

A NATIONAL SHELTER PROGRAM

ITS FEASIBILITY AND ITS COST

A REPORT

BY A GROUP OF INDEPENDENT SPECIALISTS

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Heat Effects.. .. .	Victor Paschir
Air Supply.. .. .	T.B. Drew
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Water Supply.	T.B. Drew
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PREFACE

In view of the potential impact of a National Shelter Program on major policies as well as on the economy of the Nation and the lives of all its citizens, we feel that the scientific information presented in this pamphlet should be made available to all those concerned with this issue.

Approximately 60% of the population lives in major metropolitan areas, which include cities and suburbs. It is to be expected that in case of war these areas will be attacked with nuclear bombs. As this population cannot be written off completely, shelters must be provided to protect it against blast and heat as well as against fallout.

The papers by Salvadori, Paschkis, and Drew (on air supply and shelter) deal with conditions in shelters. People in shelters are exposed to radiation even if they manage to avoid contaminated air from the outside or contamination from late-comers. Yet counting a protection factor (ratio of radiation outside the shelter to that inside) as only 100, it is assumed in this report that within the shelter the radiation effects will not be considered.

Ullmann computes the cost of such shelters for a population of 120 million, taking as the structural cost one-half of the maximum mentioned in Salvadori's paper and thus consciously sacrificing a substantial portion of the urban population. If maximum figures are taken, the expenditures would be still higher than shown in Ullmann's paper.

After a period, variously estimated at from two weeks to two months, people will have to leave their shelters. The only reason for building shelters in the first place is supposedly to allow a society to be rebuilt at least vaguely similar to ours and hence based on technology.

The people leaving shelters will, however, face serious problems. These are discussed by Drew (water supply), Yost (radiation effects on the body), Dobzhansky (genetic effects: dangers to future generations) and Melman (industrial potentialities in a post-attack era). These papers spell out the hazard upon leaving the shelter and the near-impossibility of survival.

It still might be held that protection, whatever its cost, should be attempted even if it saves only a minute fraction of our population.

However, in the final paper, Klineberg shows that from a psychological viewpoint shelters may not only fail to deter but, in fact, may substantially increase the probability of war.

Each author bears the responsibility for his individual contribution to this series of studies.

COST OF BLAST-RESISTANT STRUCTURES

BY MARIO G. SALVADORI

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A bare shelter structure designed to withstand the blast effect of a 20-megaton nuclear bomb at the rim of the ball of fire would cost \$290 per person sheltered. Because of the other effects of such a weapon, the structure would not assure human survival, but would offer protection only against the blast effects. Blast resistant structures designed to withstand pressures further from the point of detonation would cost relatively less.

The table below gives the cost per sheltered person of the blast structure of a reinforced concrete box shelter capable of resisting the blast effect of a ground burst of a 20-megaton nuclear bomb at the given distances from the center of the explosion.

COST OF BLAST PROTECTION

DISTANCE (miles from ground zero)	2.1	2.9	3.6	5.9	8.6	16.3	27.4
OVER PRESSURE (lbs per square inch)	80	50	30	10	5	2	1
COST (per person)	\$290	\$244	\$158	\$126	\$123	\$120	\$120

The reinforced concrete box gives 10 square feet of space per person and is 9 feet 6 inches high, thus permitting four bunks to be stacked one above the other. Its modular span is 14 feet. 300 pounds of material per square foot, including the concrete needed for strength, are assumed over the shelter roof for radiation protection. The walls of the shelter are designed to resist the pressure of the blast wave traveling through the earth. The floor of the shelter is 6 inches thick. No elaborate foundations are assumed to be required to resist the pressure blast on the shelter.

The reinforced concrete structure is so designed as to barely resist the blast; that is, so as to collapse for a small amount of pressure above that produced by a 20 megaton bomb.

The cost of the structure includes the necessary excavation in an average soil, and a 10% contingency increase to cover the cost of the openings. No elaborate door system, which may be needed for other than blast resistance, is considered in this cost.

The price of concrete is assumed at \$80 per cubic yard; it includes an average of 6 pounds of steel per cubic foot of concrete and the cost of forms.

Chart 1

SURFACE BLASTS distances and area of ignition

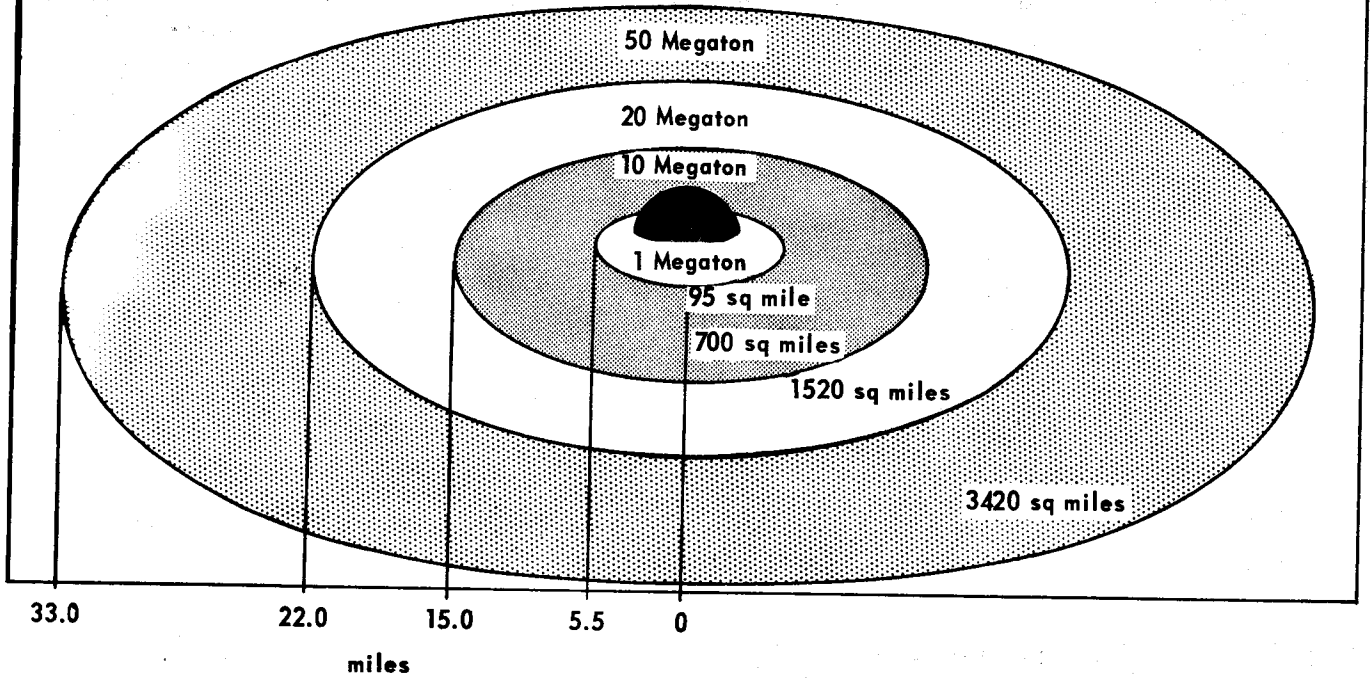
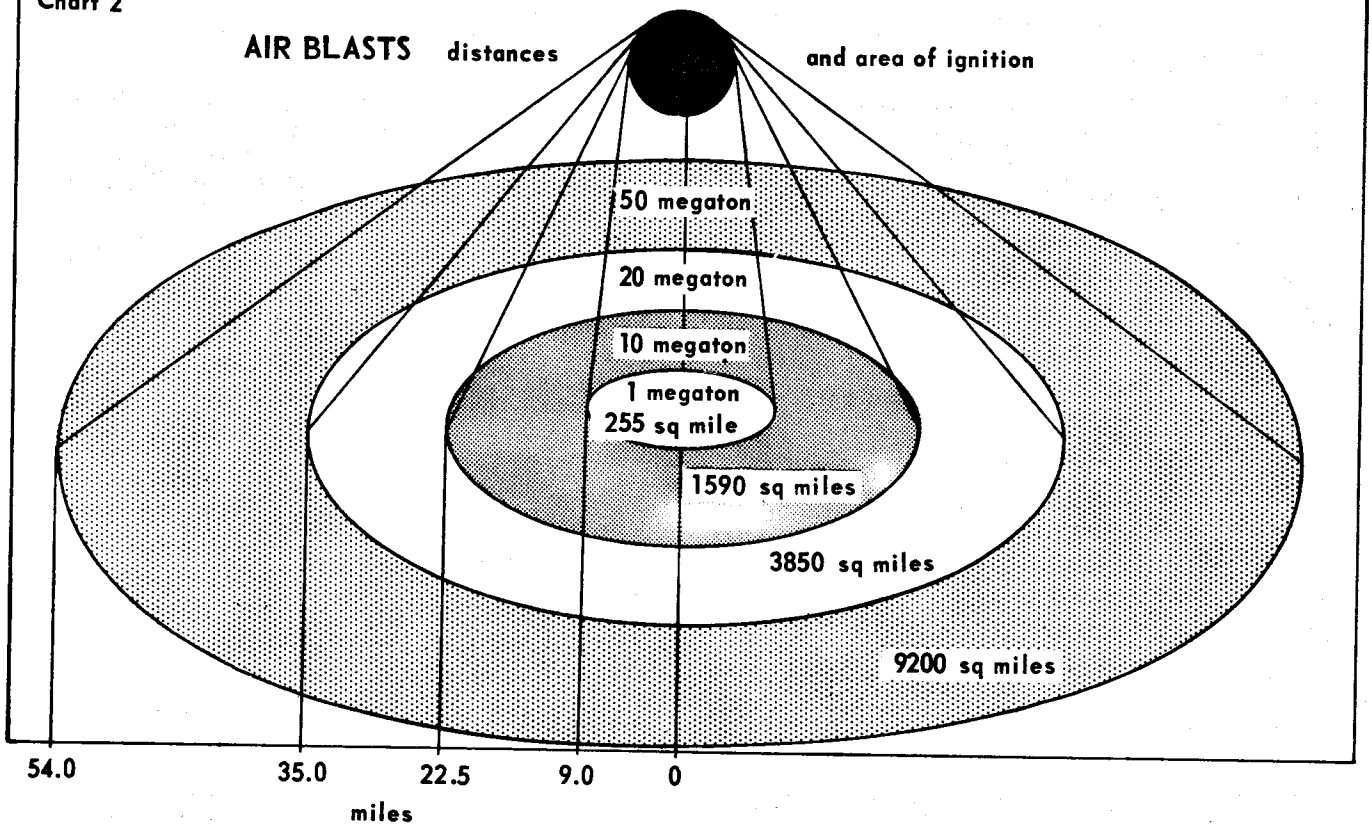


Chart 2

AIR BLASTS distances and area of ignition



The firestorm is essentially limited to the area originally ignited by the many small fires (the areas designated on the charts). A conflagration extends beyond the original confines of the fires started by the bomb. The duration of either the firestorm or conflagration is unpredictable. Estimates of several authors vary from six hours to several weeks. Temperature near the center of a firestorm is above 2200 degrees Fahrenheit; In Hamburg, following a firestorm ignited by incendiary bombs in 1943, an inspection of shelters showed that glass had been melted (2000-2300 degrees F). This observation can be used as a rough gauge of the prevailing temperature.

As a result of the blast and partly as a result of the fire, all structures in the zone of the firestorm must be expected to collapse. Thus any shelters in such area will be covered by rubble. This rubble, mixed with still smoldering material, will remain hot for extended periods of time -- possibly several weeks.

The roof of a shelter will receive heat, first from the firestorm and then from the hot rubble. Fortunately, this heatflow produces in the shelter a temperature rise of only a few degrees. It is well to remember that if the thickness of the soil and roof were decreased to less than the three feet assumed in the paper by Professor Salvadori, the thermal condition may become serious. Furthermore, such effects increase the shelter requirements for reasons similar to those described in the following section.

III. Ventilation Air

One cannot expect shelters to be provided with bottled air or oxygen to such an extent as to eliminate all need for fresh air. Fallout shelter designs always include a vent which must be kept tightly closed during the firestorm. Otherwise the firestorm would draw air out of the shelter, asphyxiating its inhabitants. If the wind should drive air into the shelter, it would be air at 2000° F, which would burn the lungs of occupants immediately (electric cremation furnaces operate at a temperature of about 1600° F).

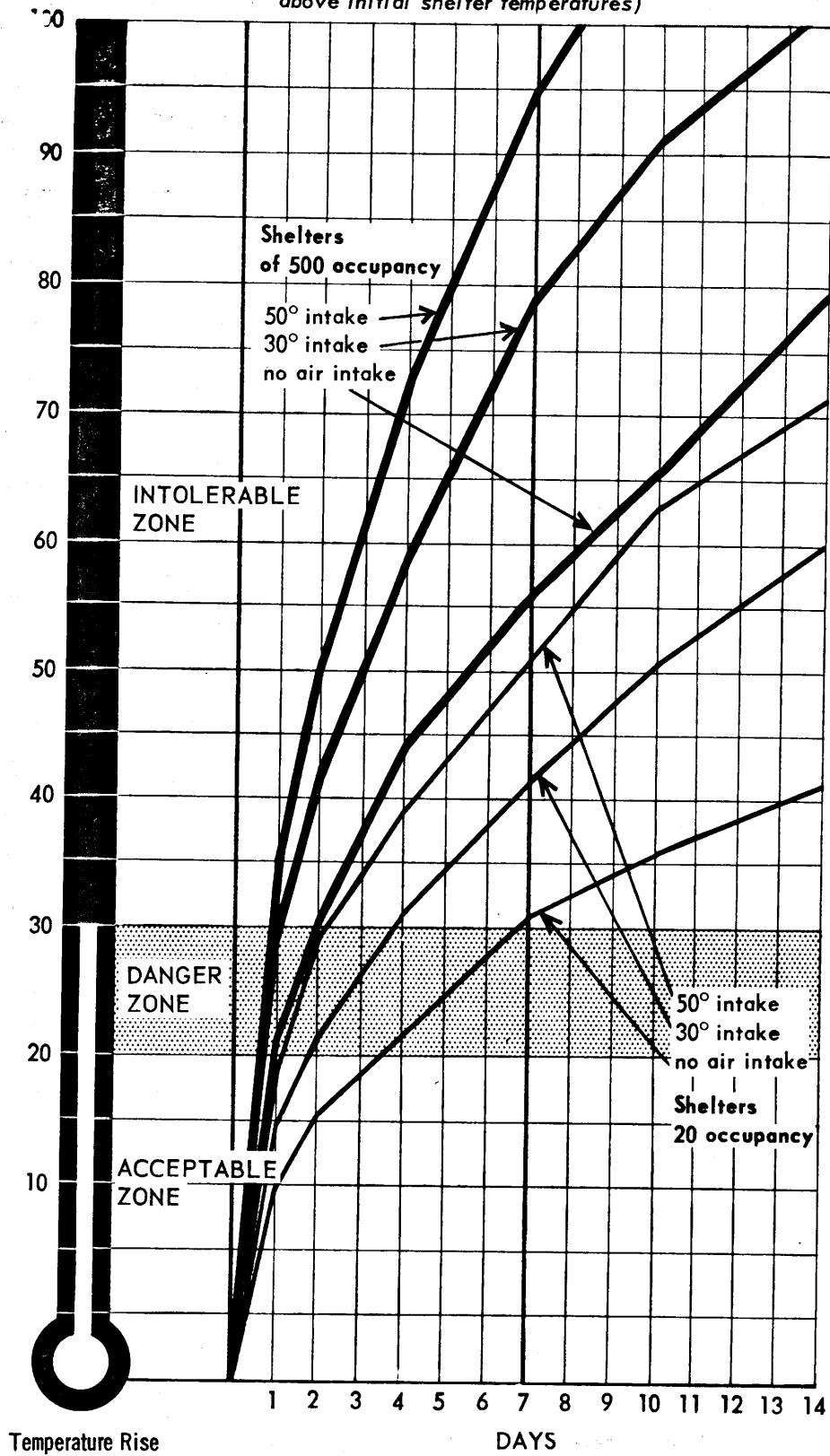
During the storm and the collapse of adjacent structures the vent is in great danger. A hole can be knocked or burned into the vent, opening the shelter to the infusion of hot air laden with radioactive debris. Or the vent can be damaged so that it will not open when the firestorm is over.

It is practically unavoidable that the vent, at least in its lower part, will be surrounded by rubble. Assuming that the vent remains undamaged, it will have to be opened eventually to let air in. The hot rubble surrounding the vent will then preheat the air flowing through the vent. The extent to which this preheating will take place cannot be predicted and depends, among other things, on the temperature of the rubble which may remain at 1,200° F for a long time. Air temperatures of several hundred degrees are possible. As this temperature is not known, the results of two extremely low estimates (30° F and 50° F temperature rise due to exposure of the rubble) are examined in chart 3. The increase will be more severe in larger shelters because the surface area of the shelter per inhabitant goes down as the shelter size increases, (This statement is based on a constant floor area per inhabitant and a standard height of the shelter.)

Chart 3

SHELTER TEMPERATURES

(Intake readings are for degrees above initial shelter temperatures)



The curves in chart 3 are based on an air supply of five cubic feet per minute per person—a figure recommended by Broida ("Effect of Mass Fires on Personnel in Shelters": Technical Paper #30, U.S. Forest Service, Aug. 1960). In normal life within small spaces, a figure of 15 cubic feet per minute per person is recommended (see "Guide" of the American Society of Heating and Ventilating Engineers, 1961 edition). The greater the air intake, the greater is the amount of heat carried into the shelter.

For each air temperature rise two curves are shown, valid for a 20-person shelter (14 x 14 ft.; 95 ft. high) and for a 500-person shelter (70 x 72 ft.; 95 ft. high).

Thus for air 30° F above shelter temperature (e.g. shelter at 70°F; air intake, due to preheat in the hot rubble at 100°F) the shelter with 500 people will reach a temperature increase of 30°F in about one day, while the smaller (20 person) shelter will reach the same temperature in 35 days. The curves take into consideration that each body generates about 400 btu/hr. (BTU is a measure of heat.)

The tolerance of the human body to elevated temperatures depends on a number of circumstances, among which humidity is particularly important. In the shelter, because of perspiration, the humidity will be high, and heat tolerance will be rather low.

K. Buettner (ASME paper 57 SA-20) indicates that under high humidity exposure to 95° F is safe for about 10 hrs., and to 90° F for about 100 hrs. Assuming an initial shelter temperature of 70° F, a rise of 20 - 30°F becomes dangerous for a protracted stay in the shelter.

IV. Heat Generation by the Body

What are the chances of survival in a shelter far away from any explosion?

It is known that nuclear weapons cause fallout which may drift great distances from the initial blast location. The only plausible claim for fallout shelters is that they will protect the population not living in obvious target areas, i.e., near any metropolitan area or significant military installation. In this case it is assumed that there would be no danger from fires, provided that --contrary to some serious predictions -- the conflagration does not feed on forests and fields. Yet even such favorable locations present a serious thermal problem. As long as the shelter is sealed in order to avoid intake of air laden with radioactive particles, the heat generated by its inhabitants will raise the shelter temperature. This temperature rise will reach dangerous levels in a few days, depending on the size of the shelter. The curves in Chart 3 marked "No Air Intake" hold for this condition, and show that the shelter temperature becomes unbearable after two days in large shelters and after seven days in small shelters.

One might suggest that the air be filtered to eliminate the radioactive particles. But a filter would increase the power required for the air intake fan. As one cannot count on electricity in the shelter, the fan would have to be hand operated. Hand power may not suffice to draw air through an adequate filter. If air or oxygen can be provided in the shelter, the vent may be kept closed.

The temperature rise in the shelter may be reduced by increasing the surface area of the shelter per occupant. The area of the 500-person shelter would have to be about 25 to 3 times larger than presently contemplated. This means the shelter of 70 x 72 ft. that is 9.5 ft. in height would have to be replaced by one 180 x 78 ft. which is 25 ft. in height to meet the minimum of 25 times the original surface area. If introduction of air which is preheated by rubble is considered, the dimensions would have to be much larger.

AIR SUPPLY FOR SHELTERS

BY T.B.DRE

Professor of Chemical Engineering
Columbia University

The primary requirements for shelter ventilation are:

- (1) Means of preventing air inflow for perhaps up to two days after a nuclear attack has ended.
- (2) Means thereafter, without dependence upon mechanical power, to draw in and expell air for a week or so.

During the first period, the problem is not so much that of preventing the entry of radioactive dust as it is that of preventing the entry of air heated by the probable fire storm to dangerously high temperatures.

The initial period may be much more than two days because it starts at the beginning of the attack. It may be possible to maintain the air in the sealed shelter sufficiently pure to avoid suffocation. This would require numerous shallow, open pans of a chemical such as moist lime to absorb carbon dioxide and tanks of compressed air or oxygen to replenish that taken in by the occupants.

The second period requires the provision of relatively large passages to the exterior so designed that they may be cleared of rubble, which might block them, and

that they may be kept tightly closed during the initial period.

There is no practicable means of filtering out the fine particles which would remain suspended in the air after two days. Therefore some contamination of the shelter by fine, possibly radioactive, dust will occur unavoidably.

It might appear likely that by suitable design of the air exit a small heat supply can create sufficient stack effect to maintain adequate ventilation. Very possibly the body heat of the inhabitants added to heat evolved by lighting equipment and any powered equipment will be sufficient in itself to create the stack effect.

In an intense nuclear attack some radioactive gases will be produced. These cannot be removed from the air supply by any known practicable means.

COST OF A NATIONAL SHELTER PROGRAM - IN DOLLARS

BY JOHN E. ULLMAN

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This section summarizes the costs developed in the preceding technical papers and traces the probable totals and their effects on the economy if a program of this magnitude is put into practice.

First, it has been assumed that 120 million people are to be sheltered. This still leaves about 60 million without deep shelters but they are expected to be either in areas where direct blast and fire effects are not likely to be great, or to have to participate in waging the war on the surface as long as possible. This assumption would give some degree of protection to that 66% of the population that would likely be killed under one pattern of a 10,000 megaton attack (See McGraw Hill study, Jan. 1962, based on data by AEC, Rand Corporation and Joint Committee on Atomic Energy). No provision has been made for double shelters at home and at work. This might require at least another 20 million places, especially in metropolitan areas.

Shelters are assumed to be of two alternative sizes. They rely on stored commodities which compromises their usefulness once they are "depleted" - it may be impossible to restock them. In general, a two-week to two-month sojourn in the shelter might be expected, but to provide the survivors with a bare start of necessities in a hostile,

post-attack world, food and water stores have been set at six months (see Ralph Lapp, Consumers Report, Jan. 1962, pp. 15-18). Even if the food supplies were for a two-month period only, the food costs would not be changed materially. No provision has been made for repeat attacks.

Land:

The cost of land obviously depends on the location of the shelters. If in urban areas, existing structures would have to be razed. There are not enough parks, vacant land, etc. to accomodate any large number of shelters. If they are not right in the city, the urban population would be unable to reach them. As shown by Professor Paschkis, a 500-person shelter would occupy one-third of an acre.

The cost of land for a single shelter would thus probably range from \$20,000 to \$500,000 or much more. Millions of dollars might be involved at some sites. Therefore an average amount of \$150,000 for each 500-person shelter would not be excessive. A 20-person shelter might be housed on suburban property at little incremental costs. Nevertheless, many would require the razing of at least one house. A land cost of \$8,000 is, therefore, a fair estimate.

To sum up, land costs will be:

For 20 persons	For 500 persons
	\$150,000

Basic Shelter Structure, excluding access:

The basic shelter structure is based on one-half the maximum estimate by Professor Salvadori; that is, \$145 per person. This still results in structural collapse within an area of 45 square miles for a 20-megaton bomb and may thus produce millions of casualties in several cities. Reducing this to 14 square miles would double the cost. In addition, the shelter will be scaled up to avoid the thermal problem dealt with by Professor Paschkis. Accordingly, a structure cost of 25 times \$145 or \$362.50 per person is derived. The only alternative would be to provide some form of air conditioning which is ruled out by the high power requirements. Moreover, its cost would be considerable.

For 20 persons	For 500 persons
\$7,250	\$181,250

Shelter access:

The cost estimates for this must necessarily be approximate. One of the reasons for locating shelters away from existing structures is to avoid, as far as possible, major blocking of the access. Even so, entrance tunnels can cave in. No generally applicable method of egress has been described thus far. Blasting out with shaped charges and similar methods require highly skilled personnel. It is thus only possible to rely on heavily reinforced entrances with mazes to block radiation and with blast doors, built like vault doors. The costs of these special products and structures will certainly aggregate at least \$400 per person for the

20-person shelter and \$100 per person for the 500 person shelter. The latter would have to have multiple exits; six have been assumed here.

For 20 persons	For 500 persons
\$8,000	\$50,000

Air Supply and Electric light:

A two-week air supply is necessary here to avoid intake of air heated by surface rubble (see Professor Paschkis' paper). A system using bottled compressed air and hydrated lime absorption of carbon dioxide is considered here. This would have to include controls for air pressure inside the shelter, venting of stale air, some small source of power for air circulation and similar equipment. A small amount of lighting is included (5watts per person). Such a system would have to be developed and it could probably not be built and stocked for less than \$1,000 per person. Recovering oxygen from the carbon dioxide would require a large power source and chemical unit, costing at least that much. If a stay longer than two weeks is needed, however, it would have to be considered. Even so, the problems cited by Professor Drew would largely remain.

Cost of air supply and electric light would be:

For 20 persons	For 500 persons
\$20,000	\$500,000

Water supply and sanitation:

A water supply of two gallons per person per day has been assumed. This compares with 25 gallons per person per day used in home design. The simplest way would be to have a reservoir with the shelter in which a two-month supply could be stored. This does not deal with the limitations on post-attack water supply cited by Professor Drew. No allowance is made for artesian wells and the like. An alternative 6-month supply should therefore be considered. The cost of the water itself is neglected, but the reservoir would cost about \$1.50 per cubic foot. The cost of the simple hand pumps may be assumed included in this figure.

An equal space is provided for waste products. This is required to drain the chemical toilets used in the first instance. The following costs are involved:

	For 20 persons	For 500 persons
For six-month period:		
Water supply, 182 days at two gallons per day (7½ gallon per cubic foot and \$1.50 per cubic foot for reservoir) \$72.75 per person	\$1,445	\$36,375
Sewage pit (same as above)	1,445	36,375
Chemical toilets (one for each 20 persons) at \$79	79	1,975
TOTAL	\$2,969	\$74,725

Food:

The average food expenditures for a worker's family range from \$1 to \$1.25 per person per day (1961 Statistical Abstract of the United States, p. 337). If processed agricultural surplus, already paid for by the government, is used, only a processing, handling and storage charge of 35 cents per person a day is estimated. As noted before, a six month supply is provided.

Thus, food costs would be as follows:

	For 20 persons	For 500 persons
Food (35¢ per day, 182 days)	\$1,275	\$31,950
Storage space (2 cubic feet per person per week @ \$1.50 per cubic feet) 26 weeks	1,560	39,000
	\$2,835	\$70,950

Food preparation:

Allowance for food preparation, equipment and utensils \$3 per person:

	For 20 persons	For 500 persons
	\$60	\$1,500

Medical supplies:

A shelter would have to be equipped with medical supplies far more elaborate than the conventional "first aid kits." At the least, one would have to provide tranquilizers, sedatives, antibiotics, digestive aids, anesthetics, as well as supplies for treating injuries, and, if then available, radiation. An estimate of \$15 per person is certainly reasonable.

The totals for medical supplies and their storage are:

	For 20 persons	For 500 persons
	\$300	\$7,500

Tools, utensils, and instrumentation:

Here are included various tools for use in the shelter as well as outside. These include radiation instruments, "fallout suits," flashlights and batteries, fire extinguishers, axes, picks, shovels, hand tools, etc. An allowance of \$40 per person is reasonable here. The totals including storage space are therefore:

	For 20 persons	For 500 persons
	\$800	\$20,000

Furniture:

Only the simplest bunks and personal lockers, etc. are envisaged, at a cost of about \$15 per person. This gives a total of:

For 20 persons	For 500 persons
\$300	\$7,500

THE TOTALS AND THEIR CONSEQUENCES

The shelters are estimated to cost about \$50,500 for 20 persons and \$1,063,400 for 500 persons, or from \$2,125 to \$2,525 per place. Applying this to the prospective shelter population of 120 million, we would have a cost of \$254 to \$302 billion. This is in the range of our present national debt and one-third of the total value of our structures in place. It would be about five times the total annual volume of construction. It is five to six times our annual collection of personal income tax and bears the same relation to our current defense expenditures. It is, in fact, about equal to our total annual personal income.

Our national debt was increased by \$243 billion between 1940 and 1947. In that time the value of the dollar was halved. A shelter program such as this would have to be put in place in about two years to have military value. Such pressure, coupled with the limitations of our industrial capacity in several areas of potential supply, would require us to submit to controls over our property, our labor, and our daily lives more thorough than ever devised by any society, least of all the United States. It would mean the end of all other construction — schools, hospitals, houses, factories, machinery *and armaments*. As it is, no restrictions due to scheduling, industrial preparation and the like are considered. Even if the above estimate, which is based on current dollars, were to be high by as much as one half, this would still be true. In fact, to alleviate the shortcomings cited, the cost would have to be substantially increased.

A parallel effort to secure industrial reserves, communications, etc. would at least double these amounts. At the same time there would be a precipitous drop in the international value of the dollar, impairing the financial stability of the whole West.

* * *

Anyone who treasures the freedoms we have, who believes that our varied and versatile industrial establishment is a major source of strength and who enjoys the good things our country has to offer, cannot but be appalled at the possibility.

WATER SUPPLY IN POST-ATTACK PERIOD

BY T.B. DREW

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“Water, water everywhere
And all the boards did shrink,
Water, water everywhere
Nor any drop to drink.”
--from Rime of the Ancient Mariner
by Samuel Taylor Coleridge

The pressing problem of water supply arises after the immediate post-attack period. The provision of canned or barrelled water for a week or so inside a shelter appears both possible and practical. The renewal of the supply raises life and death problems.

Prudent planning must assume not only that water mains will have been broken, but also that reservoirs and their watersheds, along with shallow wells, will have been grossly contaminated by the deliberate use of “dirty bombs.” Such bombs might be designed to deposit difficult-to-remove isotopes.

The only source of potable water for some weeks would be from deep artesian wells. These, in most cases, would remain uncontaminated indefinitely because the soil through which water percolates over long distances has some natural ion exchange and filtration capacity.

On the other hand, the decontamination of reservoirs and watershed can may be accomplished only by time and the action of rainfall. Ordinary water-treating techniques will not necessarily suffice to reduce the contamination. Furthermore, unless they have been locally stored, common water-treating chemicals will not be available.

The suggestion for using ion-exchange resins for decontaminating water supplies, though appealing, is largely illusory. It depends either upon the availability of replacement resin or upon the independent availability of pure water to revivify the resin.

The anticipated result of a widespread attack would entail such destruction of industry and transportation facilities that replacement of resin from other than locally buried stores could not be assumed.

Prudent planning requires that deep wells, from 100 to 200 feet, be drilled in advance. Because in many areas the water table is so low that hand pumping is not feasible and no power from mechanical sources would be available, substantial stores of fuel must be laid in. This would be used for internal combustion engines for pumping.

After a somewhat indeterminate, but moderate, period, rainwater would be reasonably potable and, in regions of adequate rainfall, could replace the deep wells if decontaminated receiving basins could be devised by the survivors.

SOMATIC EFFECTS OF RADIATION – A MANAGEABLE CONSEQUENCE

BY HENRY T. YOST, JR.

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Amherst College

In a certain sense, the people of the northern hemisphere are part of a gigantic experiment to determine the effects of irradiation at low levels. Until the results of this experiment are in, we will not be able to point to sufficiently large stores of data to say *exactly* what will happen. On the other hand, the information we have, and the theory on which our investigations are now based, indicates that *any* exposure to radiation is harmful.

To think that we can escape some effects of radiation is greatly misleading. We are in a position similar to traffic safety officers who are setting a speed limit. A limit of 40 miles per hour does not mean that no one will die or be seriously injured at that speed; it means that we are willing to tolerate a certain amount of damage which we predict will come if the speed limit is not exceeded.

The recommended level for the exposure of human beings is such a "speed limit". We agree that no one should get more than 10 r in his reproductive lifetime (about 40 years). We say that this is "safe" because we can see no easy way to lower the dose at this time, and we know that human populations have been willing to pay the price for such an exposure in the past. It is a tolerable dose; a dose which contributes to the infirmities of present-day man and to the heritable abnormalities of the future.

When we turn our attention to the prospects of nuclear war, we pass the bounds of "safe" doses altogether. It seems highly unlikely that the average dose received by sheltered survivors on the eastern coast of the United States could be less than 200 r. In fact, the report of the Rand Corporation on radiation protection continually refers to 200 r as the nationwide average dose to be received. In the case of a 10,000 megaton attack this seems conservative. It is obvious that there will be cases where radiation levels are much lower than this. It is also clear that more effective shelters might be built, if the money were available and the enemy cooperative enough to keep his attack to some presupposed level; but the 200 r level is so frequently quoted, and so consistent with the available estimates of dose-rates after a nuclear attack, that it is realistic to confine our discussion of the effects of radiation to this level.

The immediate effects of exposure would depend to a great extent upon the rate at which the dose was given. If the survivors received 200 r over the first month after the attack, the effects would be quite similar to the effects from an instantaneous dose. Nausea and hair shedding would be most pronounced. In fact the shedding of hair is one of the best indications of exposure to radiation. As a general rule, when the hair grows back the exposed individual will recover from most of the immediate effects of radiation. Failure of the hair to return is an indication of serious damage.

A dose of 10 r received in a relatively short period of time (a few weeks) would

be expressed in a depression of the white cell count of the blood and in a slight decrease in the production of antibodies (those molecules which are produced to fight infection). At a dose of 100 r, radiation sickness is quite evident, although recovery would be assured for 90-95% of those exposed. At levels of 200r about 15% of the population would die from alteration of the blood forming elements and general radiation sickness.

Another effect which cannot be neglected and which would be significant in the 100-200 r dose range is lowered resistance to infection. It is to be expected that some areas of the intestine would undergo shedding of the lining which prevents germs (always present in our food) from entering the blood stream. The result would be an increased incidence of ordinary infectious diseases in the surviving population. This effect would be coupled with a decreased antibody production and a lowered capacity of the organism to repair tissue damage brought about by impaired cellular activity. Thus, secondary illness will be a problem for the inhabitants of the shelters, both in the shelter and after emergence from shelter.

The long range effects of exposure to radiation are even more serious. Through a mechanism which is not completely understood, the effects of radiation are stored in the body to a degree which results in a shortening of the life span. This life span shortening can be estimated by the rule that 1 r will decrease the the life expectancy by 5-10 days. An exposure of 200 r would cut between 1000 and 2000 days from the life span, on the average.

In addition to this, the incidence of all types of cancer would be expected to increase. The first reports of the research committee on tumor statistics from Hiroshima indicate that the dose necessary to double the incidence of cancers of all types is about 400 r. Therefore, we must expect that survivors in shelters will show a 25-50% increase in the incidence of cancers of all types.

Leukemia should be considered separately, as it is apparently one of the "genetic" effects of radiation in somatic tissue. While there is undoubtedly a threshold for the increase in most types of cancer, there is every indication that none exists for leukemia, that is, **any** dose of radiation will increase the incidence of this disease. Moreover, the doubling dose for leukemia seems to be lower than for **all** types of cancer combined; therefore we must expect that the incidence of leukemia among the survivors will be very greatly increased.

Sterility is another important somatic effect of radiation. Women are more sensitive than men, in this respect. A dose of 200 r will induce temporary sterility in males from which a slow recovery would be expected. (However, recovery is frequently not complete and we would expect a lowering of fertility.) On the other hand, recent evidence indicates that female sterility is permanent when induced. This is not surprising, as the number of cells involved in the production of eggs is less than the number involved in the production of sperm. At a dose of 200 r, we can estimate, conservatively, that 25-50% of the surviving females will be sterile.

There are a number of other somatic effects to be expected in this dose range, but since they are less important, they will be only briefly mentioned here. Pregnant women will have to anticipate a relatively high chance of stillborn or deformed babies. Doses as low as 20 r are known to interfere with the normal developmental

processes. The younger the developing child is, the more susceptible it will be.

Hormonal imbalance is a short-range but likely event following exposure. This may result in noticeable changes in certain individuals who are already below par. The blood clotting mechanism will be altered, with the result that cuts and bruises may be more serious and in extreme cases internal hemorrhaging may result.

Finally, the effect on the nervous system is not clear. While no major changes are to be expected, there have been a number of reports of changes in certain subtle brain functions after exposure. What this might mean to a surviving population in a restricted shelter or emerging to the desolation following the attack is a problem which only the event itself can answer.

The dose which will kill all of the population is 1,000 r (about one half of the population would die at 450 r). This dose is unlikely for people in shelters. However, unsheltered people, animals and plants would receive doses far in excess of this. Thus we must assume that other somatic effects can be neglected in their case. They would be dead. The consequence of this for the survivors is obvious. Pine trees are killed at doses of 5,000 r, all mammals and birds will be killed by 1,000 r. Clearly, the somatic effects of radiation on the sheltered survivors will be most drastically expressed through the effect on non-sheltered life.

As serious as these effects are, it is clear that the somatic effects of radiation are the most manageable of all the consequences of a nuclear war. This is not surprising as fall-out shelters have been designed to meet just this problem. Unfortunately, this aspect is the least important effect of nuclear warfare. Blast, fire and genetic effects are far more important. What the shelter can do, at best, is to preserve the lives of a certain percentage of the population out of the blast and fire areas. It cannot reconstruct the devastated areas, resurrect the animals and plants for food production, or remove the radioactivity from the soil. It is essential to realize that preoccupation with the somatic effects of radiation has lead most people from a consideration of the essential problems.

It is time to forget an expensive and largely futile effort to solve one of the least important problems of a nuclear attack.

DAMAGE THAT WEAKENS THE HUMAN SPECIES

BY THEODOSIUS DOBZHANSKY

Professor of Zoology
Columbia University

One of the consequences of exposing people to high-energy radiation, such as would be released by a nuclear bomb explosion, would be genetic radiation damage. The generalized effect of such damage is to increase the incidence of defective heredity.

Defective heredity, in normal incidence, is the cause of much human misery. It is responsible for hereditary diseases, some of them grave and many incurable. It produces a variety of malformations and of bodily defects. It weakens vitality, vigor, intellectual ability, and resistance to infections. Obviously any increase in the incidence of hereditary defects in human populations would mean greater misery for more people.

Defective heredity arises through changes -- mutations -- in the materials transmitted in the sex cells from generation to generation, from parents to their children. Mutations, of course, have always been going on in the human species as in all other living species.

But radiation damage may greatly increase what may be considered the normal incidence of mutations and thus add to the burden of defective heredity. Such damage inflicted in our time will harm our descendants for many generations to come.

There is no such thing as a safe or permissible radiation exposure as far as genetic radiation damage is concerned. No matter how small, a radiation exposure has a proportionate chance to cause mutations.

If many people in the world are exposed to genetically damaging radiation, those not exposed can have little confidence of breeding a strong line of descendants. The reason is that harmful mutants can appear among their descendants whose ancestors from another line may have been exposed.

This should serve to bring home to us that genetic radiation damage is not a private affair of this or that person or family.

It is a concern of the whole of mankind.

Why is genetic radiation damage such a serious matter? After all, defective heredity has always been with us. It arises by mutation without known radiation exposure. Radiation damage merely increases the load of hereditary defects. If the damage is small, the increase will be small.

But will it be negligible?

This depends upon one's ethical standards. Is one human life lost or made miserable by hereditary disease or weakness to be considered "negligible?" How many human lives should be sacrificed? Is it right to make more people suffer because

some people will suffer anyway?

Biological science, and particularly genetics, has a lot to learn about genetic radiation damage. As is almost always the case in rapidly developing fields of science, there is much discussion and even disagreement among geneticists about some issues. But there is practically, unanimous agreement among competent people that high-energy radiation does cause genetic damage.

Big or little, this damage is undesirable.

OUR INDUSTRIAL SYSTEM UNDER A NUCLEAR ATTACK

BY SEYMOUR MELMAN

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A nuclear attack of modest size could destroy, by fire effect alone, more than two-thirds of the manufacturing facilities of the United States.

This conclusion, conservatively drawn, would mean the destruction of this country as a viable industrial system. The reason is that whatever industry remained would be without the intricate web of supplies and services that are essential for its operation.

An appraisal of the impact of nuclear war on the American industrial system requires an understanding of the nature and the extent of industrial division of labor and interdependence.

The condition of specialization and interdependence in American industry was strikingly presented by Professor Wassily W. Leontief and others in a series of input-output studies of our economy. A second example of this condition emerges from a simple analysis of the sources of supply that contribute to the stock of a single New York City supermarket.

The following tabulations, based on the Leontief studies, record the condition of dependency of the industries that produce apparel, buildings, and transportation

equipment. In each case there is listed the industries whose products are necessary inputs for the operation of the three main industries:

APPAREL INDUSTRY
requires inputs from

Agriculture and fishing
Industrial and heating equipment
Merchandise and service machines
Iron and steel products
Petroleum products and refining
Coal and coke
Manufactured gas and electric power
Communications
Chemical
Pulp and paper
Textile mill products
Leather
Rubber
Miscellaneous manufacturing industries
Construction
Miscellaneous transportation
Trade (domestic)
Trade (foreign)
Business and personal services
Government

CONSTRUCTION INDUSTRY
requires inputs from

Agriculture and fishing
Ferrous metal
Iron and steel
Agricultural machinery
Engines and turbines
Motor vehicles
Industrial and heating equipment
Electrical equipment
Iron and steel products
Non-ferrous metals
Non-metallic minerals
Petroleum products and refining
Coal and coke
Manufactured gas and electric power
Chemicals
Lumber and timber products
Furniture
Pulp and paper
Textile mill products
Rubber
Miscellaneous manufacturing
Business and personal services
Government

**TRANSPORTATION EQUIP-
MENT INDUSTRY**

requires input from:

Ferrous metals

Iron and Steel foundry products

Engines and turbine:

Machine tools

Iron and steel products

Non-Ferrous metals

Non-metallic minerals

Petroleum products and refining

Coal and coke

Manufactured gas and electric power

Chemicals

Furniture

Rubber

Construction

Trade (domestic)

Trade (foreign)

Government

This analysis means that when even one or two important inputs, such as power, are unavailable, the industry cannot function.

Regional analysis of industrial operations discloses important concentrations in particular states and localities. The manufacturing plants of the crucial machine-tool industry, for example, are concentrated in Ohio, Michigan, Connecticut, and Vermont. In these regions the most important concentrations further occur in major metropolitan centers.

Accordingly, destruction of production facilities in the major industrial centers has a more extensive effect than is indicated by the value *of* the industrial assets that have been destroyed or the value of the industrial output that has been curtailed.

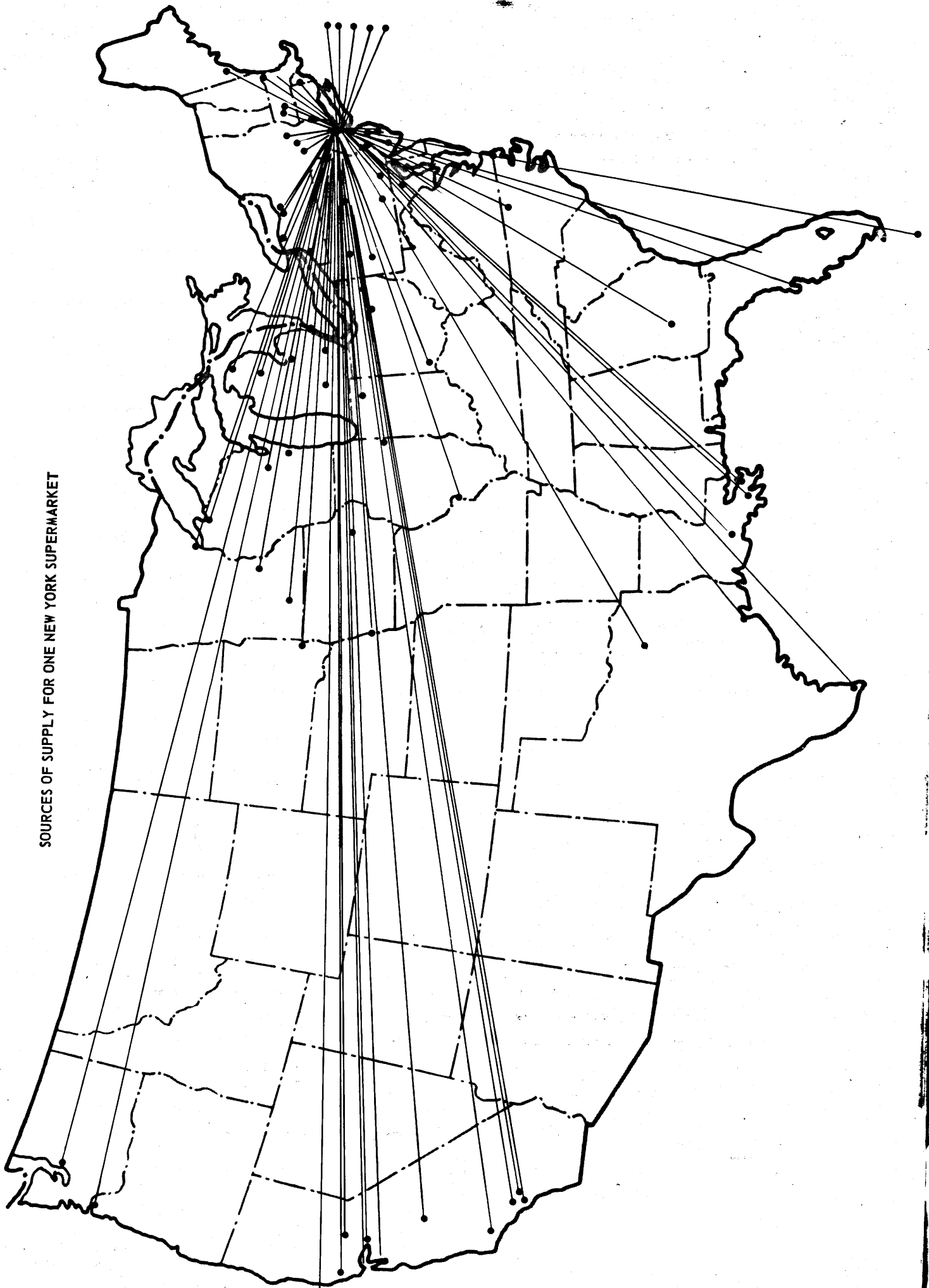
Where the outputs of an industry are crucial to many others, as in the case of machine tools, the deranging effect from curtailment of production is multiplied into many other industrial sectors and regions as well.

Another view of the condition of industrial interdependence in our society is seen from a set of observations in a grocery supermarket located at 125th Street and Amsterdam Avenue in New York City.

All together there were about 2500 separate named items on the packaged goods shelves of that supermarket. Of these 10% were examined for location of processing plants from which the items originated. The 251 sampled items were shipped from 94 processing locations in the United States and five overseas.

Twenty-nine states were sources of supply. The maximum number of items from any location was 42 - that location was New York City, itself. The map on the following page illustrates the variety of sources of supply in this supermarket from within the continental United States.

SOURCES OF SUPPLY FOR ONE NEW YORK SUPERMARKET



Much the same pattern of supply sources would hold for every sizeable supermarket in the country.

Effects of a Nuclear Attack on U.S. Industry

With this condition of far-reaching interdependence of our economic system firmly established in our minds, let us now postulate what would happen under a hypothetical nuclear attack.

For purposes of this analysis we assume an attack on 65 major metropolitan industrial centers by means of 20 megaton warheads (or their equivalent in thermal effects) on each center. It will be noted that three warheads of 1-megaton each would produce even greater thermal effects than a single 20-megaton warhead. It will be noted also that the total megatonage (1,300) used in this hypothetical attack is slightly less than the amount that was said to be "well within the capabilities of a potential aggressor" at the June, 1959 hearings of the Joint Committee on Atomic Energy.'

This analysis is deliberately conservative, taking into account only the fire effect from such an attack and omitting effects owing to blast, radiation, and fallout.

The fire effect from each 20-megaton warhead (or its equivalent in fire effect) is assumed to be a 25 mile radius around the center. This distance is within the outer limit of areas for third degree burns for human beings from 20 megaton explosions, as estimated by the Atomic Energy Commission. As a third degree burn means the charring of the full thickness of the skin, it is assumed that the heat would be sufficient to set fire to many flammable materials within the assumed radius of 25 miles. Accordingly, a large number of fires would be started very quickly upon such an attack.

Extensive fires, concentrated within a large area, produce a fire storm. A "fire storm is a high-intensity fire causing rapid consumption of oxygen and massive columns of rising gases. The partial removal of air at the surface is filled in by winds moving with great force from the surrounding area, thereby accelerating the fire storm itself until all combustible material is consumed. In the napalm bomb attacks on Hamburg and Tokyo during World War II, such fire storms were created.'

Under fire-storm conditions, the bomb shelters within these cities became containers within which occupants were either asphyxiated or charred. The numbers killed during the fire storm raids in major German and Japanese cities equaled and exceeded the number killed in the atomic bombing of Hiroshima and Nagasaki. High altitude photographs of the fire storms in progress show the spectacle of entire cities going up in flames.

Sixty-five warheads of 20 megatons each (or three times that number of one-megaton warheads) could be delivered on U.S. metropolitan industrial centers by various means, including those that are both primitive and allow for little warning time.

Soviet submarines could rise off the coast and launch primitive flying bombs similar to the German V-1 weapons of World War II. Such instruments, launched from a distance of about fifty miles off the coast, could be set to fly at low altitudes to elude radar. Submarines could probably fire several such units before

interception by defensive planes or vessels.

Flying bombs of this sort could also be launched from freighters or even smaller vessels. Again, freighters or warships off the coast could launch medium range missiles to reach into the United States for 1,000 to 1,500 miles. Such missiles, with short travel time, would not allow for very much warning even if their flight was initially detected.

Warheads could also be delivered by aircraft that are equipped for a one-way trip to the target area. These could approach American coasts from the seaward or southern side and at low altitudes.

This enumeration, which surely does not exhaust such possibilities, is exclusive of intercontinental missiles of the largest class. In this analysis, I proceed on the assumption that a determined aggressor could mount multiple approaches to each target area with high probability of penetrating all known defensive systems.

The meaning and the extent of this hypothetical attack is indicated on the map reproduced on the following page. Circles of 25 mile radius are drawn to scale over metropolitan industrial regions. The inset shows the New York metropolitan region in somewhat greater detail. These are the areas within which fire storm effects of the sort discussed in this paper would be expected from the explosion of the indicated sorts of warheads.

These sixty-five urban places correspond to the "Standard Metropolitan Statistical Areas," a formal designation used by the Census of Population and the U.S. Census of Manufacturers. The "Statistical Abstract of the United States," 1960 (page 790) discloses that these 65 urban centers account for about two thirds of total manufacturing and one third of the total population of the country.

The immediate effects of wide destruction by fire storm alone in these industrial centers would be the destruction of the country as an industrial system.

Such destruction also breaks the network of interconnections among all industries. Therefore the result is far more extensive in the disruption of production capability than is indicated by the direct effects.

When central sources of power, communication, and transportation are destroyed in individual areas, then the interlocking fabric of the productional division of labor of society is torn apart.

After such a nuclear attack the persons left alive in the areas between the metropolitan centers would be required, in short order, to provide their food, clothing, and shelter by primitive means -- relying almost exclusively on manual methods.

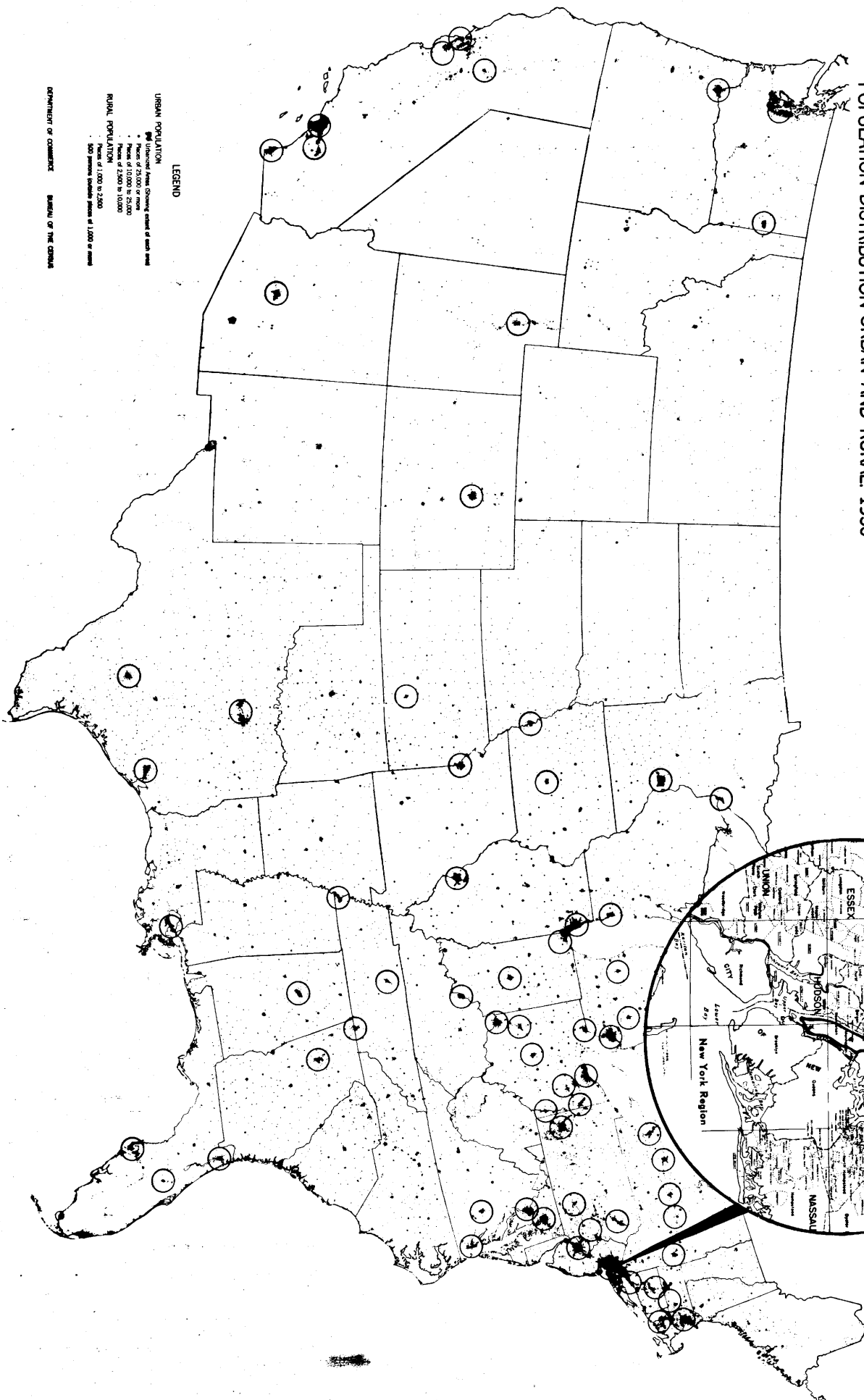
People who could not provide their elementary needs in this way could not survive.

Regular supplies of fuel, power transportation and communication services that are required for the customary operation of industrial facilities would no longer be available. Farm tractors, under such circumstances, are transformed into metal monuments by the absence of fuel. Factories and workshops could only produce as far as self-contained power plants and fuel plus raw materials supplies permitted.

Industrial recovery from disasters even as great as the Second World War occurred

SIXTY-FIVE URBAN CENTERS IN US
account for two-thirds of total manufacturing

POPULATION DISTRIBUTION URBAN AND RURAL. 1950



LEGEND

- URBAN POPULATION
- 100,000 or more
 - 25,000 to 100,000
 - 10,000 to 25,000
 - 5,000 to 10,000
 - 1,000 to 5,000
- RURAL POPULATION
- 1,000 or more
 - 500 or more

DEPARTMENT OF COMMERCE BUREAU OF THE CENSUS

under conditions where help became available from outside the disaster area. In a world war fought between the East and the West, the major industrial centers of the world would be destroyed.

Assistance would have to come, if at all, from outside the North American and European continents. The present level of industrial production in the Southern Hemisphere does not indicate the availability of large surpluses in fuel, power equipment tools, medical supplies, and consumer goods for use in saving survivors in the Northern Hemisphere.

Would the Soviets attempt to destroy the American industry?

One suggestion is that a "rational" aggressor would strive to destroy direct military targets only -- the missile and aircraft bases.

This assumes that an attacker would be prepared to leave intact an industrial system that could be used, after some delay, by an enraged population to mount desperate acts of revenge against the attacker who had scored a first round by interdicting weapons only.

Modern industry is the essential base for nuclear warfare with elaborate delivery systems and logistics of mass armies.

From this analysis, I find it unreasonable to assume that industrial "recovery," as it is culled, could take place in any time period that would allow for a meaningful restoration of industrial life.

The assumption of a workable "recovery" situation is, however, one of the foundations of civil defense programs.

Insofar as American industry operates by means of a finely integrated division of labor, the fire effect alone of a modest-sized nuclear attack would render this society no longer viable as a significant production center of the world.

FOOTNOTES:

1. **"The Structure of the American Economy 1919 to 1939,"** by Wassily W. Leontief and others, Oxford University Press, New York, 1951, second edition.
2. **"Biological and Environmental Effects of Nuclear War,"** Hearings before the special subcommittee on radiation of the Joint Committee on Atomic Energy, 86th Congress, June 22-26, 1959, P. 15.
3. **"The Effects of Nuclear Weapons,"** S. Glasstone, Atomic Energy Commission, P. 299
4. See books by Martin Caidin, **"The Night Hamburg Died,"** and **"A Torch to the Enemy,"** both published by Ballantine Books, New York, 1960.

DANGERS OF THE SHELTER PSYCHOLOGY

BY OTTO KLINEBERG

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For the individual, shelters are dangerous because they threaten to impair our cherished values. For the nation, shelters are dangerous because they reduce our will to find a peaceful solution to international problem! and because they may convince our adversaries that we are expecting -- and therefore preparing for--war .

To burrow beneath the ground for weeks, or even longer, means for human beings a denial of most of the values which have been acquired slowly and painfully in the process of creating a democratic society. Instead of community there is a splintering into isolated individuals or tiny groups. Instead of cooperation there is violent competition for available space. Instead of mutual aid, there is a selfish struggle for individual survival.

Psychiatrists speak of regression when adults behave in a manner appropriate to children. We may speak of social regression when a whole community behaves in a manner characteristic of primitive, archaic, even animal-like existence, almost to the point of recreating a Hobbesian war of all against all.

If our stake in the present ideological struggle is to preserve a way of life, we may well ask ourselves how much of our way of life would be maintained under the conditions imposed by resort to shelters. Our democratic values would be submerged in a crass and cruel struggle for survival, made even more bitter because the struggle may be futile. There will be irritations and frustrations arising from the enforced and continued contact with others for an extended period without the relief of occasional privacy; there will be anxieties concerning those from whom one has been separated; there may even be a breakdown of psychological defences because of worries about the uncertain future. Prolonged incarceration under such conditions may be a devastating experience.

More important from society's viewpoint are the wider implications of a shelter program for international relations.

Psychologists and sociologists have both stressed the importance of our attitudes as our behavior. When we believe that something is going to happen, we act accordingly, and as a consequence our beliefs may be transformed into reality.

The Columbia University sociologist Merton, for example, speaks of "the self-fulfilling prophecy". Suppose, for example, that in a small community a rumor is started that the local bank is in difficulties and is about to close its doors. (We shall have to suppose further that in this particular instance the depositors are not protected by bank insurance.) The bank may on the contrary be perfectly sound, and quite capable of handling all withdrawals which it may expect in the ordinary course of events. The rumor spreads, however, and there is a run on the bank, which cannot meet the excessive demand for funds which is now placed upon it, and it

does have to close its doors. The prediction has come true because people acted upon it.

The most direct application of this concept to international relations, and more particularly to war, has been made by Harvard Psychologist Allport who speaks of the "principle of expectancy". In essence this means that if we expect a certain event, and act accordingly, that event is more likely to occur. The expectancy of war, therefore, increases the likelihood of war.

There is nothing mysterious about this principle, if we add the proviso that the acts must be related to the production of the event. If all of us expect rain tomorrow, that will make no difference to the weather, as obviously our behavior is irrelevant to this particular outcome. If, on the other hand, everybody expected stocks to go down, and therefore sold out in a hurry, that would create an atmosphere which could certainly contribute to a drop in their value.

The late President Franklin D. Roosevelt had a clear conception of this mechanism of "expectancy" when he told us that all we had to fear "was fear itself".

As far as war is concerned, the expectation that it is definitely coming would prevent us from taking all possible measures to avoid it, and therefore make war that much more probable. The reverse is not necessarily true. War may come when we least expect it. All that is being said is that, if we do expect it, the chances of its occurrence are increased.

This analysis has important practical consequences in connection with shelters. There is a real danger that the building of shelters will lull the people into a false sense of security. It is as if they were to say to themselves, consciously or unconsciously, "We have shelters. We are safe. Let war come." This reduces our efforts to avoid war, and to that extent brings war, a little closer.

The shelter program might also bring war closer because of its potential effect on the USSR. As the Political Scientist **J.D. Singer** (*Bulletin of the Atomic Scientists*, Oct. 1961) has put it: "At the very least, it would suggest that we have markedly raised our own estimate of the probability of strategic nuclear war, and are therefore hoping to minimize its destructiveness." (p. 313) As a consequence, our potential adversaries "could assume that we are giving more serious consideration to an opening blow ourselves", or he could assume "that we are more convinced that he is planning a surprise attack and are preparing against it. In either case, it would be legitimate for him to give greater consideration to opting for that very opening strike himself".

This analysis is psychologically sound, and reflects the dangerous potential effects of the shelter program not only on our own attitudes, but also on those of our adversary. The tendency to regard shelters as "insurance" against attack is based on a misunderstanding.

Life insurance does not cause us to take greater chances than we would normally, nor in the case of life insurance, contrary to the case with shelters, do we have adversaries who are more likely to attack us just because we are insured.

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