenience foods for a short time, even after the refrigeration was off. The problem was, after the local supplies were exhausted, where could they get more?

Nerves, already frayed by the stresses of the past days, threatened to snap. Older people were irritated by the noise and commotion of children; children resented the lack of free dom. The friction between differing groups became increasingly evident, and vocal. An experiment in communal living was clearly not to the taste of many, and the discomforts, both physical and psychological, had the effect of pushing local residents out of the shelters. (There was some effort to stop them as the radiation levels still posed some hazards; they were urged at least to stay inside most of the time.) Left in the shelters, now, were mostly those out-of-town refugees who had no homes to go to.

Not all the residents of Charlottesville and Albemarle found their homes intact. In some cases they returned to find the house looted or occupied by refugees who were unwilling to give up squatters' rights. Sometimes claims were backed with guns; in a few cases, squatter and owner worked out a modus vivendi of sharing the property.

Some animals had survived, in varying states of health. Unprotected farm animals were dead, while those which had been confined to fairly solid barns with uncontaminated feed had a fair chance of surviving. Many of these farm animals, however, were missing, apparently eaten by hungry refugees and residents. Some pets had remained indoors in good de facto shelters so that, if they had found water, they needed only to be fed to regain health. Worried about the amount of food pets could consume, many families simply put them out to fend for themselves.

For the first week or so after the nuclear attacks, authorities had few options. Simple survival was the priority, the elements of which included food and water distribution, fallout protection, and retention of some civil order. Government was ad hoc, with the leadership of the city and county naturally cooperating, along with the different police forces. As the population left the shelters, however, officials felt that some more formalized system was desirable. After several long meetings — in the basement of the courthouse where the government officials had stayed to avoid fallout— an emergency government, led by the city manager of Charlottesville, was agreed on. The combined city council and the Albemarle County Board of Supervisors also elected the chairman of the board of supervisors as deputy, and the sheriff of the county as chief of public safety to oversee the combined police forces and provide liaison with those military units which were still in the area.

The powers given to the city manager were sweeping in scope, certainly far beyond any powers he had held before, and ran "for the duration of the emergency. " While some considered the new form of local government close to martial law, great care was exercised to be sure that the offensive term was not used. In effect, however, Charlottesville and Albemarle were under a highly centralized, almost totalitarian rule.

Whatever it might be called, under the new system, the city manager was able to take over all resources and their allocation. Following to some extent the paper plan that the area had developed, the new government attempted to set out priorities. It was greatly aided by the experts from the University, who volunteered time and expertise to analyzing the needs of the area. (In this respect, Charlottesville was particularly fortunate in having an extensive pool of talent on which to draw.)

However, if Charlottesville was lucky to have reasonably functioning government and a number of experienced planners and managers, and to have suffered comparatively modest disruption from refugees and fallout,

the city and county authorities were becoming painfully aware that they were not set up to 'go it alone' without any outside help. Even were the weather suitable for planting, Charlottesville was no longer an agricultural center. There wasn't enough energy to process any food that might be grown. Where would people get clothes and building materials and medicines and spare parts for the cars and buses? The very complexity of American society— its technological marvels and high standard of living — could well prove to be a barrier to the reconstruction of any one part.

* * *

During the third week after the attacks, the new rationing system come into force. individual identification cards were issued to every man, woman and child. Food was distributed at centralized points. Those without I.D. cards were unable to get their ration of flour, powdered milk, and lard–and the processing of cards could take 3 or more days. Some desperate refugees resorted to stealing I.D. cards in order to get food, while an enterprising printer started turning out forgeries within 2 days after the government had first issued cards. Rumors of hoarding and black marketeering abounded. Some of the missing supermarket food turned up in black market centers, accompanied by exorbitant prices.

Fuel supplies were dropping more rapidly than the government had hoped. Most families were heating their homes with wood, either in fireplaces or in recycled oil drums for stoves. As the winter was waning, the most desperate need was for fuel for driving motors and generators. Even the drinking water was dependent on the emergency generator that ran a single purifying system for the Rivanna Water and Sewer Authority. (Water for other uses could simply be drawn from the gravity-powered reservoir system, bypassing the filtration system entirely.) The hospital and radio stations all ran on small generators. The University could luxuriate in its coal-powered steam heat, but there was no way, save generators or candles and lanterns, to get lights.

No one was exactly certain how much fuel there was in the area. Both jurisdictions had once surveyed, for emergency planning purposes, the fuel storage capacity, and they hoped they could count on having about half of that on hand. Armed guards were assigned to those larger facilities that had not already been raided by the desperate. All private use of cars or tractors was outlawed, and the government threatened to confiscate any moving vehicles.

Electricity was restored, partially, some two weeks after the attack. Workers from the small Bremo Bluff generating plant, about 15 miles away from Charlottesville, succeeded in starting the p I ant with the coal reserves that were on hand. From then on, limited electricity use was permitted for a few hours hours a day. This was particularly pleasant for those families whose water came from electrically powered well pumps. Well water was issued to children for drinking, as it had escaped the Iodine 131 contamination which was still elevated in the reservoirs.

The radioactivity level continued to drop (after two weeks it was 0.4 rem per hour) and it was "safe" to go outdoors. However, the re suiting doses, though too low to cause immediate illness or deaths, posed a long-term health hazard. The authorities, while recognizing that everybody would receive many times the prewar "safe dose, " tried to reduce the hazards by urging people to stay inside as much as possible when not picking up food rations at the distribution centers. Life for the residents of Charlottesville revolved around those trips and figuring out ways to make do without the normal supplies and services. Some chanced outings to forage for a greater variety of food, but most were resigned to waiting. There wasn't much else they could do.

* * *

Three weeks after the nuclear attack, almost all the Charlottesville and Albemarle County residents had returned to their homes. Those few whose homes had either been occupied by squatters, or been destroyed by fire, easily

found some alternate housing with the government's help.

This left the refugees. Though the drop in fallout intensity allowed the refugees to move out of basements and interior halls, they still were forced to I ive a version of camp life. They spent their endless, empty hours waiting in lines for food, for a chance to use the bathrooms — which at least functioned now — for a chance to talk to authorities. ınformation from the outside was still sketchy, and for the refugees, this uncertainty added to their already high level of anxiety.

The city manager and the emergency government attempted to solve the refugee housing problem by billeting refugees in private homes. At first they asked for volunteers, but got few, The authorities then announced that any house with fewer than two people per room would be assigned a refugee family. Resistance to this order was strong, and, particularly in the outlying areas where it was hard to check, outright defiance was common. Families would pretend to comply and then simply force the refugees out as soon as the authorities had left. The refugees would struggle back to town, or take up residence in barns or garages.

And still the refugees came to Charlottesville, bringing with them stories of the horrors they had experienced. They camped in schools, in banks, in warehouses. By night the neoclassical architecture of the University was packed with the residents of Arlington and Alexandria. By day, the new downtown mall was awash with a floating mass of men, women, and children, who, with nothing to do, milled around the unopened stores. A retired ambassador was overheard comparing the scene to that of downtown Calcutta.

By now, the emergency government recognized that the need for food was going to be acute. Without power for refrigeration, much food had spoiled; stocks of nonperishable foods were mostly exhausted. As the shortages became clear, the price of food skyrocketed. Many people refused money for food, preferring to barter. Food and fuel were the most valuable commodities, with shoes and coats high on the list as well.

Since shortly after the attack, the city manager had been in contact both with the Federal Government and with the relocated State government in Roanoke. He had repeatedly asked for emergency rations, only to be met with vague promises and explanations about the problems of transportation. He was generally urged to cut rations further and hang on. Help would arrive when it could.

For some time, the relatively few surviving farm animals had been gradually and mysteriously disappearing. The farmers concluded that "those damned city folks" were stealing them for food, although some of the local residents were also making midnight forays on the livestock. Farmers themselves slaughtered animals they had planned to fatten-up for the future. They couldn't spare the feed grain, and they needed food now.

Finally the emergency authorities announced that they would take a percentage of every farmer's livestock to help feed residents and refugees, Farmers were outraged, considering the action simple theft. There were rumors that angry farmers had shot several agents who had tried to confiscate the animals. Though they were offered promissory notes from the city authorities, the farmers thought such payment worthless.

(The radiological experts at the University had been questioned on the advisability of eating the meat of animals with radiation sickness. Many of those beasts which had remained outside during the high fallout period were showing clear signs of illness. The experts decided that the meat would be edible if cooked sufficiently to kill any bacterial invasion — the result of the deterioration of the animal's digestive tract. Strontium 90 would be concentrated in the bones or the milk, not the muscle tissue.)

* * *

Although the city government had relatively frequent contact, mostly by radio, with the Federal and State governments, the citizens

had to rely on the occasional Presidential message that was broadcast on WCHV. Three weeks after the attacks, the President made a major address to reassure the people. He announced that the cease-fire was still holding and he saw no reason why that would change. He described the damage that the U.S. retaliatory strike had done to the Soviet Union. He also noted that the United States still retained enough nuclear weapons, most of them at sea on submarines, to inflict considerable damage on any nation that attempted *to* take advantage of the recent past. He did not mention that he suspected that the Soviets also held reserve weapons.

Describing the damage that the country had suffered, the President noted that, even with the loss of over 100 million lives, "We still have reserves, both material and spiritual, unlike any nation on earth. " He asked for patience and for prayers.

There had been broadcasts earlier by the Lieutenant Governor of Virginia —the Governor was killed in Richmond — from his shelter in Roanoke. However, as fallout in the Roanoke area was quite high (Radford just to the west had been struck), he was effectively immobilized for some time. The State government appeared less organized than the Federal.

Charlottesville was still on its own. Residents hunted game as the last of the food stocks disappeared, but the fallout had killed most animals that were in the open. Refugees were reduced to stealing. A number of people managed to fill their gas tanks with contraband gasoline and set out to forage in the mountains to the west.

Three and one-half weeks after the attack, an old propeller-driven cargo plane landed at the Charlottesville Airport with a supply of flour, powdered milk, and vegetable oil. The pilot assured the few policemen who guarded the airstrip that more would be on the way by truck as soon as temporary bridges could be built over the major rivers.

The emergency airlift was supposed to supply Charlottesville with food for a week or two. However, the officials who had calculated the allotment had overlooked the refugees. Charlottesville's population was some three times the normal. (No one was absolutely sure because the refugees moved around a good deal, from camp to camp)

The first of the deaths from radiation had occured 10 days after the attacks, and the number grew steadily. By now, it was not uncommon to see mass funerals several times a day. The terminally ill were not cared for by the hospitals — there were too many, and there was nothing that could be done for them anyway— so it was up to their families to do what they could. Fortunately there were still ample supplies of morphia, and it was rumored that college students had donated marijuana. The city set aside several locations on the outskirts of town for mass graves.

In addition to those with terminal radiation sickness, there were those with nonfatal cases and those who showed some symptoms. Often it was impossible for doctors to quickly identify those with flu or psychosomatic radiation symptoms. The number of patients crowding the emergency rooms did not slacken off. The refugees, crowded together, passed a variety of common disorders, from colds to diarrhea, back and forth, Several public health experts worried that an outbreak of measles or even polio could come in the late spring. "So far, we have been lucky not to have a major epidemic of typhus or cholera, " a doctor observed to his cotleagues.

The supply of drugs on hand at the hospitals was dwindling fast. Although penicillin could be manufactured fairly easily in the laboratories at the university, many other drugs were not so simple, even with talent and ingenuity. (The penicillin had to be administered with large veterinary hypodermics as the homemade mix was too coarse for the small disposable hypes that most doctors stocked. There was a considerable shortage of needles.) Other medications were in such short supply that many patients with chronic illnesses such as heart disease, kidney failure, respiratory prob-

lems, hypertension, and diabetes died within a few weeks.

* * *

Food riots broke out 4½ weeks after the attacks — precipitated by the first large shipment of grain. Three large tractor-trailers had pulled into the parking lot of the Citizens Commonwealth Building quite unexpectedly, the word of their arrival somehow misplaced between the Agriculture Department dispatchers and the local authorities. The trucks were greeted with cheers until the residents of Charlottesville discovered that they had been shipped raw grain rather than flour. The drivers were taken unawares when empty cans and bottles showered them and one driver jumped in his cab and departed. (The official explanation, delivered some time later, was that processed food was going to those areas where the bulk of the population was sick or injured. It was also assumed that Charlottesville had some livestock reserves.)

With only a fraction of the population knowing what to do with raw grain, a number of angry citizens broke open the sacks and scattered wheat through the parking lot. They in turn were set upon by those who wanted to conserve as much as possible. The local public safety forces waded into the melee with night sticks and tear gas.

Everyone blamed everyone else for the incident, but the fragile glue that had held public order together began to unstick.

From this time on, it was almost impossible for the local authorities, not to mention the State and Federal governments, to convince everyone they were getting a fair share. People in one section of town would watch suspiciously as delivery trucks passed them by and headed somewhere else. Blacks distrusted whites, the poor distrusted the rich and everyone distrusted the refugees as “outsiders. ”

The refugees were convinced that the local authorities were favoring the residents and tried repeatedly to get State intervention, with little success. Still billeted in dormitories, schools, and motels, the refugee camps were a breeding ground for discontent and even rebellion.

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The presence of the Federal Government was not entirely confined to the occasional delivery of food or radio broadcast. Some time before, the National Guard and the Reserve Unit were moved to North Carolina, partly to give the impression of military readiness, and perhaps to be assigned to dig out cities and start reconstruction. The Government had put out calls for volunteers to help in the reconstruction, but found that most workers, young and old, wanted to stay with their families. A system of national conscription for young men and women with no children was in the planning stage.

The Federal Government attempted to urge refugees back to where they had come from, first to assist in the rebuilding of the damaged cities which were rich in resources, and ultimately to redistribute the population to a more normal pattern. Some refugees were happy to attempt to return, particularly those whose houses were more or less intact. However, those who found their homes destroyed preferred to return to the refugee camps inland. There was nothing to hold them to their former lives. Fearful memories of the past made any time spent in the cities painful.

One day, quite without warning, the city manager was informed that one-half of his fuel stores were to be confiscated by the Federal Government, for the military and for the reconstruction effort. (Earth-moving equipment was gathering on the outskirts of the devastated cities and needed fuel.) After it was clear that there was no way to stop the Government from taking the fuel, the city manager suggested that unmarked tank trucks, well guarded, pick up the stocks at night. He was aware of the effect this action would have on the morale of the population.

Already transportation was difficult for the elderly and those who lived in the rural areas. A sporadic bus service ran from one end of town to the other once a day and an occasional school bus made a sortie out into the suburbs. Bicycles were prized, and sometimes

fought over. Those gentlemen farmers whose thoroughbred horses had been protected from fallout could use these animals for transportation, but it was risky to let the animals stand unprotected. Horse thievery had made an anachronistic reappearance.

With even less fuel, the bus service would be cut in half.

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By now, barter was clearly established as the preferred means of trade. For a time, the government had paid for commandeered foodstuff and resources with checks and prom issory notes, but no one wanted them any more. The local banks had opened for a few days, only to find all their savers lined up to withdraw everything. They closed down. Stores either never opened, or shut down quickly when they were overrun. (Many stores had been looted in the second week after the attack, when the fallout intensity had dropped.) A few people hoarded money, but most thought money worthless.

Workers in the small industries in the Charlottesville area saw no point in turning up for work if all they could get was paper money. They preferred to spend the time hunting for food and fuel. If barter was a highly inefficient way to do business — it's hard to make change for a side of beef–still, it was preferable to using worthless currency.

Psychologically, the population seemed to be in a quiet holding pattern. The refugees, many of them, had survived experiences that would mark them for years. The memories of fire, collapsing buildings, and screaming, trapped people were still vivid, and some would tremble at loud noises. However, the profound grief over what they had lost–family members, possessions, or friends — underlay emotions and made many apathetic and passive Victims of the nuclear attacks, they appeared willing to be victims afterwards too. Still shunned as outsiders by the resident population, most refugees appeared to accept the exclusion just as the surviving population of Hiroshima and Nagasaki had 30 odd years before.

The effect on the Charlottesville and Albemarle residents was less pronounced. They were disoriented. For each lucky one who had a specific job to do, there were many more who were in effect unemployed. They turned inward to their families or else friends and relatives. Their worries about the future–would there be another attack, would they go back to their old jobs, etc. — made most days rather anxious, unproductive ones. Children particularly reflected a continuous nervousness, picked up from their elders, and had difficulty sleeping at night. Though many parents hoped for a return to normalcy once the schools reopened, others quietly decided not to send their children for fear of a second outbreak of war.

* * *

Spring changed a lot of things. A new optimism surfaced as everyone looked forward to planting, to good weather and warmth. The residents of Charlottesville had survived the first hurdle; they felt confident they could survive the next.

At the University, agronomists studied the best crops to plant in the Charlottesville area. No one was certain what effect the nuclear explosions had had on the ozone layer. If indeed the ozone was severely damaged, more ultraviolet rays could reach the crops and perhaps burn them. This effect would be more pronounced on delicate crops such as peas and beans. Instead it was suggested that potatoes and soybeans be encouraged and whatever limited fertilizer became available go to farmers who followed the government guidelines.

The emergency government announced that two-thirds of the former pasture land was to be cultivated. Feed grains were to be used for humans, not livestock. Dairy cattle and chickens were the only exceptions.

The next few months in Charlottesville and Albemarle County had a slow, almost dreamlike quality. Fears of new attacks had abated. It was a time of settling into a new lifestyle, a severely simplified way of being, of making do. Children ate meat, cheese, or eggs rarely,

adults practically never. A good pair of shoes was guarded — and worn only on special occasions. (With warmer weather, most children and adults went barefoot, bringing concern to doctors that there would be an increase in parasitic diseases such as hookworm.)

Many people were unable to return to their former jobs. In some cases, their employers never reopened for business, their goods and services being irrelevant in the postattack society. College teachers, for example, had no students to teach; computer programmers had no computers to program.

For some, it was relatively easy to adapt. Electronics experts set up CB and short wave radio repair shops. Cottage industries — sandal and clothing manufacturing from recycled materials, soap and candle making — sprang up in many homes. Some workers were able to acquire new, relevant skills quickly.

Others had to make do with menial jobs– burying the dead, cleaning the streets, assisting carpenters and bricklayers — that took little skill.

And then there were those who could not fit in anywhere. Many found it difficult to adapt to the idleness. Disruption of the 9 to 5 work ethic was a disruption of basic psychological props, of a sense of identity. In the immediate period after the attacks, parents concentrated on protection of their families. Once their families were no longer directly affected, adults were robbed of their traditional roles.

By now, a few of the refugees had melted into the general population. But the vast majority were no further along than in the late winter. The drag on the area resources was significant, and many in the leadership wanted to force them out.

Charlottesville was fortunate in many respects, however. Being located on two easily repairable rail lines —with a major storage yard for cars only two counties away—there was some access to the outside world. Travel was only permitted with a special pass, naturally, and so the younger members of the community resorted to the hallowed art of riding the rods.

Government officials, many of whom had visited Charlottesville and the University frequently in the past, kept in closer contact with the city than with many other locales. Doubtless the area residents benefited with more Federal assistance, As a result, Charlottesville became the unofficial “capital” of the area, economically and politically.

But as autumn approached, a universal depression settled on the residents and refugees. Starvation had been held at bay by the planting — but crop yields were smaller than expected. No one was cold, but the weather was still fine. There seemed to be no appreciable progress towards preattack conditions. Those young men and women who had been conscripted to build housing for the Nation’s refugees returned with gloomy reports of the devastation to the Nation’s commerce. The east coast was effectively leveled. Where factories were rebuildable, the shortage of materials precluded their operation.

Recognizing that many families would have to make do without heating oil or gas, the Agriculture Extension Service issued pamphlets on how to make your own wood-burning stove. Fortunately for Charlottesville and the surrounding area, trees were plentiful. However, the momentum that had started with the spring planting slowed,

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Winter was harder than anyone had expected. There were few additional deaths that could be directly attributed to the nuclear blast effects or the radiation; however, a large percentage of the surviving population was weakened. Lack of medicines, lack of adequate food and reasonable shelter, plus the lingering physical and psychological effects, meant that many were unable to work effectively, even if there were work available. An epidemic of flu raged through the cities of the east where refugees were huddled in camps. Many died, especially children and old people. Although vaccine for this particular, common

strain of flu had been developed, the stocks had been destroyed in the attacks

In the northern sections of the country, food supplies were inadequate and poorly distributed. The average diet — day in, day out — consisted of unleavened bread and potatoes, where there was enough of those. As animal herds, both domestic and wild, had been decimated by fallout and indiscriminate hunting, the only available meat came from dogs, cats, and rats — those animals whose living habits protected them from fallout. Dietary deficiency diseases appeared.

Growing children were the first to notice the lack of replacement clothes–particularly leather shoes. Coats and blankets were highly prized in the cold climates.

Next to food, the most severe shortage was housing. Even with the temporary barracks that had been erected in a cluster around the damaged cities, refugees were crowded two or three to a room, Kitchens were shared by four and five families; bathrooms by as many as 12 people.

Although there was relatively little work to occupy time, and schooling was strictly curtailed, if indeed it existed, there was also very little available recreation. The entertainment industry located in California and New York had been particularly hard hit. Local TV stations could broadcast and rebroadcast those old films and cartoons they had in stock, but little was fed nationwide, In the small towns, public libraries were overwhelmed. In the large cities, the libraries had been destroyed. There were no movie houses to speak of; there were no professional sports. The lack of recreation, perhaps a minor problem, still served to underscore the bleakness of the winter.

In Charlottesville alone, several thousand people died in the first winter after the nuclear attack.

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A year almost to the day after the nuclear war between the United States and the Soviet Union, Charlottesville was host to a blue ribbon panel of experts on reconstruction planning. The University had not returned to normal — there were no undergraduate classes as the students had been conscripted for reconstruction work in the cities — but it was a natural meeting place since so many centers of learning had been destroyed.

The questions before the group centered on setting priorities: what were the goals and how could the country reach them?

The U.S. Government still existed, if in a Slightly reordered form. The President, now permanently located in the Midwest along with the surviving Members of Congress and the Cabinet, retained the emergency powers he had taken just after the attacks. (Congress had had no choice but to ratify his assumption of these extraordinary powers at the time. However, there was growing resentment that he showed few signs of relinquishing them. Congress was reduced to a kind of advisory body, its Members spending most of their time on helping constituents relocate or obtain a id.)

The State governments had, by and large, reestablished themselves, often in new locations. Virginia's government was located in Roanoke, for example, under the Lieutenant Governor. State governments were not as well respected as before; citizens tended to blame them for the mixups in aid distribution. Only the refugees looked to the States for assistance against the local governments, which they distrusted. The residents of an area such as Charlottesville were most loyal to their local government, particularly when that government had a reputation of basic evenhandedness.

Everyone, however, was growing hostile to the imposition of strict governmental controls over their lives —what they could or could not buy, or eat, where they could travel, etc. In certain rural sections, such as Nelson County, south of Charlottesville, farmers had barricaded themselves off, ignored government orders, and occasionally, it was rumored, took potshots at the government agents.

Attempts to conscript the able-bodied to rebuild the damaged areas often failed miserably. Many simply walked off the job and returned to their families. Since there were no

adequate records remaining of the prewar population, and no records at all of war deaths, the Government found it an impossible task to track down offenders. (Criminals in medium- and light-security detention facilities had simply evaporated into the population.)

Charlottesville, like the rest of the undamaged parts of the country, still had a huge refugee population that was unwilling or unable to return to former homes. The majority were in camps such as the large facility in the old Lane School, and children were in day care or orphanages, depending on the status of their surviving families. If anything, the refugees were both more apathetic and more rebellious when faced with simple assignments. Lawless bands of teenaged refugees roamed the countryside, hijacking supply trucks and raiding farms and villages. Partly it was simple bravado, partly a way to feed themselves. Most refugees simply sat and waited for the next meal.

Yet even now, the flow of refugees continued. The winter had driven out those who could not find enough to eat or enough shelter. Stories of Vermont families subsisting on maple syrup and wild rabbits might have proven entertaining in the retelling, but those who had survived did not want to repeat the performance.

The medical problems were still acute. Drug supplies were almost exhausted, but the weakened population remained more susceptible to disease. The birth rate had fallen drastically 9 months after the attacks, partly because of the radiation, which produced temporary sterilization – but there had also been a rise in miscarriages, stillbirths, and abnormalities. Infant mortality soared. Experts worried that an unprecedented increase in cancer, particularly in children, could be expected in several years. And there was still the possibility of some devastating epidemic as cholera running unchecked through the population. The Blue Ridge Sanatorium in Charlottesville, which had seen few tuberculosis patients in the last years before the attacks, was making plans to convert back to specializing in the disease. TB was making a comeback.

The Nation's economy was in shambles. The bulk of the oil refining capacity had been knocked out, and only a few facilities were functioning again. The small oil wells around the country that were situated away from target areas produced more oil than the refineries could handle— and it was only a fraction of the need. Coal mining, mostly by the time-honored pick and shovel method as strip mining took heavy equipment, was the only industry that could be called booming. (There was a major migration to the mining areas by the unemployed.) Agriculture, of course, was a major undertaking for much of the population. However, yields from the farms were considerably below what had been hoped for. The lack of pesticides and fertilizer cut heavily into the crops and there was concern about a major insect invasion next summer. Food processing —wheat and corn milling particularly– showed encouraging signs of recovery.

Most major industries, however, were in disarray as a result of lack of energy, lack of raw materials, and lack of managerial expertise. The world economy was staggering from the effect of losing both the United States and the Soviet Union as suppliers and markets. (If the Latin Americans were able to make small fortunes on selling the U.S. refined petroleum, political pressures were building in those countries to raise the prices to double the current rates.)

An efficient system of money still had not been reestablished. The Federal Government paid the military and other Federal employees with dollars and tried to preserve purchasing power through a series of price controls. However, most people were reluctant to accept dollars in exchange for essentials such as food or clothing. As a result, a barter system continued to flourish and the black market, with its highly inflated prices, continued to encourage defiance of the law.

Most experts believed that the experience of post-World War II in Europe and Japan could provide the model for currency reform, including replacement of the dollar, that was necessary to restore an economy based on the divi-

sion of labor. However, the resolution of two policy issues stood in the way. First, should the market, on one hand, or Government control, on the other, determine the distribution of scarce resources? Second, should the new money go to those with legitimate claims, pensions, promissory notes for goods confiscated during the postattack period etc., or to those who held productive jobs, or even to the entire population even if many were more drag than help to the recovery? Politically, the Government was unable to deny any one of the groups; practically, it was obvious the Government could not satisfy al I three.

It was clear that if the economy did not get moving again soon, it might never. Already there were indications that manufacturing was not reestablishing itself with anywhere near the speed the planners had hoped. The amount of shipping, by rail and by truck, was actually down from the mid-summmer high.

"We are in the classic race, " remarked one of the participants who had written a major study of postattack recovery some years before. "We have to be able to produce new goods and materials before we exhaust our stored supplies. We can continue to eat the wheat that is in the grain elevators of the Midwest for another year, perhaps. But after that, we have to have the capacity to grow new wheat, When our winter coats wear through, we have to have the capacity to weave the cloth for new ones. When our railroad cars break down, we have to be able to make new ones, or replacement parts. Right now we are a long way from that capacity. " Privately, he and a group of conferees agreed that heavy controls on the economy, and ultimately on the population, would be the only way to get things going. Resources, both material and human, were severely limited,

One of the major problems, it was obvious to everyone, was the drag the huge refugee population had on the recovery effort. While numbers of workers were actively engaged in the rebuildin$_g$ of the cities as well as the factories and services that powered the economy, there were as many more who were unemployed and unemployable for the time being. Their skills were not suited to the priority tasks. Several participants had prepared a statement on what should be done with these nonproductive members of society. "We cannot let this mass of people drain our resources while they do nothing to contribute, " it was rumored to say. "If we cannot let them starve outright, we suggest that they be issued only that amount of food which is minimally necessary to sustain life. They should be moved to camps away from the center of activity for reason of public morale. " The report was suppressed but several copies were leaked to the press anyway.

The most basic disagreement among the participants in the conference was over the level of reconstruction that might actually be feasible. Optimists cited the phenomenal recovery of Japan and West Germany after World War II and insisted that these be the models for the United States in the next 5 to 10 years

Pessimists, noting the major differences between the post-World War 11 era and the situation of Japan and Germany, felt these examples were irrelevant, or worse, misleading. "Everyone forgets the amount of aid that came in from outside in the late '4o's and early '50's. We don't have the United States, wealth to turn to. Such a goal is unrealistic and unreachable, even with absolute controls on the economy. "

The pessimists were divided. Some saw the Nation building itself along the line of some of the Asian nations, which boasted a small technologically advanced segment in the midst of a large agrarian or unskilled worker population, on the model of India or Indonesia. Some thought technology itself would eventually disappear from American society. "If you don't have computers to run, you don't train computer programmers, " one expert was overheard to say. "After a while, in a few generations, no one remembers how the machines worked at all. They remember the important things: how to plant crops, how to train draft horses and oxen, how to make a simple pump. We will have survived biologically, but our

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way of life is going to be unrecognizable. In several generations, the United States is going to resemble a late medieval society."

Because the conferees could not agree on what was a reasonable goal, much less how to get there, the conference report straddled all fences and concluded nothing. Follow-up task forces were appointed and the conferees agreed to meet again in the summer. Perhaps by then they would have a better idea of whether or not they were winning the race.

APPENDIX D–SUMMARY OF REPORT ON EXECUTIVE BRANCH CALCULATIONS

[Note: The full report, classified SECRET, is available separately to qualified requesters.]

PURPOSE

This appendix summarizes and analyzes studies of the direct effects of nuclear attacks that have been performed by and for various agencies of the executive branch of the U.S. Government in recent years. This review ineludes those studies whose results are currently viewed by the sponsoring agency as being valid and applicable to the current through mid-1980's time period, with the U.S. and Scviet forces projected under a SALT I I agreement.

SCOPE

The estimates of the direct effects of nuclear attacks presented in this paper represent analyses performed by or for the Department of the Defense (DOD), the Arms control and Disarmament Agency (ACDA), and the intelligence community. Although these analyses describe the direct effects of nuclear attacks in terms of population fatalities and attack damage objectives against military, leadership, and economic target systems, it is recognized that a more meaningful basis for assessing the direct effects of nuclear attacks would be to analyze the effects of such attacks in terms of postwar national survival and recovery To date, however, analytical capabilities have not permitted such analyses, I n fact, the complex issues concerning national recovery should nuclear war occur, or the postwar power and recovery capabilities of the belligerents, have as yet not even been properly formulated for analysis. Until that is accomplished, analyses of the direct effects of nuclear attacks will continue to focus, as have the studies used for this analysis, on one-dimensional first-order direct effects

Furthermore, all analyses examined in this study assume a “two-shot” nuclear war — the Soviets strike first against all targets included under a particular scenario and the U S. retaliates against a similar set of Soviet targets. More protracted (and more likely) attack scenarios are not examined. Hence, such factors as the feasibility of sustaining population in a “ protected or evacuated” posture over a protracted duration, either i n a continuing crisis with no nuclear attacks or one with attacks repeated every few days or so, are not reflected i n the damage estimates available from these studies and included in this report

Five questions provided the focus for the analytical results exam in this study:

1. How many people would be killed by:
   – Prompt effects of nuclear explosions?
   – Fallout radiation?
2. What number of nonfatal but disubling injuries could be expected?
3. What areas would possibly receive damaging levels of overpressure and how many people live o r work i n those areas?
4. What areas **would** receive what levels of fallout contamination ?
5. What would be the possible extent of fire damage, and what mechanisms would create it?

Answers to these questions, as provided in the various studies used in this analysis, are given i n the following section.

SUMMARY OF RESULTS

In viewing the estimated direct effects of nuclear attacks, particularly population casualties, it is important to focus on the *relative* numbers for the various nuclear attack scenarios examined, as opposed to the absolute. The analyses on which these estimates are based do not take into account the many imponderable associated with such a cataclysmic event, the majority of which would cause higher levels of human devastation than are indicated by the analyses of hypothetical attacks. A significant imponderable is the uncertainty of human behavior. Would people really react as planned and as assumed in the computer models? Also, our ability to simulate even the immediate direct effects from thousands of nuclear detonations based on data extrapolateions from single bursts is suspect because of its inherent uncertainties. And, finally, the inability to assess the longer term prospects for the immediate survivors, which would depend not only on the availability of subsistence levels of food, medical supplies, etc., but also on how quickly they could adapt to a radically unfamiliar environment and social structure, further limits the validity of these estimates as a net assessment of the damage to be expected as a result of nuclear war.

Population Damage

Table D-1 summarizes in terms of total national population high- and low-range fatality estimates derived from the various analyses used for this report. In view of the many uncertain factors involved in such estimates, it is not possible to synthesize a "best estimate" range from the results of the studies used for this analyses.

Differences within and between the low and high ranges listed in the table are due primarily to differences in force alert status, weapons laydown, population protection level, population data base, and/or evacuation scheme assumed.

Table 0-1 .–OTA Attack Cases–Executive Branch Fatality Estimates

Case	OTA attack cases	Population posture	Percent of national fatalities: Low range	Percent of national fatalities: High range
2	Small attack on U.S.		(not available)	
	Small attack on U.S.S.R.		(not available)	
3	Attack on U.S. ICBMs	In-place	1-3	8-10
	Attack on Soviet ICBMs	In-place	< 1	1-4
	Attack on U.S. CF	In-place	< 1-5	7-11
		Evac.	–	5-7
	Attack on Soviet CF	In-place	1	1-5
		Evac.	1-2	
4	Attack on U.S. CF, OMT, & ECON	In-place	35-50	59-77
		Evac.	10-26	32-43
	Attack on Soviet CF, OMT, & ECON	In-place	20-32	26-40
		Evac.	9-14	
3 (excursion)	Attack on U.S. CF and OMT	In-place	14-23	26-27
		Evac.	–	18-25
	Attack on Soviet CF and OMT	In-place	5-17	22-24
		Evac.	6-9	
4 (excursion)	Attack on U.S. CF, OMT, ECON, and population	In-place	–	60-88
		Evac.	28-40	47-51
	Attack on Soviet CF, OMT, ECON, and population	In-place	–	40-50
		Evac.	22-46	

NOTE: CF = counterforce targets. OMT = other military targets. ECON = economic targets.

For Soviet First-Strike Attacks on the United States, Against:

ICBM Targets Only (Case 3). – The 1- to 3-percent spread in the low range results from assureing two 550-kiloton (kt) optimum height-of-burst (OPT HOB) weapons per silo (1-percent national fatalities) versus assureing one 550-kt OPT HOB and one surface burst 550-kt weapon per silo (3-percent national fatalities). The 8- to 10-percent spread in the high range results from assuming one 3-megaton (Mt) OPT HOB and one surface-burst 3-Mt weapon per silo (8 percent) versus assureing two 3-Mt surface bursts per silo (1 O percent). The difference between the ranges is due to the difference in the yield of the assumed weapons.

All Counterforce Targets (Case 3).–The less than 1-to 3-percent low range for *in-p/ace U.S. population* fatalities results from the difference in fallout protection levels assumed by DOD and AC DA. The less than l-percent value assumes an enhanced U.S. in-place fallout protection program that would provide a fallout protection factor (PF) of at least 25 for the entire population. The 3-percent value assumes in-place fallout shelters providing PFs of 10 to 1,000 and that 90 percent of the population would use the shelters. The unprotected portion of the population is assumed to be equally divided between a PF of 3 and 6. The 7- to 11-percent high range also results from differences in fallout protection levels assumed by DOD and AC DA. In this case, the 7-percent value assumes the current U.S. in-place fallout protection program. PFs as low as 5 are assumed for about one-half of the U.S. rural population, and PFs as low as 15 for one-quarter of U.S. urban population. The 1 l-percent value assumes essentially no U.S. civil defense program and a PF of 3 for the entire U.S. population. The difference between the ranges reflects the differences in the assumed fallout protection levels.

All Counterforce Targets (Case 3).– The 5- to 7-percent high range for *evacuated U.S. population* fatalities reflects ACDA's assumptions concerning the amount of fallout protection available for the combined rural and evacuated urban population. The 5-percent value assumes 66 percent of the total exurban population would be able to obtain fallout protection of 10 to 40 PF. Those persons not protected were assumed to be equally divided between between a PF of 3 and of 6. The 7-percent value assumes only **33** percent of the total exurban population would be able to obtain fallout protection of 10 to 40 PF. The rest were assumed to be equally divided between a PF of **3** and 6. This range of values is listed as "high" because it results from assuming that no expedient fallout protection upgrading could be achieved by the evacuated population.

Counterforce, Other Military Targets, and Economic Targets (Case 4). — The 35- to 50-percent low range for *in-p/ace U.S. population* fatalities results from assuming day-to-day alert (35-percent fatalities) versus generated forces (50-percent fatalities), and that 90 percent of the U.S. population are sheltered in available civil defense shelters. The 59- to 77-percent high range reflects differences in weapons laydown and population protection level. The 59-percent value assumes a generated forces Soviet attack with about 60 percent of the weapons air burst and that only 66 percent of the U.S. population are sheltered in available civil defense shelters. The 77-percent value also assumed a generated forces attack, but with all weapons ground burst and no civil defense sheltering of the population. The reasons for the differences between the ranges are the differences in assumed population protection levels and weapons laydown.

Counterforce, Other Military Targets, and Economic Targets (Case 4). — The 10- to 26-percent low range for *evacuated U.S. population* fatalities results from differences in assumed weapons laydown. The 10-percent value assumes about half the attacking weapons are air burst. The 26-percent value assumes all weapons are ground burst. Both values in the low range assume expedient upgrading of fallout protection could be achieved by the evacuated population, that is, a fallout PF of at least 25 for the entire U.S. population. The 32- to 43-percent high range reflects ACDA's assumptions as to the fallout protection that could be achieved by the evacuated population. The 32-percent

value assumes 66 percent of the total exurban population would be able to obtain fallout protection of 10 to 40 PF. The 43-percent value assumes only 33 percent could obtain such protection. Those persons not protected in each case were assumed to be equally divided between a PF of 3 and of 6. The difference between the ranges can be attributed to: 1) The differences in the levels of fallout protection assumed. The low range assumes expedient upgrading. 2) The less extensive evacuation scheme used by ACDA. The low range (DOD results) assumes 80 percent of all U.S. risk area population is evacuated. The high range (ACDA results) assumes only cities of more than 25,000 population are evacuated. 3) The larger, about 1,000 more equivalent megatons (EMT), attack laydown used by ACDA.

Counterforce and Other Military Targets (Case 3 excursion).—Within the low range, the spread in values, for *U.S. population in-place,* results from day-to-day alert versus generated forces attacks. Within the high range, the spread reflects day-to-day alert versus generated forces plus low protection levels (no civil defense assumed) versus an assumed in-place civil defense population posture. The difference between ranges is primarily due to the difference in assumed population protection levels.

Counterforce and Other Military Targets (Case 3 excursion).—The 18- to 25-percent range for *U.S. population evacuated* is based on ACDA analysis and reflects ACDA's assumptions as to the percent of exurban population that would have sheltering available in host areas. The 18 percent corresponds to 66 percent having available shelters and the 25 percent corresponds to 33 percent having available such shelters. This range probably represents high estimates because of the evacuation scheme assumed by ACDA. The 47-percent value assumes degraded protection levels based on DOD's sensitivity analysis, and evacuation of 80 percent of all risk area population. The 51-percent value also reflects degraded protection levels, only 33 percent of the total exurban population are able to obtain protection in rural shelters, and ACDA's less extensive relocation scheme. Once again, the range also reflects the effect of ground bursting all weapons versus air bursting about half the weapens The difference between the ranges is due to differences in assumed population protection levels,

Counterforce, Other Military Targets, Economic, and Population (Case 4 excursion).— In this case the 60- to 80-percent fatality range for U.S. population in-place reflects the impact of the protection levels assumed. The 60-percent value corresponds to the high protection levels used by DC PA. The 88-percent value corresponds to the more modest levels assumed by OSD analysts. This range is listed as "high" because of the severity (all ground bursts and all but 10- to 15-percent of Soviet weapons) of the attack used.

Counterforce, Other Military Targets, Economic, and Population **(Case** 4 excursion). — The 28- to 40- percent low range for *U.S. population evacuated* reflects the d inferences between DOD's and ACDA's assumptions concerning levels of fallout protection, evacuation scheme, and weapons laydown. The 28-percent value assumes expedient upgraded protection levels as specified by DCPA and evacuation of 80 percent of all risk area population. The 40-percent value reflects ACDA's less extensive evacuation scheme (only cities with population greater than 25,000 are evacuated) and no expedient upgrading of protection levels. In addition, the 28-percent value results from an attack with all weapons ground burst and the 40- percent value assumes about half the values are air burst. The 47- to 51-percent high range also results from differences in fallout protection, evacuation scheme, and weapons laydown. In this case the 47-percent value assumes degraded protection levels based on DOD's sensitivity analysis, and evacuation of 80 percent of all risk area population. The 51-percent value also reflects degraded protection levels, only 33 percent of the total exurban population are able to obtain protection in rural shelters, and AC DA's less-extensive relocation scheme. Once again, the range also reflects the effect of ground bursting all weapons versus air bursting about half the weapons. The difference between the ranges is

clue to differences in assumed population protection levels.

For U.S. Retaliatory Attacks on the U. S. S. R., Against:

ICBM Targets Only (Case 3).– The low, less than l-percent, value assumes one OPT HOB weapon per silo In this case fatalities are less than 1 percent for attacks using only 40-kt, only 200-kt, or only 1-Mt weapons The high range of 1 to 4 percent results from assuming one ground-burst weapon per silo. In this case the 1-percent value assumes only 200-kt weapons and the 4-percent value assumes only 1-Mt weapons are used. The differences between the range reflects the effect of OPT HOB weapons versus ground bursting al I weapons.

All Counterforce Targets (Case 3).– The less than 1-percent low value for *in-p/ace Soviet population* assumes relatively good fallout protection for the entire Soviet population and, in the case of ACDA's analysis, a U.S. attack based on a preplanned laydown using in part U.S. ICBMs that do not survive the Soviet first strike. The high range reflects differences in weapons laydown, population protection levels, and data bases used by ACDA and DOD. The less than l-percent value reflects ACDA's preplanned attack laydown, relatively good fat lout protection assumptions, and use of a coarser Soviet population data base. The 5-percent value reflects DOD's attack lay down, which does not attrite U.S. weapons due to a Soviet first strike, lower fallout protection assumptions, and use of a finer Soviet population data base The difference between the ranges results from all these differences i n dassumptions.

All Counterforce Targets (Case 3).– The less than 1- to 2-percent variation results from differences in population protection levels assumed by ACDA for *evacuated Soviet population.* The less than 1 -percent value assumes 66 percent of the exurban population use available sheltering. Those not using such sheltering are assigned protection levels of 3 and 6 in equal shares. It is difficult to judge whether this represents a low or high range On one hand the range could be considered on the low side because of the coarseness of the Soviet data base used by ACDA. Conversely, the evacuation scheme assumed by ACDA would suggest that it be considered a high range.

Counterforce, Other Military Targets, and Economic Targets (Case 4). — l-he 20- to 32-percent low range for *in-place Soviet population* fatalit results from d inferences i n force alert status and weapons laydown assumed T he 20-percent value reflects day-to-day alert forces and an attack using only 40-kt air-burst weapons against economic targets. The 32-percent value reflects generated forces and an attack using d mixture of weapens against economic targets. The 26- to 40-percent high range reflects differences between ACDA and DOD assumptions. The 26-percent value from ACDA analysis assumes relatively good population protection levels and a lower amount of EMT used against economic tar-gets than assumed i n the DOD analysis. The W-percent value from DOD analysis reflect lower population protection levels, a finer population data base, and a larger attack against economic targets than used i n the ACDA analysis. The difference i n assumptions made by DOD, AC DA, and the interagency intelligence group.

Counterforce, Other Military Targets, and Economic Targets (Case 4). — The 9- to **14-percent** range reflects the difference in poplation protection levels used by ACDA for evacuated *Soviet population.* The 9-percent value assumes 66 percent use available shelters The 14 percent assumes only 33 percent use available shelters It is difficult to judge whether this reflects a low or high range. The coarseness of the Soviet data base used by AC DA would suggest it be treated as a low range Conversely, the ACDA evacuation scheme would suggest it be considered a high range.

Counter-force and Other Military Targets (Case 3 excursion) .—The differences within both ranges for *Soviet population in-p/ace* reflects the variation in protection levels assumed by AC DA. The difference between the ranges is due to the alert status of U.S. forces used.

Counterforce and Other Military Targets (Case 3 excursion).–The 6- to 9-percent range

reflects the variation in protection levels assumed by ACDA for *evacuated Soviet population, 66* percent use available shelters versus **33 percent. As** in the previous cases, with Soviet population evacuated, it is difficult to judge if this is a low or high range of fatalities.

Counterforce, Other Military Targets, Economic, and Population (Case 4 excursion). — Fatality estimates range from 40 to 50 percent for Soviet *population in-p/ace* based on DOD analysis. The variation is primarily due to differences in assumed population protection levels. Given the rather low protection levels assumed by DOD, the range probably represents the high level of Soviet fatalities.

Counterforce, Other Military Targets, Economic, and Population (Case 4 excursion). — Fatality estimates range from 22 to 26 percent for Soviet *population evacuated* based on ACDA analysis. The variation reflects differences in assumed population protection levels; 66 percent use available shelters versus 33 percent. Once again it is difficult to judge whether this is a high or low range. The coarse data base used by ACDA suggests their estimates are low, but the evacuation scheme suggests they might be high.

In examining the fatality ranges listed in table D-1 it should be noted that the differences between U.S. and Soviet fatality levels for comparable attacks and population postures can be primarily attributed to:

- The nature of the nuclear attacks assumed in the various studies; that is, the assumption that the Soviets attack first and the United States retaliates in the various attack scenarios examined,
- The higher yields of Soviet weapons, which result in significantly higher levels of nuclear yield detonating in the United States than the U.S.S.R. for comparable attack cases.

Although the data on nonfatal injuries available from the studies used in this analysis are quite limited, the results suggest that:

- For attacks against ICBMs or counterforce target sets, nonfatal injuries would about equal fatalities.
- For attacks that include economic targets, but not population per se, nonfatal injuries would vary from about 20 to 40 percent of total casualties.
- For attacks including population, nonfatal injuries vary from about 8 to 25 percent of total casualties.

Military and Economic Damage

Unlike population damage levels, which (except for excursions to Case 4) result only collaterally from attacks on other target sets, damage levels against military and economic target sets are input objectives used in structuring the attack laydowns examined in the various analyses on which this report is based. Damage levels attained against these target systems in the studies examined in this analysis were:

For Soviet First-Strike Attacks Against the United States:

Counterforce Targets (Percent Total Damaged).— ICBMs (42 to 90 percent), SAC bomber bases (90 to 99 percent), and submarine support facilities (90 to 99 percent).

Other Military Targets (Percent Installations Damaged). –Major military leadership facilities (90 to 95 percent), State capitals (95 percent), DCPA and FPA emergency operating centers (95 percent), and other military installations (77 to 90 percent).

Economic Targets. – 70- to 90-percent damage of the national manufacturing value of the economic targets attacked.

For U.S. Retaliatory Attacks Against the U. S. S. R.:

Counterforce Targets (Percent Total Damaged).— Bomber bases (70 to 90 percent).

Other Military Targets (Percent Installations Damaged).– Major military leadership facil-

ities (70 to 90 percent), major political leadership facilities **(7o to 90 percent), and other miliitary install at** ions **(20 to 50 percent).**

Economic Targets. – 70- to 90-percent damage of the national manufacturing value added plus capital replacement cost of the economic targets attacked.

As in the case of population fatalities, the **differences between U.S. and Soviet damage** levels against strategic forces, other military **targets, and economic targets can be attrib-**uted to the assumption that the Soviets strike first and to the larger yields of Soviet weapons.

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APPENDIX F–GLOSSARY

[This glossary is excerpted from the larger one in The *Effects of Nuc/ear Weapons,* 3rd cd., compiled and edited by Samuel Glasstone and Philip J. DoIan, prepared and published by the U.S. Department of Defense and the U.S. Department of Energy, Washington, D. C., 1977.]

Alpha Particle: A particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass of four units and an electric charge of two positive units.

Cloud Column: The visible column of weapon debris (and possibly dust and water droplets) extending upward from the point of burst of a nuclear (or atomic) weapon.

Crater: The pit, depression, or cavity formed in the surface of the Earth by a surface or underground explosion. Crater formation can occur by vaporization of the surface material, by the scouring effect of air blast, by throwout of disturbed material, or by subsidence. In general, the major mechanism changes from one to the next with increasing depth of burst. The apparent crater is the depression which is seen after the burst; it is smaller than the true crater (i. e., the cavity actually formed by the explosion), because it is covered with a layer of loose earth, rock, etc.

Dynamic Pressure: The air pressure that results from the mass air flow (or wind) behind the shock front of a blast wave. It is equal to the product of half the density of the air through which the blast wave passes and the square of the particle (or wind) velocity behind the shock front as it impinges on the object or structure.

Electromagnetic Pulse: A sharp pulse of radio frequency (long wavelength) electromagnetic radiation produced when an explosion occurs in an unsymmetrical environment, especially at or near the Earth's surface or at high altitudes. The intense electric and magnetic fields can damage unprotected electrical and electronic equipment over a large area.

Fallout: The process or phenomenon of the descent to the Earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself. The early (or local) fallout is defined, somewhat arbitrarily, as those particles which reach the Earth within 24 hours after a nuclear explosion. The delayed (or worldwide) fallout consists of the smaller particles that ascend into the upper troposphere and into the stratosphere and are carried by winds to all parts of the Earth. The delayed fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

Fire Storm: Stationary mass fire, generally in built-up urban areas, causing strong, inrushing winds from all sides; the winds keep the fires from spreading while adding fresh oxygen to increase their intensity.

Fission Products: A general term for the complex mixture of substances produced as a result of nuclear fission. A distinction should be made between these and the direct fission products or fission fragments that are formed by the actual splitting of the heavy-element nuclei. Something like **80** different fission fragments result from roughly 40 different modes of fission of a given nuclear species (e. g., uranium-235 or plutonium-239). The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains over 300 different isotopes of 36 elements.

Gamma Rays (or Radiations): Electromagnetic radiations of high photon energy originating i n atomic nuclei and accon:panying many nuclear reactions (e. g., fission, radioactivity, and neutron capture). Physically, gamma rays are identical with X-rays of high energy, the only essential difference being that X-rays do not originate from atomic nuclei but are produced in other ways (e. g., by slowing down (fast) electrons of high energy).

Height of Burst (HOB): The height above the Earth's surface at which a bomb is detonated in the air. The optimum height of burst for a particular target (or area) is that at which it is estimated a weapon of a specified energy yield will produce a certain desired effect over the maximum possible area.

Kiloton Energy: Defined strictly as **10^{12}** calories (or 4.2 x 10^{19} ergs). This is approximately the amount of energy that would be released by the explosion of 1 kiloton (kt) (1 ,000 tons) of TNT.

Megaton Energy: Defined strictly as 10^{15} calories (or **4.2 x 1022 ergs). This is approximately the amount** of energy that would be released by the explosion of 1,000 kt (1 million tons) of TNT.

Neutron: A neutral particle (i. e., with no electrical charge) of approximately unit mass, present in all atomic nuclei, except those of ordinary (light) hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced by both fission and fusion reactions in nuclear (or atomic) explosions.

Nuclear Radiation: Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true. X-rays, for example, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atom i c nuclei,

Nuclear Weapon (or Bomb): A general name given to any weapon in which the explosion results from the energy released by reactions involvin g atomic nuclei, either fission or fusion or both. Thus, the A- (or atomic) bomb and the H- (or hydrogen) bomb are both nuclear weapons. It would be equally true to call them atomic weapons, since it is the energy of atomic nuclei that is involved in each case However, it has become more-or-less customary, although it is not strictly accurate, to refer to weapons in which all the energy results from fission as A-bombs or atomic bombs. In order to make a distinction, those weapons in which part, at least, of the energy results from thermonuclear (fusion) reactions of the isotopes of hydrogen have been called H-bombs or hydrogen bombs.

Overpressure: The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion. The variation of the overpressure with time depends on the energy yield of the explosion, the distance from the point of burst, and the medium in which the weapon is detonated. The peak overpressure is the maximum value of the overpressure at a given location and is generally experienced at the instant the shock (or blast) wave reaches that location.

Rad: A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of nuclear (or ionizing) radiation per gram of absorbing material, such as body tissue.

Rem: A unit of biological dose of radiation; the name is derived from the initial letters of the term "roentgen equivalent man (or mamreal). " The number of reins of radiation is equal to the number of rads absorbed multiplied by the relative biological effectiveness of the given radiation (for a specified effect). The rem is also the unit of dose equivalent, which is equal to the product of the number of rads absorbed and the "quality factor" of the radiation.

Roentgen: A unit of exposure to gamma (or X) radiation. It is defined precisely as the quantity of gamma (or X) rays that will produce electrons (in ion pairs) with a total charge of 2.58 x 10^{-4} coulomb in 1 kilogram of dry air. An exposure of 1 roentgen results in the deposition of about 94 ergs of energy in 1 gram of soft body tissue. Hence, an exposure of 1 roentgen is approximately equivalent to an absorbed dose of 1 rad in soft tissue. See *Rad.*

Thermal Radiation: Electromagnetic radiation emitted (in two pulses from an air burst) from the fireball as a consequence of its

very high temperature; it consists essentially of ultraviolet, visible, and infrared radiations. In the early stages (first pulse of an air burst), burst), when the temperature of the fireball is extremely high, the ultraviolet radiation predominates; in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum, For high-altitude bursts (above 100,000 feet [30,480 meters]), the thermal radiation is emitted as a single pulse, which is of short durartion below about 270,000 feet [82,296 meters] but increases at greater burst heights