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AN ANALYSIS OF CIVIL DEFENSE IN NUCLEAR WAR.(U)
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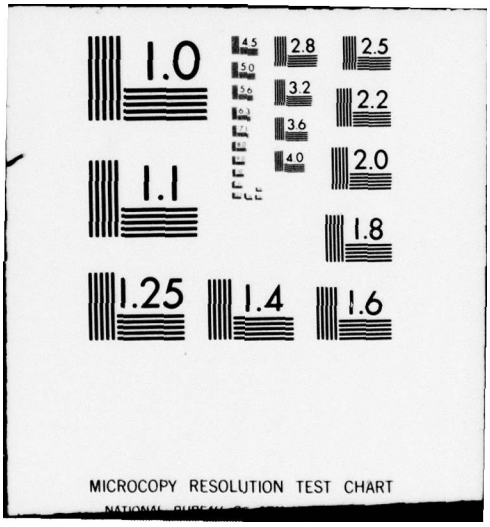
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UNITED STATES ARMS CONTROL AND DISARMAMENT AGENCY

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Summary

This report presents a summary of the effectiveness of civil defense in a nuclear war. The results are applicable to the mid-1980s time period with the U.S. and Soviet forces projected under a SALT TWO agreement. The analyses were based on a Soviet first strike and a U.S. retaliatory attack.

A comparison was made of the vulnerability of the U.S. and the Soviet Union to nuclear attack. It was found that both countries are roughly equally vulnerable although urban density and population collocation with industry is greater in the Soviet Union.

The effect of the U.S. retaliatory attack against key Soviet industry caused:

- 65 to 70 percent destruction from a normal day-to-day alert of our strategic forces;
- 85 to 90 percent destruction from a generated alert of these forces.

Any attempts at industrial hardening would be of little use in view of the fact that detonating weapons at lower altitudes can create immensely greater levels of blast overpressure. Furthermore, future U.S. weapon systems would offset 1½ to 3 fold increases in hardness.

While people were not targeted, human fatalities from the attacks were still immense, on the order of 100 millions from the prompt effects alone, without civil defense. In-place shelter protection could reduce the fatalities by 20%, but this effect would be offset if the strategic forces were put on generated alert. Evacuation of the urban areas, if it can be implemented, would substantially reduce the fatalities from short-term effects to the order of 25 to 35 million in the Soviet Union. However, weapons could be used against the evacuated population with ground bursts, causing as much as 70 to 85 million fatalities in the Soviet Union even if the Soviet evacuation and sheltering plan is fully implemented. U.S. fatalities were generally found to be even higher than Soviet fatalities due primarily to factors not associated with civil defense; that is, the analyses were based on Soviet first strikes and Soviet weapons have higher yields than U.S. weapons. The less extensive U.S. sheltering capability would be a minor factor in this difference.

Many other effects of nuclear war are also discussed, including:

- The destruction of 80% of all Soviet cities with populations above 25,000.
- The massive destruction caused by fires that could not be fought due to radiation and lack of water.
- The extreme radiation doses (up to 30,000 roentgens) in the urban areas.

— The large casualty rates for people located in even very hard blast shelters.

— The fact that people that survive blast would have to stay in shelters for weeks or months.

— The shortage of food and water which would force many people to leave shelters.

— The fact that there would be 30 to 50 million injured in addition to the high fatality levels.

— The shortage of medical care due to destruction of hospitals (80% of all Soviet urban hospitals were destroyed).

— The effect of the attacks on agriculture - crops would be only moderately affected but livestock destruction would be serious.

— The effect of the attack on the earth ozone layer, in addition to the possible long term genetic and climatic changes.

One can conclude from the above that:

— The fatalities and industrial damage presented in this report represent only a part of the total disaster of a massive nuclear war.

— Many of these effects are difficult to measure and simulate on computers; nevertheless, they are real factors which must be considered.

— While some civil defense activities, such as evacuation, have some effect on the immediate post attack environment, their benefits in the long run have not yet been established.

An Analysis of Civil Defense in Nuclear War

I. Introduction

The purpose of this report is to present an unclassified summary of a series of detailed analyses of the potential effectiveness of civil defense in a nuclear war environment. The results of the analyses are applicable to the mid-1980s time period. Moreover, they assume that U.S. and Soviet strategic forces will be in accordance with the forces currently projected under a SALT TWO agreement. The analyses were performed on large scale strategic exchange computer models using the best projections of the characteristics and capabilities of U.S. and Soviet forces.

Most of the analyses deal with damage to the Soviet Union. It should be noted, however, that comparable damage would occur in the U.S. Comparisons of U.S. and Soviet damage are made in a number of pertinent places. All the analyses assume a Soviet first strike against U.S. strategic forces, other military targets and industry; followed by a U.S. retaliation with its surviving forces (except for a reserve) against a similar set of Soviet targets.

The following topics are addressed in this paper:

- Overview of the Soviet civil defense program;
- Vulnerability of U.S. and Soviet civil sectors;
- Attack scenarios;
- Effect of attacks on Soviet industry;
- Industrial hardening;
- Human fatalities from attacks;
- Other factors.

II. Soviet Civil Defense

The Soviet Civil Defense Program* is a substantial program which has been ongoing for over 30 years. It is a military controlled organization, estimated to consist of over 100,000 full-time civilian and military personnel. The cost of this program in 1976 has been estimated at about 400 million rubles, which represents less than 1 percent of the estimated Soviet defense budget. While 400 million rubles equates to approximately $500 million at the official rate of exchange, a

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* See detailed description in "Soviet Civil Defense," Central Intelligence Agency, NI 78-10003, July 1978.

parallel program would be much more expensive to duplicate in the U.S. because it is highly labor intensive. The cost of 100,000 civil defense workers alone would be on the order of $1.5 billion in the U.S., and the total cost of a duplicate program in the U.S. would be about $2 billion.

The Soviet civil defense organization has published several books and manuals, a number of which have been translated into English by U.S. agencies. These publications as well as other open source references to the Soviet civil defense program depict a system which is broad in scope and devoid of gaps, in conceptual terms. An assessment based wholly on Soviet literature would greatly overestimate the reality as well as the effectiveness of the system.

The most tangible aspect of the Soviet civil defense program is the presence of hardened underground shelters. At the present time the Soviets are believed to have blast shelters for most of their leadership. In-place protection is estimated to be sufficient for 10 to 20 percent of their urban population, based on a shelter space allowance of 1.0 and .5 square meters of floor space respectively. ACDA believes that $.5M^2$ is unrealistic due to the expected extended shelter stay times that would be required. Note that $.5M^2$ is equivalent to a square that is only 28 inches by 28 inches.

The Soviets have developed plans for evacuation of the urban areas. These plans consist of transporting the urban population by rail, motor vehicles or on foot to relocation sites in rural areas. In the rural areas the urban population is to be housed with rural hosts and to be protected from fallout by upgrading the protection of existing buildings or by the construction of expedient shelters. Although the Soviet Union has never tested a large scale city evacuation, it was assumed in the analysis presented here that 80% of the urban population could be evacuated.

The Soviet Union has plans for the protection of industry. Despite these plans, however, there is little evidence of industrial dispersal or hardening. The reason for this lack of action is undoubtedly the huge cost and limited effectiveness of such measures. The only major Soviet accomplishment in the industrial protection area is the building of shelters for part of the work force. In addition, there is a program for the training of civil defense workers.

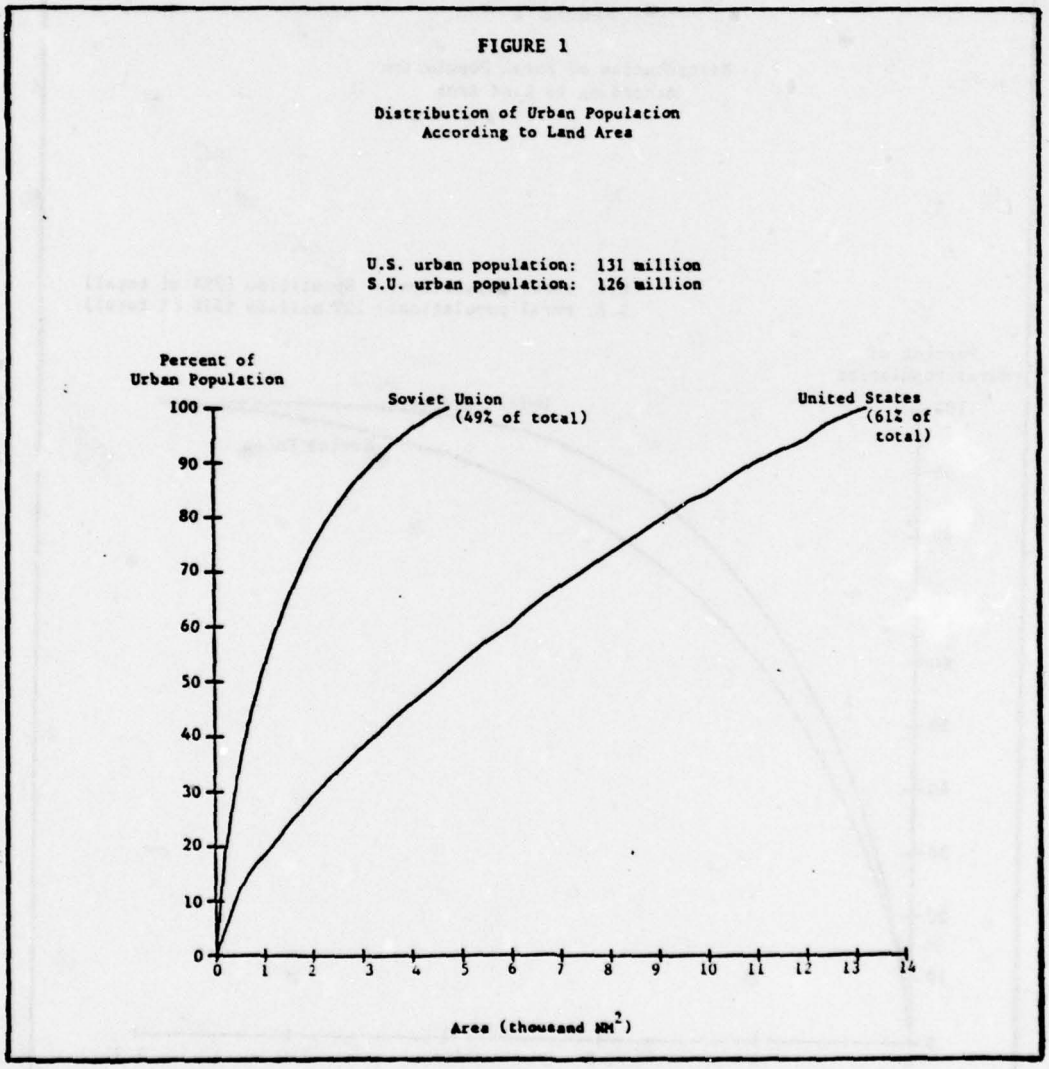
III. Comparison of U.S. and Soviet Targets

An issue that often arises in comparing the U.S. and the Soviet Union is the question of whether the Soviet Union, because of its large land area, has an inherent advantage over the United States. In order to investigate this issue the question of whether population and industry are more dispersed in the Soviet Union than in the United States was addressed.

Figure 1 compares the distribution of the urban populations by land area. This figure was constructed by taking the urban population (that is, the people that live in cities of 25,000 or larger) and cumulatively adding each residential district* from the largest one to the smallest one; then plotting the percent of the urban population as a function of the area of these districts. As can be seen from the figure the Soviet urban population lives in an area of less than 5000 NM^2, while the U.S. urban population lives in an area of about 14,000 NM^2. Clearly Soviet cities are more densely populated than are U.S. cities. This result is not surprising given that the Soviet urban population lives mostly in apartment houses while in the U.S. the private home is more common.

FIGURE 1

Distribution of Urban Population
According to Land Area



* The methodology used did not include non-populated urban areas such as commercial districts, rivers, lakes or large parks. Thus, total land area used in this comparison is less than the computed area based on city limit dimensions.

Figure 2 compares the distribution of the two rural populations by land area and indicates that the U.S. and Soviet rural population each live in an area of 2 to 2.5 million NM^2. Therefore, despite the fact that the Soviet land mass is considerably larger than the U.S. land mass, the rural populations of the two countries live in areas of similar size.

FIGURE 2

Distribution of Rural Population
According to Land Area

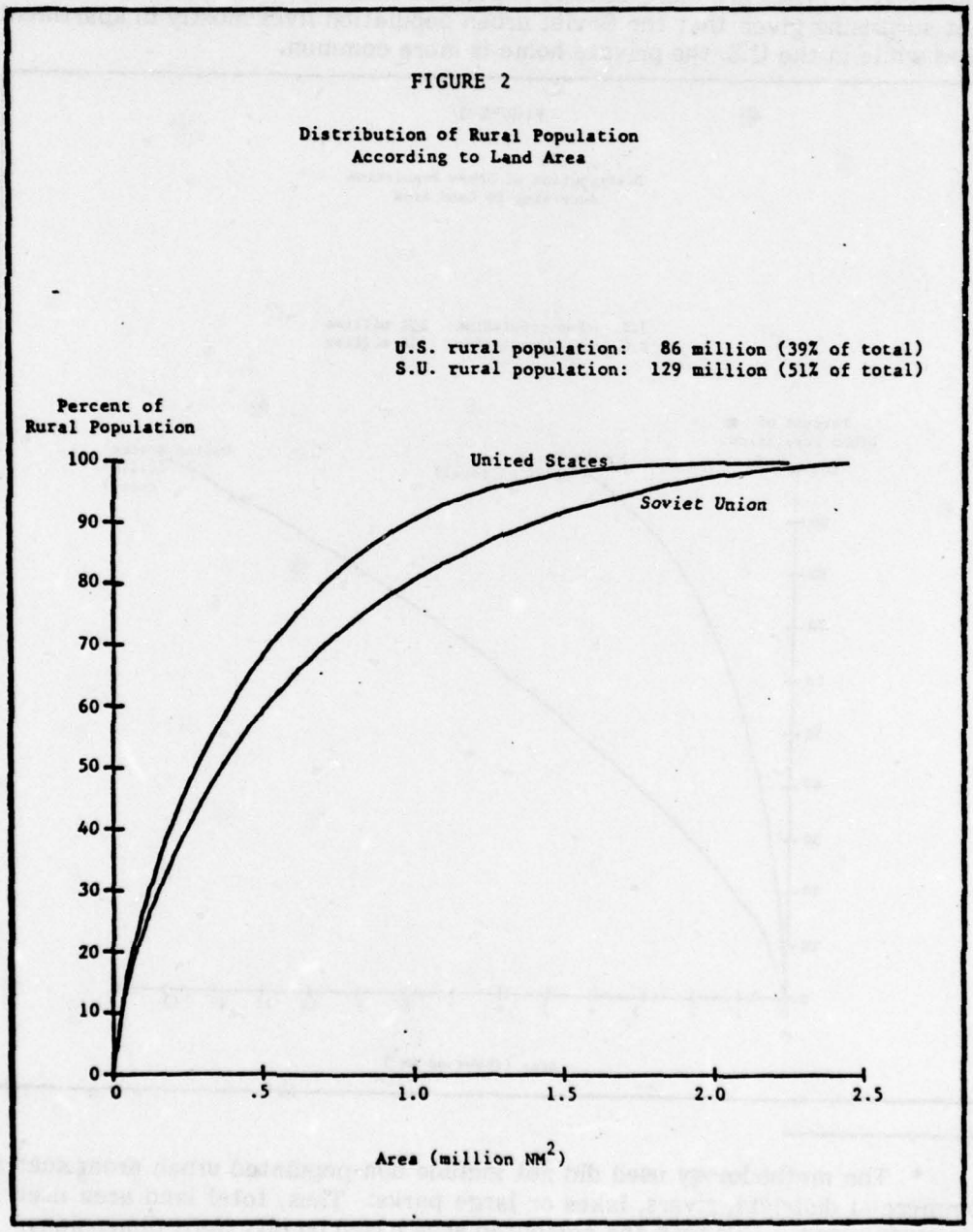
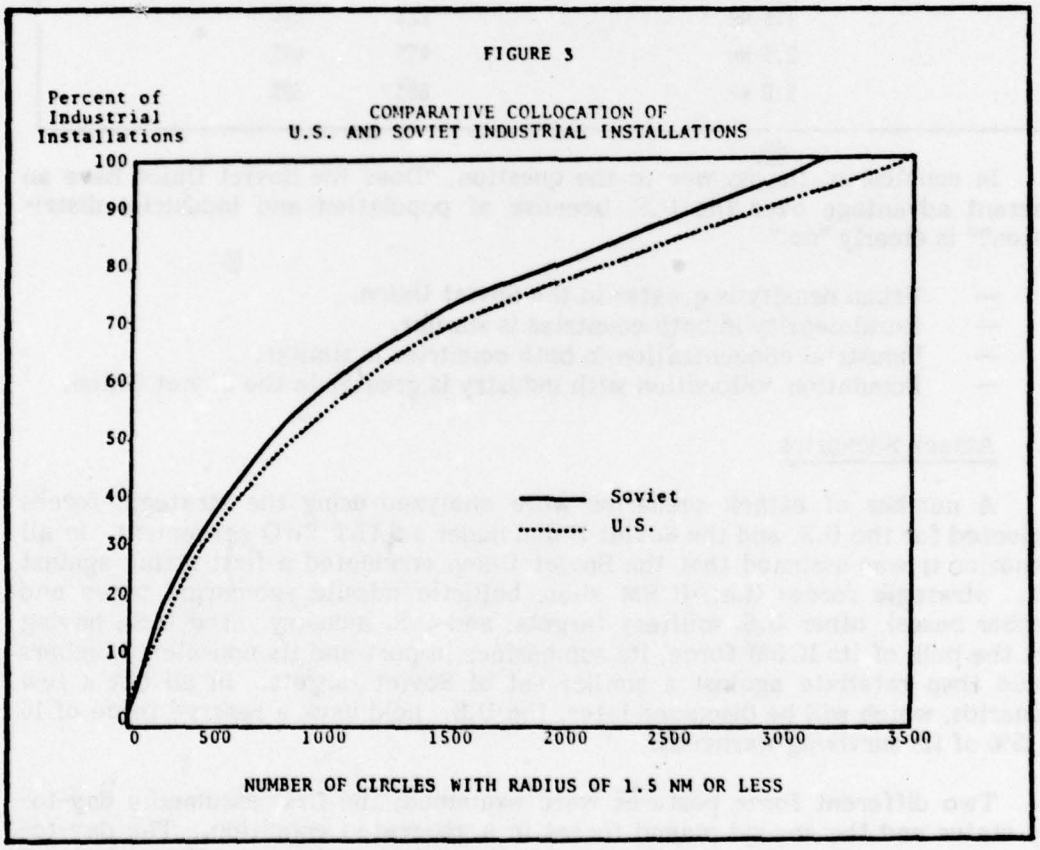


Figure 3 compares the collocation of industrial establishments. This figure was derived by computing the minimum number of circles with a radius of 1.5 NM* necessary to encompass all of the industrial installations in each country. The circles were then accumulated from the largest to the smallest (in terms of the numbers of industrial facilities enclosed within each circle) to form the curve shown. An inspection of this figure readily shows that the industrial concentrations in the U.S. and the Soviet Union are similar. Another interesting observation that can be made from this figure is that approximately 1300 of these circles (i.e., weapons) are sufficient to cover 70% of the industrial installations in either of the two countries. A more detailed analysis of Soviet industry shows that, in fact, key industries have more than half of their production in less than 200 plants. These facilities produce primary metals, chemicals, petroleum, construction equipment, agricultural equipment, railroad equipment, synthetic rubber and electric power generators.

FIGURE 3



* The destructive radius of a medium sized nuclear weapon against a soft target.

Figure 4 compares the collocation of population with industry. An inspection of this figure shows that the Soviet population lives closer to industry than does the U.S. population. This result stems from the fact that the U.S. has a more widely dispersed urban population and a large number of private automobiles which permit workers to live further from their work.

FIGURE 4

COLLOCATION OF POPULATION WITH INDUSTRY
(PERCENT OF POPULATION)

PERCENT OF POPULATION LIVING WITHIN:	U.S.	S.U.
1.0 NM	9%	16%
1.5 NM	22%	31%
2.5 NM	45%	44%
5.0 NM	68%	52%

In conclusion, the answer to the question, "Does the Soviet Union have an inherent advantage over the U.S. because of population and industrial distribution?" is clearly "no."

- Urban density is greater in the Soviet Union.
- Rural density in both countries is similar.
- Industrial concentration in both countries is similar.
- Population collocation with industry is greater in the Soviet Union.

IV. Attack Scenarios

A number of attack scenarios were analyzed using the strategic forces projected for the U.S. and the Soviet Union under a SALT TWO agreement. In all scenarios it was assumed that the Soviet Union conducted a first strike against U.S. strategic forces (i.e., ICBM silos, ballistic missile submarine bases and bomber bases), other U.S. military targets, and U.S. industry. The U.S., having lost the bulk of its ICBM force, its submarines in-port and its non-alert bombers would then retaliate against a similar set of Soviet targets. In all but a few scenarios, which will be discussed later, the U.S. held back a reserve force of 10 to 15% of its surviving warheads.

Two different force postures were examined; the first assumed a day-to-day status and the second placed forces in a generated condition. The day-to-day posture is the normal alert posture for strategic forces. The generated posture simulates the alert readiness which would occur in times of tension. Certainly if the Soviet Union implemented its civil defense posture, the warning this action would provide would result in U.S. strategic forces being placed on generated alert.

The results presented deal primarily with damage to the Soviet Union from the U.S. retaliatory attack. However, it should be noted that damage to the U.S. would be of similar magnitude. Furthermore, if the forces were larger than those projected under SALT TWO and/or if the U.S. were to strike first, the damage to the Soviet Union would be greater.

V. Effect of Attack on Soviet Industry

The effect of the U.S. retaliatory attack on Soviet industry was evaluated at the 10 psi level. That is, industrial facilities were assumed to be destroyed if they were subjected to overpressures of 10 pounds per square inch or more. This amount of overpressure is equivalent to wind blast of 600 miles per hour or more. In actual fact, most industry is softer than 10 psi. Furthermore, this is only the damage caused by blast and does not take into account the damage caused by other effects, particularly fires, which could be expected to cause complete burnout in areas exposed to somewhere between 3 and 5 psi.

Figure 5, for example, shows the percent of the total Soviet production capacity of primary metals that was destroyed in the simulated attacks. The

FIGURE 5

Damage Assessment -- PRIMARY METALS PRODUCTION/PROCESSING

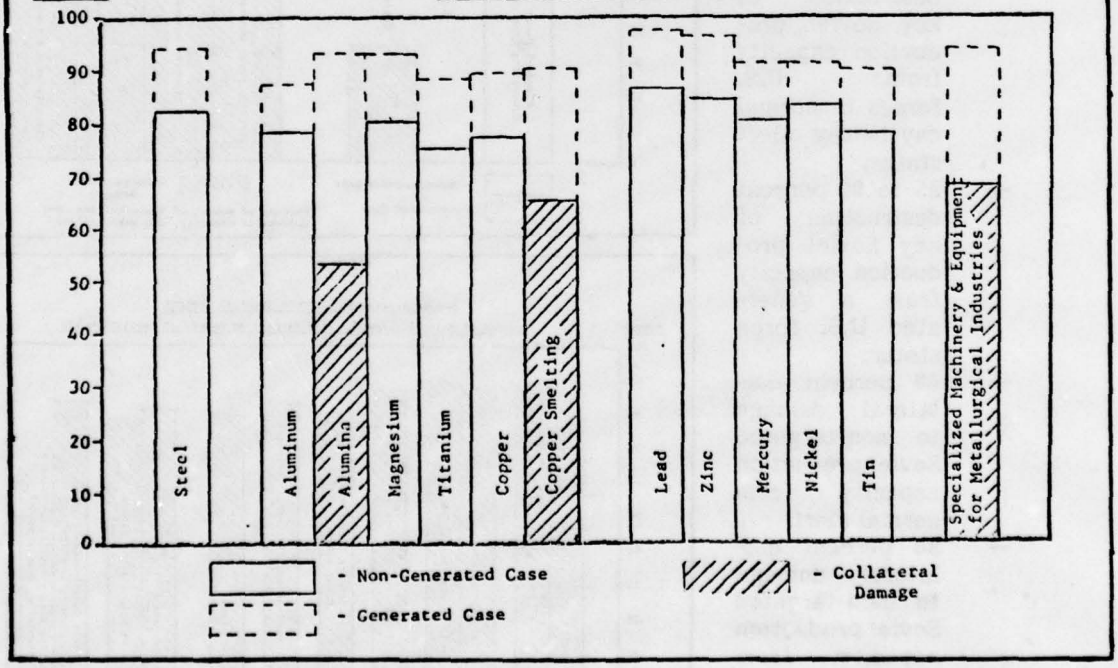
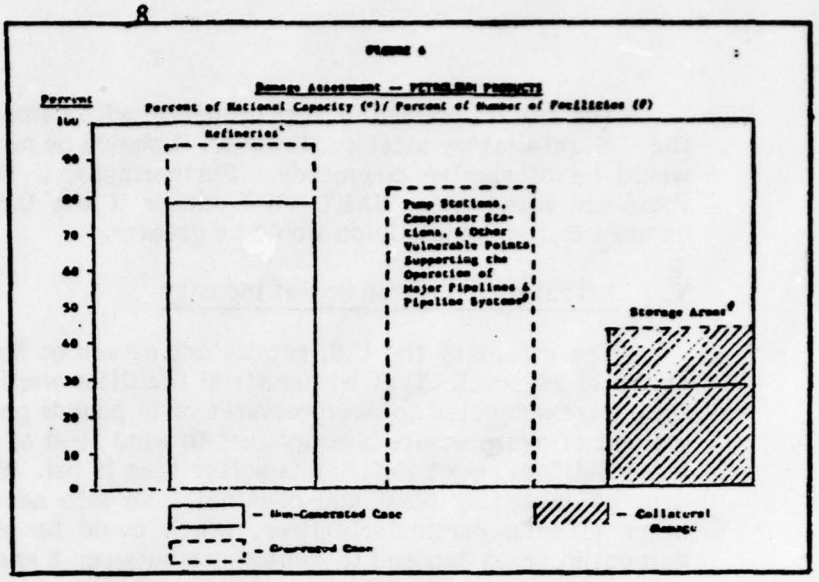


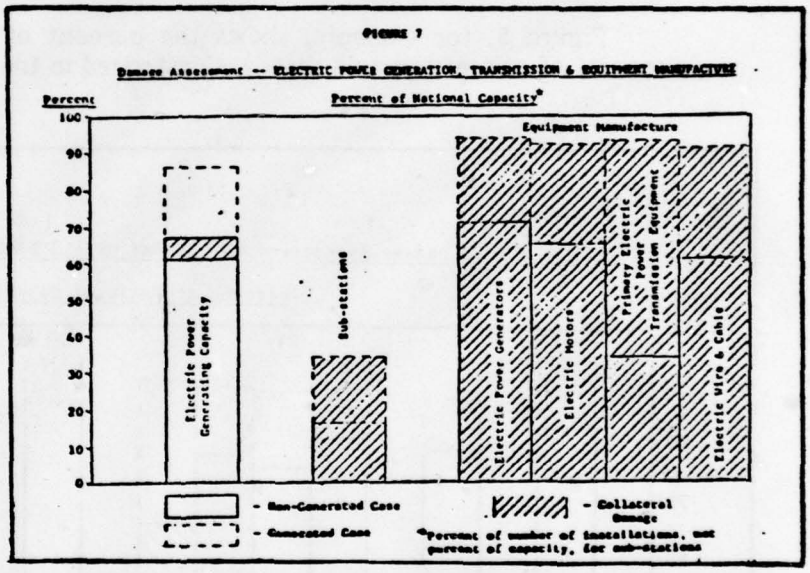
figure shows these results for both the day-to-day (non-generated) and the generated force postures. In addition the figure shows collateral damage to industrial facilities that were not targeted but which received damage because of their proximity to targeted facilities.

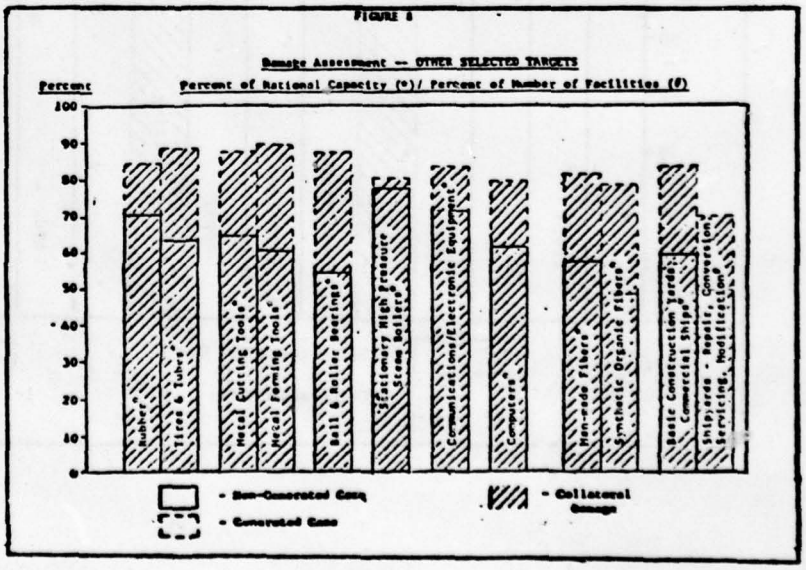
Figures 6, 7 and 8 show similar results for petroleum products, electric power generation and an assortment of other selected industries. Other industrial categories received similar damage.

In summary this representative U.S. attack on industry caused:

- 65 to 70 percent destruction of key Soviet production capacity from U.S. forces in normal day-to-day alert status;
- 85 to 90 percent destruction of key Soviet production capacity from a generated U.S. force status;
- 60 percent collateral damage to non-targeted Soviet production capacity from normal alert;
- 80 percent collateral damage to non-targeted Soviet production capacity from generated alert.







VI. Industrial Hardening

The question of hardening industrial plants and equipment has been raised at various times. In considering this question it is necessary to consider three factors; first, the range at which nuclear weapons can generate overpressures; second, the fact that overpressures can be greatly increased by setting off the explosions at lower altitudes; and finally, how much overpressure can be withstood by plant and equipment. On this last point it should be noted that, even at immense cost, we do not find it possible to build missile silos to sufficient hardness to withstand the overpressures of modern nuclear weapons delivered with high accuracy.

To illustrate the effect of blast overpressure, Figures 9 and 10 show the structural damage, respectively, to a brick house subjected to 5 psi overpressure at the Nevada Test Site and to the Mitsubishi steel plant at Nagasaki after subjected to 6 psi overpressure. Clearly these pictures show the destructive effect of 5 to 6 psi.

As noted earlier, in this analysis damage was measured at the 10 psi level and the weapons used against industry were detonated at heights of burst to optimize the size of the 10 psi overpressure effect. In order to investigate the potential effect of some industrial facilities being hardened, an analysis was made of the effect of detonating the weapons at low altitudes. This analysis showed that, with ground burst, the 10 psi damage level presented earlier would be reduced by 5 to 10 percent but that the overpressure over the center of the target area would be greatly increased.

FIGURE 9

STRUCTURAL DAMAGE FROM AIR BLAST

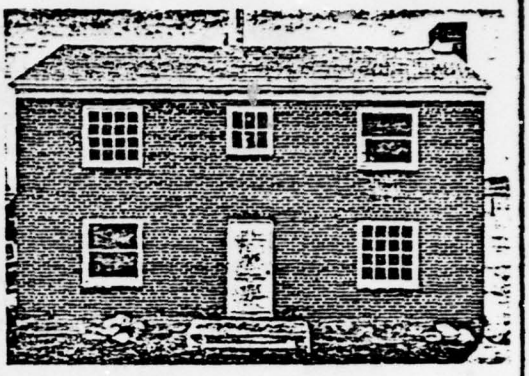


Figure 5.29. Unreinforced brick house before a nuclear explosion, Nevada Test Site.

Figure 5.30. Unreinforced brick house after a nuclear explosion (5 psi overpressure).

Figure 10

Industrial Damage at 6 psi Overpressure

Machine Shop at Mitsubishi Steel and Arms Plant - Nagasaki, Japan - August 1945

Figure 11 shows 40 kiloton and 1 megaton nuclear weapon ground bursts over a Soviet refinery. It can be noted in this figure that the 40 KT weapon creates an 80 psi overpressure over the entire facility, and that the 1 MT weapon creates a 300 psi overpressure circle much larger than the facility. Figure 12 presents a similar display for a very large U.S. plant, the Boeing Auburn facility. It can be noted that a 1 MT weapon covers the entire facility with 80 psi of overpressure, while a 40 KT weapon covers it with 10 psi. A 40 KT weapon detonated at the center of this facility would therefore result in 100% damage expectancy, if accuracy of weapon delivery is taken into account the damage expectancy to this large plant would be 90% from the effects of blast alone. Fires and other effects would of course cause additional damage.

In addition to the capability to detonate weapons at low altitudes is the fact that the new weapons that are entering the U.S. inventory in the 1980s will create larger overpressures. New U.S. SLBMs will create approximately 50% higher overpressures than current SLBMs and the ALCM will roughly triple the overpressure of

FIGURE 11

OVERPRESSURE CONTOURS -- SOVIET REFINERY

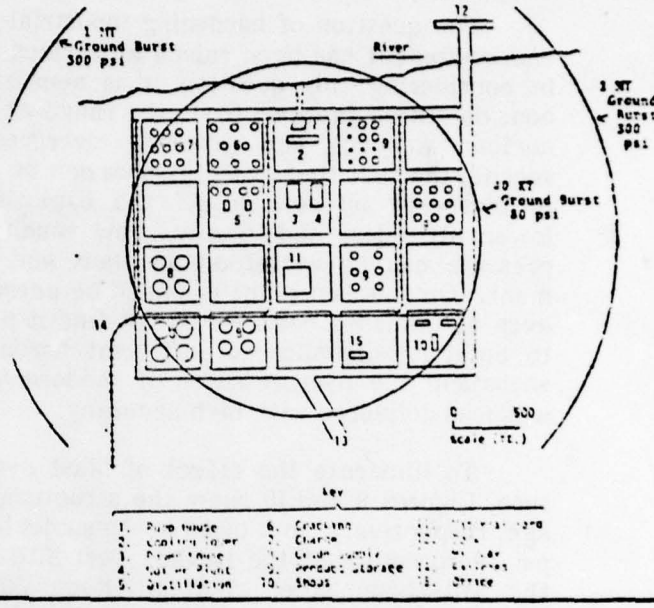
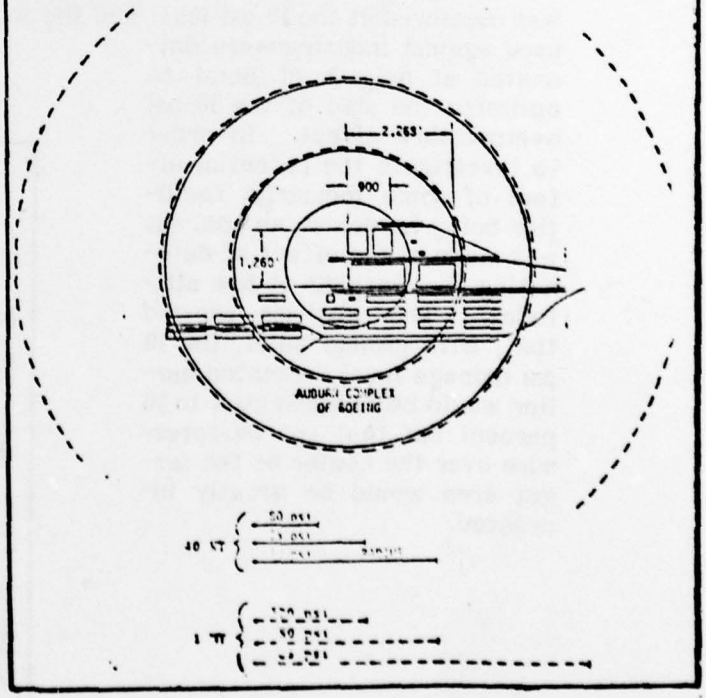


FIGURE 12

OVERPRESSURE CONTOURS -- BOEING AUBURN FACILITY

40 KT and 1 MT Ground Bursts



our current SLBM. Clearly it is much easier to introduce more effective weapons to overcome attempts at hardening than it is to harden industrial plants and equipment.

In summary we conclude that attempts to harden above-ground facilities is a futile exercise, and that even buried facilities which are targeted cannot survive. Selected pieces of equipment could be expediently hardened to improve survival in peripheral areas; however, hardening machinery in targeted facilities would be of little use. Any attempt to harden can be easily overcome by detonating weapons at lower altitude with only a minor reduction in the 10 psi destruction capability. Future U.S. weapons would offset 1½ to 3 fold increases in hardness even if such increases could be physically and economically accomplished.

VII. Human Fatalities From the Attacks

As noted earlier the attacks were directed against strategic forces, other military targets, and industry. The population was not attacked directly but an evaluation was made of collateral damage to population. The fatalities reported in this section refer only to those occurring from blast, radiation, and short term fallout effects. Over a longer period many additional fatalities would occur.

Figure 13 presents U.S. and Soviet fatalities for the generated and non-generated attacks under various civil defense postures. The first row, "No civil defense," represents the results for people in their normal activities around their homes. In this case U.S. fatalities would be 105 to 130 million, and Soviet fatalities 80 to 95 million. The second row, "In-place protection," represents a posture where the population takes protection in the best available shelters but does not evacuate urban areas. While this posture reduces the fatalities by about 20% in the non-generated case, it should be noted that the generation of the strategic forces offsets these reductions. The third row, "In-place protection with urban evacuation," assumes that 80% of the urban population evacuates the

FIGURE 13

Fatalities from Attack on Counterforce, Other Military Targets and Industry (millions)

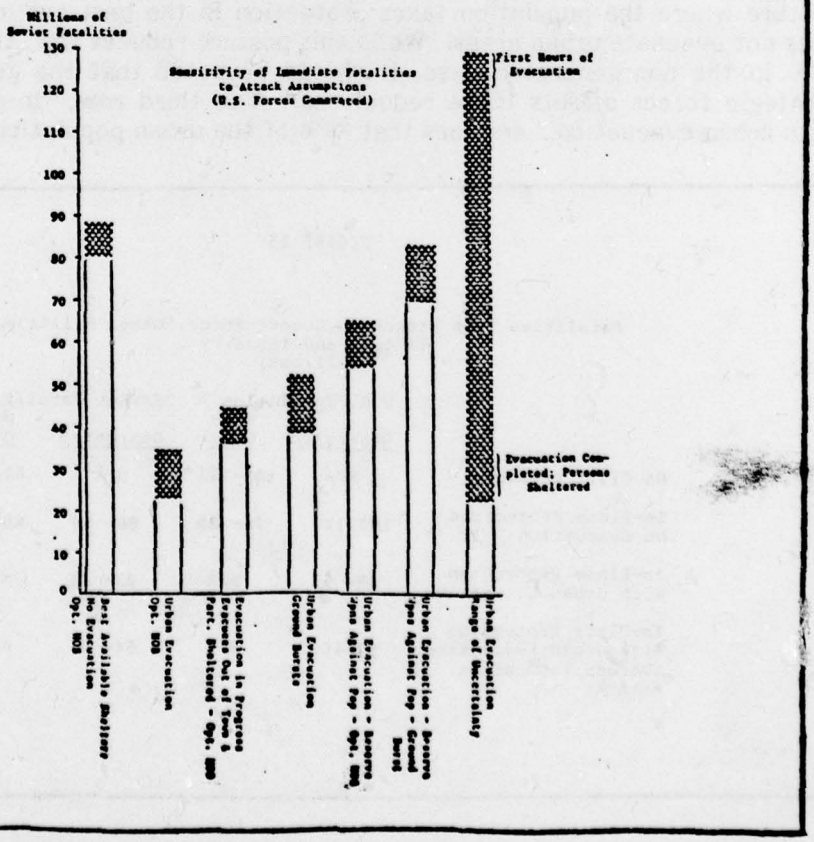
	U.S. Fatalities		Soviet Fatalities	
	Generated	Non-Gen.	Generated	Non-Gen.
No Civil Defense	N/A	105-131	N/A	81-94
In-Place Protection No Evacuation	107-126	76- 85	80- 88	60-64
In-Place Protection With Urban Evacuation	69- 91	N/A	23- 34	N/A
In-Place Protection With Urban Evacuation (Direct Population Attack)	87-109	N/A	54- 65	N/A

cities to ranges up to 150 km and that the remaining 20% take protection in the best available shelters. The evacuated people are located with the rural population, and both the evacuees and rural people go to the best available rural shelters and build hasty shelters. This posture represents an immense civil defense effort and no analysis was made to determine the feasibility of implementing such a posture. In fact it is highly questionable whether the U.S. or the Soviet Union could effectively achieve this posture, which would result in substantial reductions in fatalities. The fourth row presents a civil defense posture similar to the third row, but the attacks include the use of the residual weapons to directly target the evacuated population. As can be noted, directly targeting evacuees substantially increases the fatalities from the short term effects of nuclear war.

In Figure 13 U.S. fatalities are higher than Soviet fatalities. There are two primary reasons for these results which are unrelated to civil defense. First the analyses were based on Soviet first strikes which caused losses to our strategic forces; a U.S. first strike would obviously have resulted in many more weapons down on the Soviet Union. Second, the Soviet Union has higher yield weapons which result in more fallout. Finally the Soviet Union's better shelter program also makes a minor contribution to this difference.

A more detailed analysis of Soviet population losses is shown in Figure 14. The first two bars represent the "No civil defense" and urban evacuation case

FIGURE 14



shown earlier. The third bar shows the fatalities that would occur if the U.S. attack were initiated when the Soviet evacuation is about half completed. The fourth bar is the urban evacuation case shown earlier, but with a U.S. attack in which all weapons are ground burst. This ground burst attack, as noted earlier, would reduce the industrial damage by 5 to 10 percent but would create much more fallout. The fifth bar is the evacuation case with the reserve U.S. weapons used against the evacuated population that was shown on the previous chart. The sixth bar represents the same case as the fifth bar, except that all U.S. weapons are ground burst. This case is important because it shows a fatality level that the U.S. can impose even if the Soviet Union is totally successful in carrying out its evacuation and shelter protection plans. As can be noted, in this case U.S. strategic forces can cause 70 to 85 million fatalities from the short-term nuclear effects alone. Finally, the last bar shows the wide uncertainty associated with evacuation. If the attack were to occur during the early hours of evacuation the fatalities would be even higher than in the no civil defense case. As the evacuation progresses, the fatality levels would decrease.

In summary, the effectiveness of civil defense in protecting population is primarily a function of the level of force generation and urban evacuation. The survivability of the population is not significantly increased by in-place shelter protection. The results are sensitive to a variety of other factors such as the protection levels assumed; whether weapons are ground or air burst; how many people evacuate, how far they go, where they go and what they do when they get there; and finally, whether the evacuated population is targeted.

An observation can now be made with respect to civil defense. The results indicate that evacuation can significantly reduce the fatalities resulting from the short-term effects of nuclear war. However, a number of questions arise:

- Can evacuation be implemented?
  - It probably can with or without an evacuation plan.
  - It would undoubtedly result in utter chaos. A good evacuation plan might somewhat reduce the level of chaos.

- Who is better equipped for evacuation?
  - The U.S. with one car for every two citizens and a vast highway system? or
  - The Soviet Union with a plan but limited transportation?

- The real problem is sustaining the evacuated population; who is better equipped for sustaining the evacuees?
  - The U.S. with large surpluses of goods and food and many non-urban housing facilities? or
  - The Soviet Union with chronic shortages, limited distribution capabilities, and limited non-urban housing?

Finally, it should be kept in mind that, while no one has practiced evacuation, on every major holiday approximately 50 million Americans "evacuate" their homes and travel to resort areas. The Soviet Union has no comparable capability.

VIII. Other Factors in Nuclear War

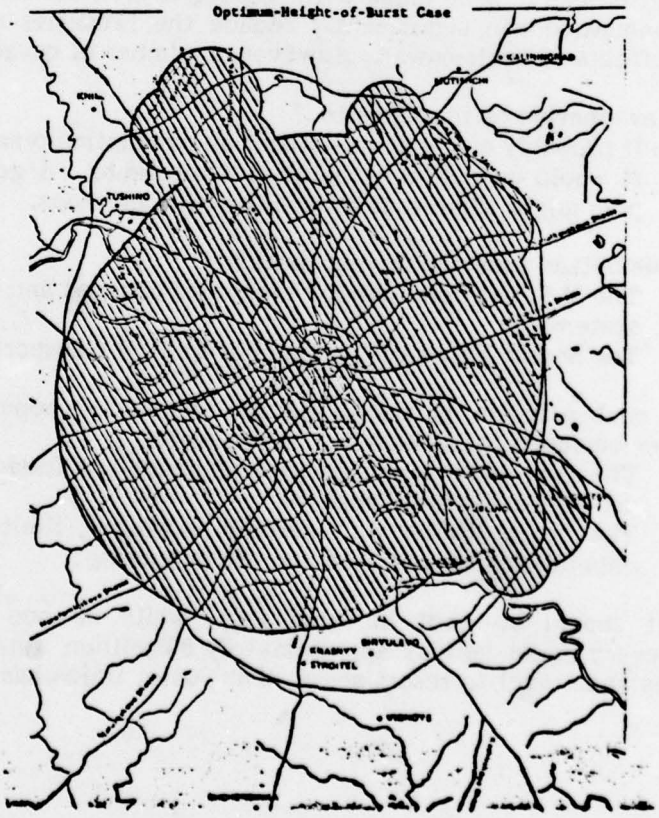
The damage reported so far in this paper refers only to the short-term effects of nuclear detonation on industry and people. There are, however, many other effects of nuclear war, some of which are discussed in this section.

A. Effect of Nuclear War on Cities. In order to examine the effect of nuclear war on cities, a detailed analysis was made of the results of the simulated attacks on Moscow. In this attack approximately 60 warheads went down within the Moscow city limits. Such an attack represents about 1400 times as much megatonnage and 300 times as much equivalent megatonnage (EMT) as went down on Hiroshima and Nagasaki in 1945. Peak overpressures throughout the downtown Moscow area were so severe (over 100 psi) that not a building or tree would remain standing. Clearly these attacks are orders of magnitude larger than the Hiroshima and Nagasaki bombings.

Much of the damage to cities, however, does not just come from blast overpressures; secondary fires would also be a significant factor. Generally, it is estimated that total fire burn-out would occur to the 3 to 5 psi levels. Figure 15

FIGURE 15

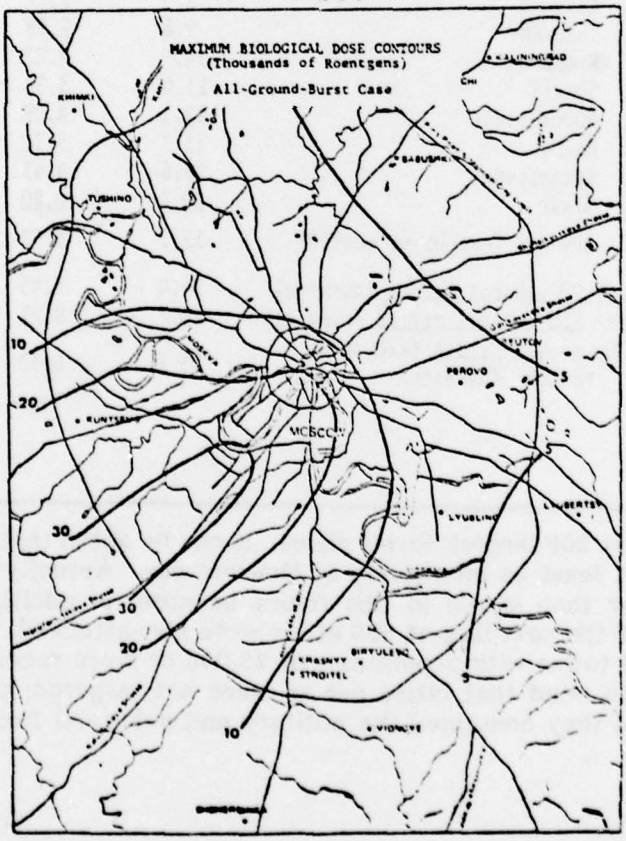
5 PSI OVERPRESSURE CONTOURS-MOSCOW
Optimum-Height-of-Burst Case



shows the 5 psi overpressure contour that would occur from this simulated attack on Moscow. This figure shows that the burn-out area would cover 85 to 90% of the total urban housing. This estimated burn-out area does not assume that a "fire storm" would occur, but it is based on an estimate that fires once started could not be fought because of the intense radiation environment and the fact that the water supply would be destroyed.

Figure 16 shows radiation dose contours over the city in thousands of roentgens. Almost the entire city is covered by more than 5000 roentgens and, in some parts of the city, the dose is above 30,000 roentgens. To understand the magnitude of this radiation, one must keep in mind that only doses of 100 roentgens or less can be absorbed by human beings without serious consequences. Such a dose will not create illness, although it will substantially increase the risk of cancer and other diseases. A dose of 200 roentgens will cause incapacitating radiation sickness to 50% of the people exposed to it, and a dose of 450 roentgens will cause 50% fatalities to the people exposed to it. Clearly, no

FIGURE 16



human being exposed to the kind of radiation dose that would exist in Moscow could survive unless he was well sheltered.

Lest one believes that Moscow is a special case, Figure 17 demonstrates that other Soviet cities would be exposed to similar levels of damage. In this figure, the number of warheads and the amount of EMT per million people is

FIGURE 17

WEAPONS AND EMT ARRIVING IN RELATION TO URBAN POPULATION

(WEAPONS DOWN WITHIN 10 NM OF CITY CENTERS)

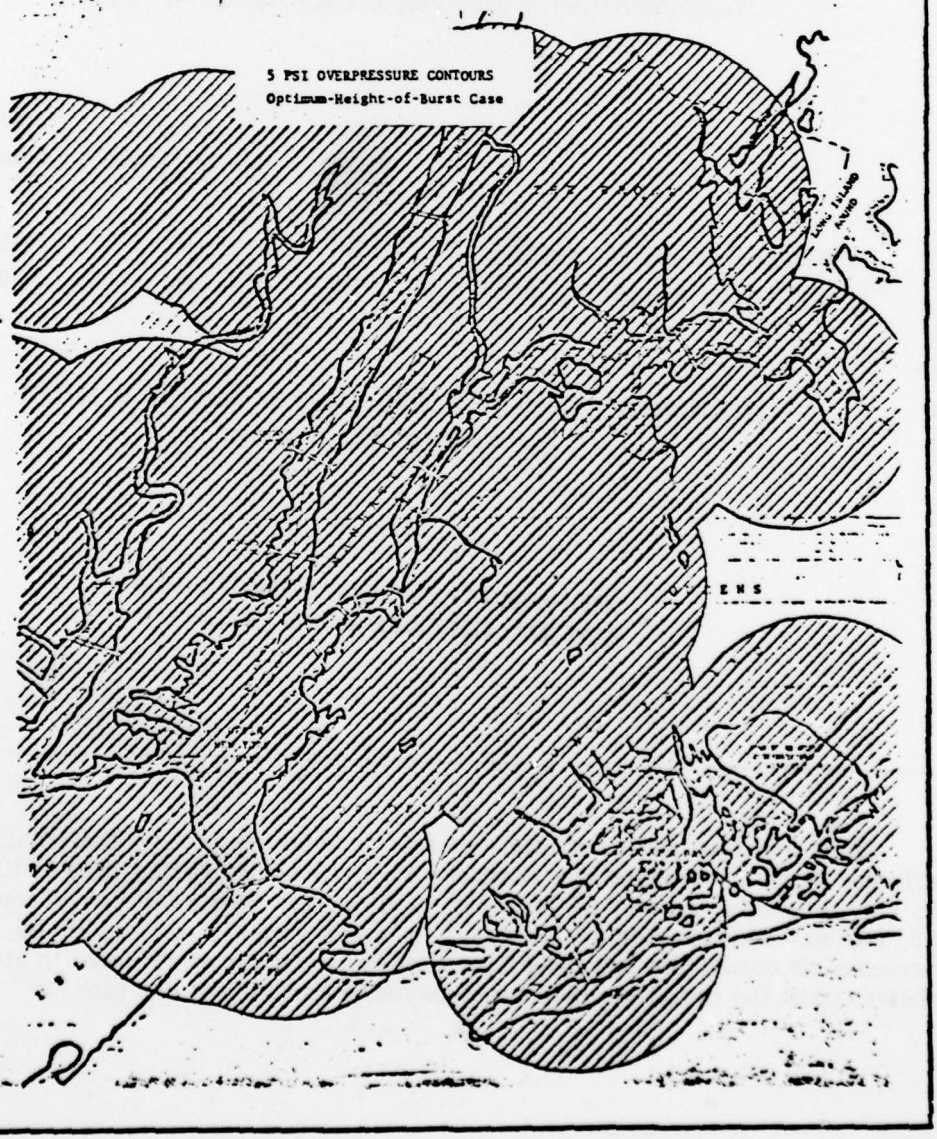
TEN LARGEST SOVIET CITIES	PER MILLION POPULATION: NUMBER OF WARHEADS	PER MILLION POPULATION: AMOUNT OF EMT
1. MOSCOW	8.8	2.99
2. LENINGRAD	11.4	2.99
3. KIEV	8.9	1.97
4. TASHKENT	9.6	2.58
5. KHARKHOV	14.1	4.02
6. GORKIY	11.4	3.98
7. NOVOSIBIRSK	12.1	4.08
8. BAKU	11.7	3.30
9. SVERDLOVSK	16.6	4.43
10. MINSK	20.8	6.80
AVERAGE (EXCLUDING MOSCOW)	12.3	3.52
NEXT 40 LARGEST CITIES (AVERAGE)	14.4	5.45
NEXT 150 LARGEST CITIES (AVERAGE)	25.7	8.21
200 LARGEST CITIES (EXCLUDING MOSCOW (AVERAGE)	19.1	6.33

shown for the next 200 largest Soviet cities. It can be noted that the other cities were attacked at least as intensively as Moscow was. Actually the total attack was even greater than shown in this figure because, in addition to these 200 cities, 450 out of the next largest 600 cities were also attacked. In all 80% of all Soviet cities and towns with populations of 25,000 or more received at least one weapon. Keep in mind that cities per se were not targeted; these cities were attacked because they contained the military and industrial facilities that were targeted.

Finally, it should be understood that similar devastation would occur in the United States. Figure 18 illustrates the 5 psi (total burn-out) area that would occur in the greater New York City area. Clearly the cities of both countries would be devastated.

B. What About Shelters? An analysis was made of the survival potential of people in shelters in the Soviet urban areas. Soviet civil defense manuals specify that shelters are built to a hardness of 14 to 28 psi. There has been some

FIGURE 18



debate in the U.S. about whether these shelters are harder than these specifications. In this analysis we assumed that the Soviet urban shelters were 50 or 100 psi hard. Figure 19 gives the fatalities and casualties for people in the shelters during the attacks simulated in these analyses. If the shelters are 100 psi hard, 20% of the occupants would be killed and 40% injured, for a casualty rate of 60%; if the shelters are 50 psi hard, then 30% of the occupants would be killed and an additional 60% injured, for a casualty rate of 90%.

FIGURE 19

INJURED AND KILLED IN URBAN SHELTERS NEAR INDUSTRIAL PLANTS

	Killed	Living Injured	Total Casualties
In 100 PSI Blast Fallout Shelters	20	40	60%
In 50 PSI Blast Fallout Shelters	30	60	90%

LACK OF MEDICAL CARE WILL INCREASE KILLED BY ABOUT 10% IN 30 DAYS
MANY SURVIVORS WILL BE MAIMED

Now consider people in shelters that manage to survive the blast and fire effects. Someone located in a shelter with a protection factor (PF) of 100 would, in the southeast corner of Moscow, still be exposed to doses of more than 30,000/100 = 300 roentgens. Actually a much larger dose would be received because, to obtain the full 100 PF protection, a person would have to stay in the shelter until the radiation level has decayed, a period that can last for several

months. Figure 20 shows two shelter-use patterns that illustrate the difficulty of radiation avoidance even in excellent shelters. Note that even in a highly protective shelter with a PF of 500, if an occupant stayed 100% of the time in the shelter the first month after the attack and 75% of the time in the shelter during the second month of the attack, 30% of the urban area would be too "hot" for this kind of a regime—that is, he would have to stay in the shelter for an even longer period. In the second pattern illustrated occupants leave the shelters for 2% of the time during the first months; in this case 60% of the urban area is too "hot" for this regime. Any lesser shelter stay time would of course make this situation even worse.

Another factor to be considered is reentry to the urban areas by people that have not been exposed to any radiation. The first problem would be to find such people, since 80% of the total Soviet population (including the evacuated population) is located in areas that are exposed to 100 or more roentgens. Even people that have received no dose at all would have to wait one month to reenter half the urban areas, two months to reenter three quarters of the urban areas, and up to six months to reenter the entire urban area.

C. Food and Water Supplies. Stock requirements of food and water would vary from one week to several months depending on the fallout pattern. Furthermore, destruction of the transportation nodes would delay redistribution of supplies by two months or more. Stocking two months of supplies is a major problem. Undoubtedly many survivors would have to leave shelters prematurely to obtain supplies and would be exposed to radiation.

D. Medical Care. In addition to the fatalities presented earlier in this report, it is estimated that there would be 30 to 50 million injured. The care of these injured people would be an immense problem and many would die. Hospital and medical facilities would be very scarce, for example, in the generated attack

FIGURE 20

EFFECT OF USE PATTERN

SHELTER EFFECTIVENESS

TO AVOID RADIATION ILLNESS (100 REM)

SHELTER USE PATTERN			NEAR PERFECT SHELTER PF = 500	GOOD SHELTER PF = 40	BASEMENT PF = 10
FIRST MONTH	SECOND MONTH	THEREAFTER			
100 % IN SHELTER	75% IN SHELTER 25% INDOORS	75% INDOORS 25% OUTDOORS	30% OF URBAN AREA DENIED	65% OF URBAN AREA DENIED	80% OF URBAN AREA DENIED
98% IN SHELTER 2% OUTDOORS	75% IN SHELTER 25% INDOORS	75% INDOORS 25% OUTDOORS	60% OF URBAN AREA DENIED	70% OF URBAN AREA DENIED	85% OF URBAN AREA DENIED

80% of the urban hospitals in the Soviet Union were destroyed (93% of the Moscow hospitals were destroyed). Hospitals, of course, were not attacked; they are, however, located near many of the military and industrial facilities that were targeted.

In addition to the large number of injured people, there would be a large increase in disease due to poor sanitation, crowded living conditions ($\frac{1}{2}$ to 1 square meter per person in shelters), shortage of food and medical supplies, and reduced resistance to disease due to radiation exposure.

In summary, the number of injured and sick people would be at least an order of magnitude larger than in any previous war.

E. Agriculture. An estimate was made of the effect of these nuclear attacks on agricultural crops. The results are sensitive to the time of the year the attack occurs. If the attack takes place during the growing season, then up to 30% of the crops could be lost. On the other hand, if the attack is in the winter the effect on crops would be minor. A considerable amount of uncertainty surrounds these estimates. It seems that crops would not be too seriously affected, yet we find that on Bikini Island 25 years after the completion of our nuclear tests, crop contamination problems still exist.

The situation with livestock is much more serious. Over half of the grazing animals would die and over one quarter of large farm animals fed on stored food would die.

The above damage to agriculture is estimated only from the effects of blast and fallout; it does not take into account the potential effect of "ozone" depletion and other potential climatic changes.

F. The Ozone Problem. A considerable amount of uncertainty is associated with estimating the effects of nuclear war on the ozone layer. Even greater uncertainties exist when considering long term climatic and genetic changes. Many of these effects were studied by the National Academy of Science*. In this analysis the estimates produced by the National Academy of Science were translated to the attacks conducted in this simulation.

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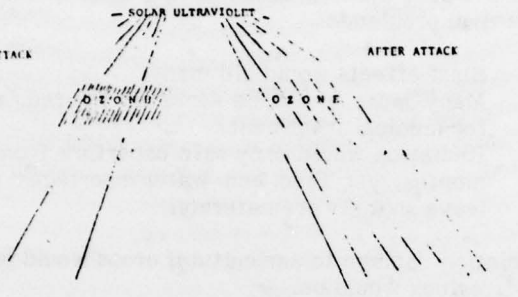
* "Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonation," National Academy of Science, Washington, D.C., 1975.

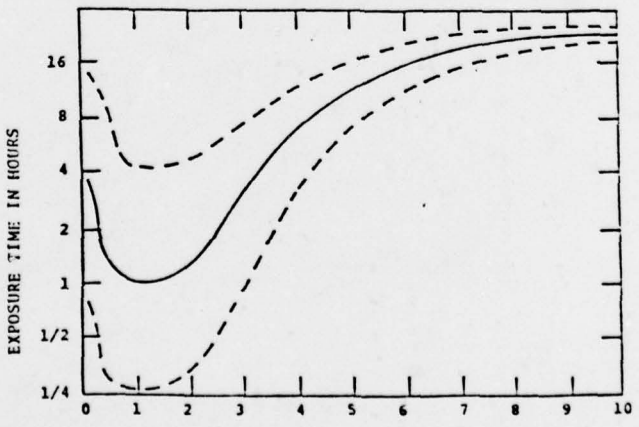
Figure 21 is a sketch which illustrates the effect of depletion of the ozone layer. Before the attack, exposure to the ultraviolet rays of the sun can produce

FIGURE 21



a nice sunburn after exposure of $\frac{1}{2}$ to 1 hours; after the attack such exposure would produce blistering burns on the body. Plants and animals of course would be subject to similar increases in ultraviolet rays and many would be destroyed. The most serious aspect of the depletion of the ozone layer is illustrated in Figure 22. This figure shows that the worst depletion occurs one year after the attack and that the ozone layer does not return to its normal stage for a period of 6 to 7 years. Considering that this effect would cover the entire northern hemisphere of the earth, it represents a very serious factor. Reduction of the ozone layer in the southern hemisphere would be a less severe, but not an inconsequential, problem.

FIGURE 22



G. Summation of the Effect of Other Factors

— Soviet urban areas would be virtually leveled by a U.S. retaliatory attack.

— Those who stayed in urban areas, even in hardened shelters, would have serious survival problems:

- Blast effects would kill many.
- Many more would be seriously injured, with limited prospects for medical treatment.
- Radiation would deny safe departure from shelters for weeks or months; yet food and water shortages would force many to leave shelters prematurely.

— Radiation damage to agricultural crops would probably not be serious, but damage to livestock would be.

— Those who survived all these obstacles would still face the specter of an ozone depletion problem that could effectively prevent daytime outside activity for several years, and could destroy all but the most resistant crops and livestock.

IX. Conclusions

— The fatalities and industrial damage presented in this report represent only a part of the total disaster of a massive nuclear war.

— Many of these effects are difficult to measure and simulate on computers; nevertheless, they are real factors which must be considered.

— While some civil defense activities, such as evacuation, have some effect on the immediate post attack environment, their benefits in the long run have not yet been established.