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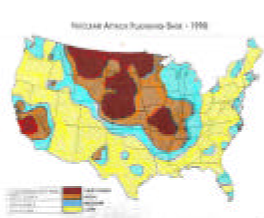
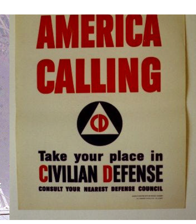
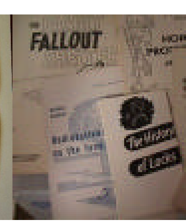
  



FEDERAL EMERGENCY MANAGEMENT AGENCY FEMA 160 / October 1988

Recovery From Nuclear Attack

PREFACE

This report on Recovery From Nuclear Attack should be of interest to all concerned with civil defense and nuclear attack.

As pointed out in the report, the "impossibility" of recovery is often advanced as a reason for doing nothing to develop an effective civil defense program for the United States. However, those who have devoted years to the study of civil defense in general, and postattack problems in particular, do not agree that recovery would be impossible.

There is no doubt whatsoever that if a large-scale nuclear exchange should ever occur, the result would be a massive disaster for the societies involved. The death, suffering, misery, and long-term consequences of various types would have few if any parallels in human experience—and certainly none in the history of the United States. But this is not the same as saying that recovery would be "impossible." As the report says, "in years of research, no insuperable barrier to recovery has been found."

The genesis of this publication was the perceived need to respond to not infrequent inquiries on nuclear attack recovery issues. The starting point was a 1979 "Research Report on Recovery From Nuclear Attack," published by the Defense Civil Preparedness Agency—a predecessor to the Federal Emergency Management Agency. Based on research and new concerns, the document is a significantly revised and updated effort to deal with the difficult issues of the effects of the use of nuclear weapons against the United States.

RECOVERY FROM NUCLEAR ATTACK

INTRODUCTION

Should emergency planners, emergency preparedness managers, and citizens be concerned with the prospects of recovery from the awesome destruction caused by a possible nuclear attack on the United States? Would there be anyone left to face the postwar world?

It is clear that the superpowers are agreed that "a nuclear war is not winnable and should not be fought." But the conclusion that nuclear war is not winnable is often transformed into the proposition that nuclear war is not survivable. This inaccurate perception may give comfort to some that such a war will not occur. But it also can discourage many others from taking those modest "commonsensical" steps that would improve greatly their own chances of survival, should a nuclear war in fact occur.

Survival Odds— Many people, perhaps a majority of U.S. citizens, are likely to survive even an "all-out" attack by the Soviet Union, which presently has the greatest capability to threaten us. By "survive" is meant to be alive at least thirty days afterward. Just how many would survive would depend greatly on the kind of attack and its size, to say nothing of civil defense. By "kind of attack" is meant what overwhelming national purpose the Soviets might have for launching the attack and therefore what sorts of targets—military, industrial, transportation, or government facilities—might be the objects of the attack. By "size of attack" is meant how many warheads might arrive at targets and the explosive yield of the resulting detonations.

Needless to say, how many would survive can vary greatly even with a low level of civil defense preparedness because of problems in predicting very reliably the kind and size of attack that might occur. Both the U.S. and Soviet governments have spent a great deal of time and effort gaining an understanding of nuclear weapon effects and calculating the damage and fatalities that might result from various kinds and sizes of attack. This is needed, of course, for each to plan properly its defenses and force structure. In the civil defense field, those planning for survival or arguing against such plans have tended to emphasize an all-out or "massive" nuclear attack, even though such an attack is *not* the most likely.

An up-to-date estimate of survival odds is provided by the "Nuclear Attack Planning Base—1990," called NAPB-90 [1], published by the Federal Emergency Management Agency in 1987 without considering a superpower START treaty, which, if consummated, could markedly reduce the warheads available on each side. NAPB-90 does, however, reflect the drastic changes that occurred between 1975 and 1985 in the Soviet strategic arsenal. These changes came about by the substitution of MIRVs (Multiple Independently-targetable Reentry Vehicles) for single large-yield warheads on most Soviet ballistic missiles. There are now many more warheads of much smaller explosive power, with an overall reduction of total explosive yield available and reduced levels of potential radioactive fallout. Coupled with significant improvements in weapon accuracy, the Soviets could threaten more reliable damage to critical target facilities while reducing damage to nearby population centers.

Assuming some warning but otherwise merely a "duck and cover" civil defense, the chances of injury or death in an NAPB-90 attack are about:

— 1 in 3 of being killed outright by blast or thermal effects;

— 1 in 25 of being killed by fallout radiation;

— 1 in 6 of being injured or ill but not fatally;

— Almost 1 in 2 of being uninjured.

It can be seen that the majority are expected to survive, even with rudimentary civil defense. It can be anticipated that START agreements to halve the threat would further improve prospects for survival.

And, of course, other civil defense measures could add substantially to survival as well. In fact, spontaneous evacuation of urban areas on a fairly large scale could add tens of millions of survivors, especially in an attack with relatively few surface-burst weapons and thus a reduced fallout threat. Experience just before and during World War II and in the Korean and Vietnamese conflicts, as well as recent opinion surveys suggest that evacuation from U.S. cities could reach 50% during an escalating crisis, even in the absence of detailed evacuation plans or official advice to leave. In the 1979 Three Mile Island accident, about 40% of the people living within 15 miles of the nuclear power plant evacuated spontaneously with no official advice to do so. These spontaneous evacuees totaled about 145,000 people.

Yes But . . . Most opponents of attack preparedness are quite aware that nuclear war is survivable in the sense just outlined although some have distorted the facts of weapon effects to make the prospects of survival as dim as possible. For the most part, however, opponents dismiss these claims of survivability as only temporary and of little consequence. Ultimately, they argue, the longer term effects of the attack will kill off those who survive initially and render any prospects of societal recovery meaningless. Government studies that project recovery of prewar economic health in perhaps a decade are dismissed as flawed. A number of barriers to recovery—the most recent, "nuclear winter"—has been advanced in an effort to make good the claim that a nuclear war is not survivable. Herein, we will sum up what is known about these barriers to postwar recovery.

In The Aftermath No one should underestimate the shock and disruption to our society that would be caused by a nuclear strike, particularly one of massive or "all-out" proportions. Several motion pictures and television films ranging from "On the Beach" to "The Day After" have attempted to describe the horror, destruction and chaos in the immediate aftermath with varying degrees of success. But these imaginative visualizations fail to convey the "big picture." For example:

(1) Although no formal census of survivors would be possible for quite some time, one in the aftermath would probably show a U.S. population of about 125 to 150 million persons—approximately the same as it was in the 1930s.

(2) The population would no longer be predominantly urban since the urbanized areas contain many of the critical targets. Therefore, a considerably higher percentage of the rural population would survive.

(3) There would be relatively fewer very young or very old survivors since these age groups would be most vulnerable to weapon effects, stress, and disruption. The sex ratio would remain about the same.

(4) The life expectancy of the average survivor would be shortened somewhat by radiation exposure, by as much as five years in the worst circumstances.

(5) There would remain proportionately fewer doctors and hospitals, corporate headquarters and executives, petroleum refineries, pharmaceutical plants, and public administrators, since these tend to be concentrated in the larger cities or are targets in themselves.

(6) There would be an increase in the percentage of orphans and other dependents in the population as well as an increase in broken families. Even if an entire family were together at the time of attack, some family members might have survived while others had not.

(7) There would be drastic changes in the composition of the labor force both in terms of geographic availability and distribution of skills.

(8) About 50 percent of the manufacturing capacity of the nation would likely be destroyed and an additional quarter damaged, some of it irreparably by fires. Some portion might not be usable for weeks or months in fallout areas until radiation levels decayed or decontamination had been accomplished.

(9) Many domestic and wild animals and crops would be destroyed or injured, primarily by fallout radiation. However, compared to people, a higher percentage would survive.

(10) The postattack survivors would need to learn to function in an environment in which the ionizing radiation background would be many times higher than any experienced by the prewar society. They would have to learn how to minimize the consumption of contaminated food and water and how to ration carefully their exposure to external sources of radiation as they struggled to survive and recover, even though there would be a shortage of radiation measuring instruments.

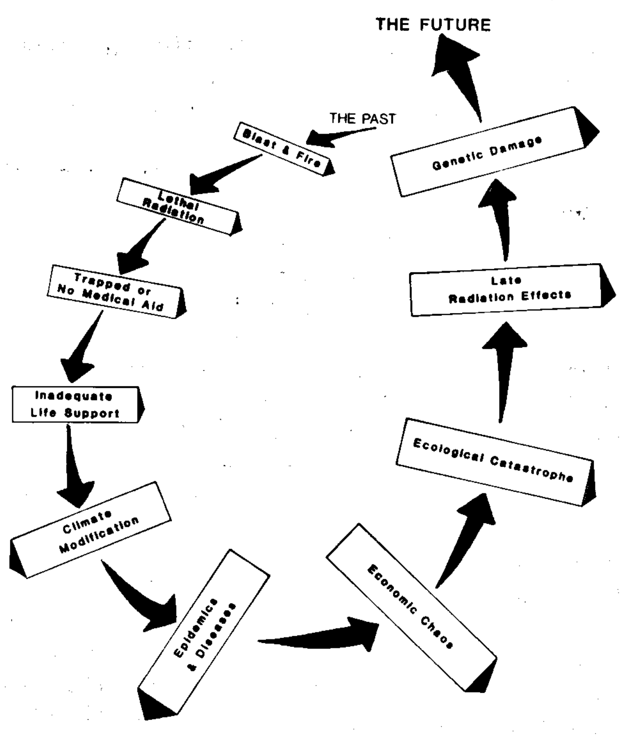
(11) Despite the shock and disruption of attack, widespread panic would not occur. The general behavior of the survivors would probably be adap-

tive rather than maladaptive, as it is found to be in major peacetime disasters. By and large, people could be counted upon to participate constructively i[illegible]re efforts to achieve local and national r[illegible]ery goals. They would continue to do so as long as there appeared to be leadership that seemed to know what it was doing. People would contribute as long as their efforts did not appear to be wasted and provided they and their families shared fairly in the available supply of the basic requisites for existence—food, water, shelter, etc.

What Would the Survivors Face? Survivors of the blast, fire, and early fallout radiation effects still would face an uncertain future. Serious additional hazards and obstacles would have to be overcome before the society to which they now belonged returned to a semblance of its pre-attack status. Some of the hazards would have to be faced immediately, while others would not become important until months or even years later.

It is useful to consider the difficulties confronting the survivors as "an obstacle course to recovery." This idea is illustrated in Figure 1, which is taken from the current version of the Attack Environment Manual [2]. Before recovery could start, individuals must survive the blast and fire effects, fallout radiation, and the prospect of being trapped without rescue or medical help. Once through the immediate postattack period (roughly the first week), there would still be many obstacles to overcome, beginning with the possibility of insufficient life support needs, such as food, water, and shelter.

TEN BARRIERS TO WELL-BEING*



*Source: Reference 13

FIGURE 1

The major elements in this "obstacle course to recovery" and the appxoximate times during which they would be most important are outlined below:

Time After Attack	Obstacle
1-2 days	Blast and Fire
1-7 days	Fallout Radiation
2-7 days	Trapped or No Medical Treatment
5-50 days	Life Support Inadequacies
2 weeks-1 year	Epidemics and Diseases
2 months-2 years	Climate Modifications
1-2 years	Economic Breakdown
5-20 years	Late Radiation Effects
10-50 years	Ecological Effects
2-several generations	Genetic Damage

These obstacles are not necessarily independent of each other. For example, people could expose themselves to fallout radiation in search of food or water which would later contribute to the late radiation effects and genetic damage. Or malnutrition and radiation exposure could lower resistance to diseases.

For explanatory purposes, however, each of these obstacles will be considered separately. The times associated with each item are not intended to be precise, but are given to provide a rough idea of when this obstacle is likely to be of greatest importance. The discussion assumes some general knowledge of nuclear weapons effects. Thus, familiarity with the information in FEMA's Attack Environment Manual (Reference 2) would be most useful to the reader. Although discussed in sequence, the main relationship between barriers will be noted so that one is not left with the impression that postattack recovery is simply a matter of overcoming one obstacle at a time.

BLAST AND FIRE

For those living near potential targets of attack, such as military bases and important industrial plants, the very first hurdle on the road to postattack recovery is pure survival of the direct effects of nuclear detonations. The citizens of Hiroshima, Japan, were totally unaware of the existence of such weapons and many were in the streets watching the high flying aircraft. Many thousands were terribly burned by the thermal radiation or "heat flash" from the nuclear explosion high above the city. Merely being indoors would have prevented most of these deaths and burn injuries. People are generally indoors most of the time and civil defense warning devices or broadcasts during a tense crisis could minimize the number in the open.

We know a considerable amount about the survivability of people in single family residences and in large buildings, much of the information drawn from the Japanese experience. People will survive better in basements rather than aboveground. The survival odds quoted in the introduction are, however, based on aboveground locations where the average survival level or "median lethal overpressure" is about 5 pounds per square inch (psi).

The greatest misunderstandings about initial survival have to do with the threat of fires caused by the nuclear explosion. Most of the ensuing fires are ignited by the heat flash of the detonation although some are caused by blast damage to electrical wiring and gas lines. The blast wind is also known to blow out or extinguish a large part of the ignitions, but smoldering debris can reignite and, if located among other flammables, can grow into substantial fires. If not brought under control, such fires can spread and coalesce into mass fires under favorable conditions. Most nuclear fire experts, such as Dr. Stanley Martin, tend to visualize the region of active fire spread as a ring around the epicenter between the 5-psi and 2-psi blast levels where most buildings are damaged but not in total collapse. Within this doughnut-shaped region, severe mass fires called "firestorms" cannot be ruled out if very densely built-up areas like city centers happen to be there. Closer in at higher overpressures, building damage tends to be too severe to support more than occasional fires and smoldering debris piles.

In 1963, when the Kennedy Administration was proposing a fallout shelter program, Dr. William Schreiber, a professor of electrical engineering at the Massachusetts Institute of Technology, told a Congressional committee that large nuclear weapons detonated at high altitudes could incinerate tens of thousands of square miles causing fires that "would be of such an intensity that one would expect few survivors." [3] This prediction did not stand the test of peer review but the myth of massive fire deaths has persisted for over twenty years. More recently, Von Hippel, Levy, and Daugherty of Princeton University presented a paper [4] at a National Academy of Sciences seminar in 1985 in which it was alleged that a 1-megaton air burst over a city would result in complete burnout of the area out to the 2-psi blast level (a radius of over 7 miles) within which *everyone would die.* Similar predictions have appeared in the New England Journal of Medicine and other distinguished scientific and technical publications.

The evidence is quite different. Fire deaths at Hiroshima and Nagasaki were so few that they could not amount to more than one or two percent of the total. If a firestorm occurred at Hiroshima, as is sometimes alleged, its lethality was very low. This low lethality has been recorded in many other fire raids in World War II and in large peacetime fires. The exceptions are a handful of mass fires in German cities that generated the term "firestorm." The firestorm at Hamburg has received major attention [5][6][7]. At Hamburg, an especially severe mass fire killed about 40,000 of the 280,000 people who lived in the mass fire area. About 50,000 persons were in special shelters and none were lost. The remainder were in building basements and suffered 18 percent fatalities. The rate of loss in other German firestorms, such as Dresden, was somewhat less but generally in the neighborhood of 15 percent. Thus, fire deaths in air-burst nuclear attacks could range from a few percent to as high as 18-20 percent.

Would firestorms occur as the result of nuclear attack? Some British experts, including designers of the Hamburg fire raids [8], believe it most unlikely. However, if city centers are not attacked, but rather military bases and industrial areas, the appropriate conditions for development of a firestorm could arise. Nonetheless, firestorms are likely to be rare events under nuclear attack conditions. Accordingly, the survival odds described in the introduction assume fire conditions similar to those which occurred in Hiroshima.

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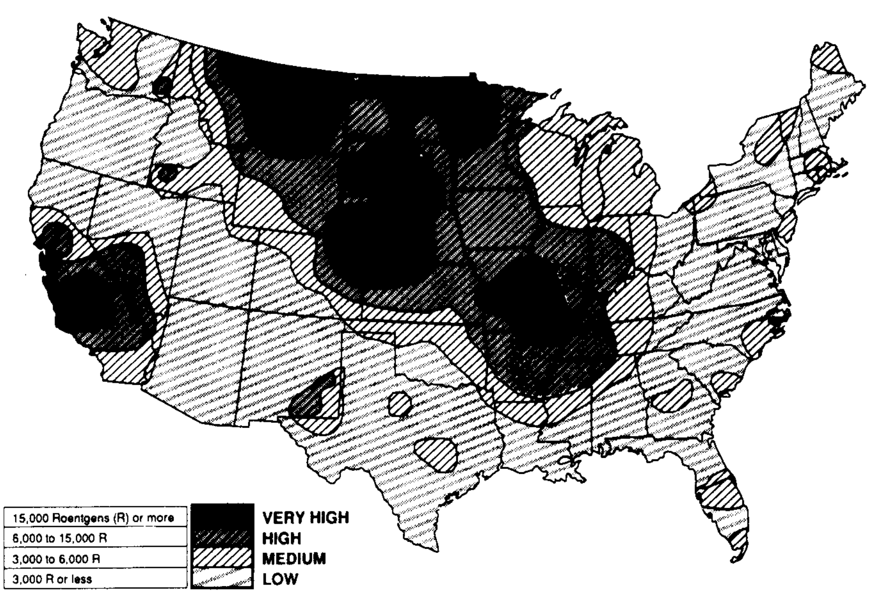
LETHAL RADIATION

Fallout radiation from surface-burst nuclear weapons potentially could threaten not only persons in the vicinity of detonations but also those at a great distance. The greatest uncertainty in this threat lies in the question of whether the weapons in the attack would be air burst or surface burst. Unless the nuclear weapon is detonated at or near the ground surface, very little lethal radiation would be delivered to the survivors of blast and fire. Dr. William Schreiber, already cited, scoffed at the use of surface burst weapons except "in attacks on hard missile bases, where very high (100 to 200 psi) overpressures were needed." He concluded that "attacks on cities are most likely to utilize fallout-free air bursts or high altitude bursts." The recent FEMA study, NAPB-90, tends to agree although it extends the use of surface bursts to hardened command canters and certain air fields. As a result, the highest levels of fallout radiation would be largely limited to the North Central United States, as shown in Figure 2.

FALLOUT HIGH RISK AREAS

NUCLEAR ATTACK PLANNING BASE - 1990



FEMA2/US/USSR-008

Figure 2

It should be pointed out that an air burst nuclear weapon produces just as much radioactive material as a surface burst, but because this is associated with the residues of the weapon itself, the radioactive particles are carried high into the atmosphere where most of their energy is expended harmlessly while drifting around the world. The radioactivity created in a surface burst is associated with the larger particles of crater material, which fall more rapidly to the ground before much radioactive decay has taken place.

Another uncertainty in assessing the current fallout radiation threat lies in the changes in the Soviet missile force. The single warheads on Soviet missiles have been largely replaced by multiple warheads. When this happens, the total explosive power (yield) carried by the missile is reduced substantially. For example, if a heavy rocket originally fitted with a single 25-megaton warhead is retrofitted with, say, 10 MIRVs, the total yield of the ten smaller warheads will be only about 8 megatons. The amount of radioactive material produced is thus greatly reduced, providing the fraction of the explosive yield caused by fission (as opposed to fusion) remains the same. Some fission is required to initiate the fusion process in all thermonuclear weapons but there is a tendency for the fission-fusion ratio to increase as the yield is reduced. This may compensate somewhat for the anticipated reduction in total yield in any future attack.

Together with the inherent uncertainties of wind and weather that also affect the direction and extent of fallout, the foregoing uncertainties suggest that earlier estimates of the consequences of nuclear attack that featured mostly multi-megaton ground-bursts probably overstate the extent of lethal radiation. On the other hand, an all-air-burst attack is also unlikely. Hence, use of best available shelter will continue to represent good civil defense and plans for recovery must continue to include measures to deal with the potential delays caused by residual fallout radiation.

Despite its relatively short history of research, relatively more is known about nuclear radiation and its effects on humans, animals, and crops than most of the other effects of nuclear attack. But scientists inadvertently keep complicating the task of communicating with emergency planners and operators. In the beginning there were "roentgens," the measure of ionization in air, which is what civil defense instruments measure. To this term was added "rad," "rep," and "rem," important to scientific exactitude but of little concern in attack preparedness. Now, an international body has standardized scientific usage. One consequence is the introduction of a new unit, the Gray (Gy) as the measure of absorbed dose, with 1 Gray equal to 100 rads. Technical papers are now using these "SI" units and the Gray will be encountered in some of the quotations later on. Such terms are unlikely to replace those in civil defense use today.

As for radiation exposure, the National Council on Radiation Protection and Measurements (NCRP) after a comprehensive review of all available data, recommended a "penalty table" for use in civil defense [9]:

	Accumulated radiation exposure (R) in any period of		
	One Week	One Month	Four Months
Medical care will be needed by:			
NONE	150	200	300
SOME (5 percent may die)	250	350	500
MOST (50 percent may die)	450	600	—

According to this table, the median lethal exposure is 450 roentgens (R) for fallout radiation received in a short period of time (less than one week). Periodically, medical persons write papers alleging that the true value is much lower than that accepted by the NCRP.

TRAPPED OR NO MEDICAL AID

Some survivors in the damaged area around nuclear explosions may be trapped in debris or critically injured. If rescued and treated promptly for wounds, these persons who would otherwise die might be saved. Little or no rescue or field treatment of trauma occurred at Hiroshima and Nagasaki and, since official estimates of survival are based on the Japanese experience, the survival odds in the introduction assume neither rescue nor medical aid.

The potential lack of medical doctors after a nuclear attack has received a great deal of publicity, mainly because of the efforts of a group perhaps unaware that survival odds already account for lack of medical aid. How many additional survivors could be expected as the result of effective rescue or medical aid is a matter of speculation. One cue may be the one or two percent of those at risk who were fatalities in wartime mass fires other than firestorms. Many of these may have been entrapped or rendered non-ambulatory by injury in the combined high-explosive and incendiary air raids. The authoritative Effects of Nuclear Weapons [10], which does not attempt to estimate fire deaths, notes that the relatively low incidence of serious mechanical injuries among survivors might be accounted for by entrapment in the fire area.

In the 1950s, when low-yield air bursts were the main consideration, organization and training of rescue and medical field units was given considerable emphasis. The advent of the multi-megaton, fallout-producing thermonuclear weapons put an end to these programs. The recognition that most of the smaller warheads of today may be air bursts over specific military or industrial targets, as well as the ongoing organization and training of rescue and medical units in preparation for a catastrophic earthquake or other major peacetime disaster, suggest that current assumptions of no rescue or medical aid may be overly pessimistic.

Even if the number of additional survivors that could be expected from rescue and medical aid may prove small, lifesaving is not the only measure of worth. The two activities act together to ease the pain and suffering of survivors, a humanitarian value that would assure much ad hoc effort in damaged areas where lethal fallout radiation does not preclude action. Further, postattack recovery is likely to be facilitated to the extent that effective surgical and other medical procedures allow more of the injured to become active contributors in the surviving work force.

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INADEQUATE LIFE SUPPORT

Among the most urgent necessities of life for the survivors are drinking water, food, and shelter from the elements. In addition, there are other important aspects of life support that will demand early action by surviving elected officials and emergency service professionals. These include early restoration of communications, electric power, and public health measures.

Leadership, in the person of elected officials and their emergency management staffs, can be expected to survive at least as well as the general population. We say "at least as well" because a long standing program of construction of protected emergency operating centers (EOCs) has resulted in the creation of many hundreds of facilities in which local authorities would be likely to remain effective if their constituents were among the survivors.

The first steps on the road to postattack recovery are most likely to occur in areas that are substantially free from attack effects. These are usually understood to be mainly rural areas but may include some cities of substantial size. A major uncertainty in this regard is whether the weapons were mainly air burst or mainly burst at the surface to produce fallout. In either event, there would be many unaffected communities where recovery can start as soon as it was judged that further attack was unlikely.

Virtually all activities needed to provide life support and health care to the surviving population would require sources of energy: electric power, gas, petroleum fuels, and the like. Of these, electric power is the energy source of widest immediate use. Electric power would be needed for the all-important communications among civil defense forces and between the government and the people. Except for limited use of gravity systems, water service could not be restored nor could sewage disposal become effective without an electric power supply.

Recovery activities would largely be limited to daylight hours unless building and street lighting were available. Treatment of injured survivors also would be difficult unless electric power was available. One special problem of immediate significance in the postattack period is the fate of food, mainly meat, in cold storage and freezers at wholesale, retail, and household levels. These supplies of protein would be of great nutritional value to the survivors. However, unless power for refrigeration were available within about a week of power loss, these potentially valuable supplies would become organic wastes constituting a potential health hazard until collected and disposed of.

Electric power would be needed to operate fuel pumps so that public safety vehicles, repair vehicles, and essential transport could continue to operate. Many of the tools and equipment used in the repair of communications, water, sewage, and other key facilities also require electric power. Finally, electric power would be needed in undamaged industrial plants where essential survival items such as pharmaceuticals must be produced.

Widespread loss of electric power may be expected as the result of the electromagnetic pulse (EMP) from nuclear bursts, particularly bursts at high altitude that can affect large areas. Energy from EMP can be collected by metallic objects causing power surges that can damage electrical and electronic equipment. The items that are most sensitive are solid-state electronic components, such as microchips and transistors. The larger items of electrical equipment, such as transformers and motors, are much less sensitive to EMP. Electric power utilities have not done much to protect their system controls from EMP and hence power may fail from operational upset. Loss of power is unlikely to be corrected within days after attack although power company crews are well organized to deal with the consequences of lightning strikes, which are similar to EMP. The magnitude of the early repair effort could be managed by the establishment of priorities for repair of systems in otherwise functional areas.

Radio broadcast systems are especially vulnerable to EMP due to the size of the collectors in the system (antennas and power lines) and the vulnerability of the transistorized circuits. There are, however, many known ways of protecting radio broadcast systems, including shielding of sensitive components, introduction of arrestors to block transmission of surges through long line collectors, and disconnecting sensitive units. Emergency generators also would be required to provide for operation in the event of electrical power failure during the early period after an attack. A substantial number of commercial broadcast stations are now equipped with generators and protected against EMP. But public safety base stations are generally not so equipped. Mobile units and portable radios are generally not sensitive to EMP.

The vulnerability of telephone lines to EMP is less than that of radio broadcast systems. American telephone companies have taken measures to protect long lines from effects of nuclear attack, including EMP. The rugged and conservative design of local exchanges and their lack of dependence on commercial power make it likely that they also would survive EMP effects with a minimum of disruption. Thus, early communications among emergency units may be by telephone and mobile-to-mobile radio. Communications with the public generally would require broadcast radio operation or mobile bull horns.

People who must remain in fallout shelters because of continuing high fallout radiation levels in the outside environment may run out of food and water. Unless adequate supplies of water for drinking are maintained, severe consequences will be experienced within a day or two. People would either leave the shelter in search of water, thereby exposing themselves to excessive radiation doses, or become ill from dehydration. If water is completely denied, deaths would begin to occur in a few days. Emergency forces must be organized to direct survivors in fallout areas to areas of lower risk (remedial movement) or to resupply the shelter areas.

It is obvious that the more food and water stored so as to be directly accessible, the better. It was for this reason that the national food and water stockpiling program was carried out in the 1960s. With such a program, the need for rapid reestablishment of food, water, and power is less critical. Those supplies are no longer in place. Local authorities are expected to have plans to place local stocks in shelters or instruct the public on what to take to shelter.

Food supplies are less critical than water. Most people could survive a period of several weeks on a severely limited amount of nourishment. The most important consequence could be hunger-motivated pressure to emerge prematurely from shelter in search of additional food supplies. As is the case with almost any kind of severe stress, the early victims would be those with the least resilience—the very young, the very old, and the infirm.

Radiological contamination of food and water would not be a serious complicating factor. With simple precautions people could avoid use of food and water containing excessive contamination levels. Most people would not be affected to any significant extent.

For the longer term, the provision of food and water would have to be undertaken in an organized way. Most communities are situated on water courses that provide ample supplies of drinking water after simple treatment. Food and allied supplies in the wholesale warehouses are adequate for several months if distributed on a regional basis.

In some localities, and under some conditions, the shortages could be severe. Extremely hot or cold weather, radiological contamination, and disrupted transportation and communications systems could have a serious impact. The example of Leningrad during the German siege of World War II provides perspective. Leningrad withstood this siege for nearly two and one-half years with almost no outside source of supply. No city in the United States experiences the severity of weather that wintertime brings to Leningrad. Yet as Harrison Salisbury has said [8]: "Leningrad had survived without light, without heat, without bread, without water."

In the aftermath of nuclear attack, survivors confronted with extensive shortages could do what the citizens of Leningrad could not do—leave. In damaged areas, far less serious conditions are only a few miles away. In heavy fallout areas, safe transit to areas of much lower hazard is only a matter of an hour or two if automotive transport is available. Therefore, even though communications may be limited for many days, survivors would stream out of the more severely affected areas over a period of time to find means of life support.

In areas receiving substantial amounts of fallout, radiation could affect agricultural production by damaging crops and farm animals. High levels of radiation can damage some agricultural crops, but only during a small part of the growth cycle. Since crops over the entire U.S. are generally at different stages of growth, only a small fraction of the total crops would be vulnerable to radiation damage at the time of attack. Concerns about temporary changes in rainfall patterns noted later suggest other threats to agriculture in the first crop year. Fallout material that lands on plants can be washed off and the edible parts eaten without serious risk. It is also important to note that the U.S. grows a much greater amount of food crops than the U.S. population needs in any one year. This surplus production, together with the large quantity of stored wheat and other grains, would provide adequate supplies during the first year after attack. Unfortunately, these bountiful stocks of food are stored in or near the producing areas in the midwest. Within a month after attack, surviving State and Federal agricultural officials would have to organize the transport of grains and other stocks of food to the survivors throughout the country.

There are other aspects of life support following a nuclear attack that are nearly equal in importance to the availability of drinking water and food. The most important of these are public health measures and protection against the elements. Adequate sanitation appears to be the critical public health need. An early recovery milestone would be to regain the use of flush toilets, allow bathing and personal hygiene, assure the cleansing of cooking utensils, and provide for the laundering of clothes. These measures would help greatly in preventing the spread of disease so often predicted as a barrier to recovery. Waterworks and sewage disposal plants thus rank just below electric power systems on the list of critical facilities.

Protection against the elements requires housing, clothing, and depending on the season, heating supplies. Emergency housing is important both for health reasons and for morale. Just as the opportunity to take a bath would be likely to mark an early post-attack milestone, so would the opportunity to sleep in a bed or cot with some degree of privacy. Although much housing is likely to be destroyed or damaged, surviving housing units are relatively roomy compared to most other countries of the world. A measure of housing adequacy would likely be the criterion of 40 square feet per person used following peacetime disasters.

Providing adequate life support for the survivors undoubtedly would be the critical task for local governments and their emergency management staffs. Where this task is accomplished successfully, a basis would exist for surmounting all of the remaining barriers to recovery.

CLIMATE MODIFICATION

The provision of adequate life support to the survivors of a nuclear attack is not at all a certainty, as the foregoing discussion has indicated. Yet it is not sufficiently unlikely to satisfy those who believe (or want to believe) that a nuclear war is not survivable. Accordingly, science-fiction writers, Sunday supplement editors, and some scientists have speculated about dramatic and potentially disastrous alterations of the natural environment, particularly the climate. Predictions have ranged the whole spectrum from a "new Ice Age" to the melting of the polar ice caps, thereby flooding the great coastal cities of the world. None of these conjectures appears to be solidly based on fact.

In the 1970s, attention was focused on potential damage to the ozone layer high in the earth's stratosphere, which shields life on earth from harmful ultraviolet radiation from the sun. Exposure to normal summer sunlight can cause skin cancer (a highly curable cancer), sunburn, and cataracts. Sunscreen creams and special sunglasses are currently used to minimize these effects. A 1975 study by the National Academy of Sciences [11] concluded the predicted depletion of the ozone layer would not be catastrophic. According to a 1985 study by the National Academy of Sciences [12], the detonation of some 80 percent of the world's strategic nuclear stockpile might reduce the ozone layer by about 50 percent by the end of one year, with half the loss restored by natural processes in two to three years. Ultraviolet radiation from the sun would increase to about three times its normal rate at mid-latitudes, causing an estimated 10-percent increase in skin cancer, assuming the survivors took no precautions. By way of comparison, this increase in ultraviolet radiation would be only about one-tenth the increase now experienced by living in Dallas, Texas, rather than Minneapolis, Minnesota.

These estimates of ozone depletion resulting from a nuclear war contain great uncertainties and generally tend to err on the side of overestimating rather than underestimating the problem. After a review of the various causes of error, the most recent report of the National Adademy of Sciences [12] concludes:

> "All of these factors combine to make any rational estimate of error limits in ozone depletion a virtual impossibility. The numbers calculated here, though given to two figures, should be viewed as plausible values that are based upon the best methods available to the committee."

The most recent attempt to project a "doomsday" outcome of nuclear war has been labeled "Nuclear Winter." In 1982, the Swedish environmental journal *Ambio* offered a special issue on the broad range of environmental consequences of nuclear war. The preamble to that special issue stated:

> "There is a considerable fear for the continued existence of man on earth; in the end, that fear, as it gains momentum, may well lead to more effective means for the prevention of a nuclear catastrophe."

One of the articles in the *Ambio* special issue, "Twilight at Noon," by Drs. Paul Crutzen and Stephen Birks, was seized upon as the basis for the Nuclear Winter thesis. Crutzen and Birks had claimed that the fires created in a large-scale nuclear war would create enough smoke lifted into the stratosphere to block out as much as 99 percent of the sun's light for several months, resulting in a period of darkness and cold.

Led by Cornell University astrophysicist Carl Sagan, some American scientists quickly made additional computer runs using a single one-dimensional model of the atmosphere. Instead of a planet with continents and oceans, the model postulated a featureless, bone-dry sphere. Instead of nights and days, it used 24 hours of sunlight at one-third strength everywhere. Instead of the highly variable and often smoldering smoke emissions anticipated by fire researchers, the model assumed a ten-mile thick soot cloud created instantly. The result was a maximum summertime temperature drop of up to 65 degrees Fahrenheit, forecasting a most serious impact on people, animals, and plants. Starting with a 1983 conference in Washington, D.C., and a Sagan article in *Parade* magazine, the nuclear winter hypothesis has received wide publicity.

How plausible or likely are these predictions? More complex global calculations have given average temperature drops that are one-half to one-third those initially publicized. The effect of the oceans was responsible for a 200 percent error. Even so, a temperature drop of 20° Celsius (36° F) could have a serious impact. In 1986, Starley Thompson and Stephen Schneider, scientists at the National Center for

Atmospheric Research (NCAR), published new results and declared, "On scientific grounds the global apocalyptic conclusions of the initial nuclear winter hypothesis can now be relegated to a vanishingly low level of probability." [13] They had used their powerful CRAY I computer to process a global model that was fully three-dimensional and had been very successful in reproducing the main features of normal climate and weather, results that give confidence in the model's realism. Instead of a "nuclear winter," Thompson and Schneider expect a nuclear cool spell, perhaps 20° Fahrenheit lower than normal for a month during the Northern Hemisphere summer.

These results have not been given the publicity of the original doomsday predictions. Said Dr. Walter Orr Roberts, distinguished atmospheric physicist:

> "To me the NCAR results look convincing. They will be contested widely, which is a proper and necessary part of any new scientific result. But when the dust and smoke settles, I suspect we will find ourselves facing the moral issue of whether the blast destruction and radioactive fallout of a nuclear war are a sufficient deterrent—without the added threat of an equal or greater number of deaths from the cold and dark of a nuclear winter." [14]

Agriculture now appears to be the human activity most vulnerable to climatic changes resulting from nuclear attack. An average reduction in temperature of even 20° Fahrenheit in the summer might be made up of actual temperatures both higher and lower than 20° below normal. The lower ones can approach freezing in the interior of the continent. Moreover, reductions in rainfall have been predicted that may be more serious than temperature changes [15]. A 50 or 75 percent reduction in rainfall for two months during the growing season could seriously affect crop yields in unirrigated farm lands. Thus, the surplus grains stored in the midwest could assume even greater importance.

EPIDEMICS AND DISEASES

In contrast to the more imaginative doomsday theories of climatic catastrophe, the possibility of life-threatening epidemics of disease in the months following a nuclear attack is an all too real hurdle facing the survivors on the road to postattack recovery. There are a number of potential contributors to an increased incidence of epidemics and diseases in a post-nuclear war society. They include:

(a) Many sanitation facilities and waterworks could be destroyed, damaged, or disrupted in urbanized areas. Elsewhere, failure of electric power could disrupt water and sewer systems in small cities and towns for a considerable period of time.

(b) Loss of personnel and disorganization in public health agencies could result in the lowering of public health practices and disease surveillance systems. Higher than normal patient-to-doctor ratios also could contribute to inadequate prevention and treatment.

(c) There could be inadequate supplies of preventive, prophylactic, or therapeutic products, such as vaccines, antitoxins, and antibiotics, as well as other necessities for disease control, in the face of production losses and distribution problems.

(d) Survivors of nuclear war may have higher susceptibility to infection because of exposure to nuclear radiation. Other consequences of attack that have been suggested as contributing to lowered immune response are enhanced ultraviolet light if the ozone layer is damaged, burns and injuries, malnutrition, and psychological stress. Sufficient clinical data to establish quantitatively the seriousness of this immune problem are not available.

There are a few factors that counterbalance the negative aspects above and that would serve to limit or prevent the spread of epidemics or the increase of debilitating diseases. They include:

(a) Most of the great epidemic diseases of the past—cholera, smallpox, typhus, and yellow fever—do not exist in the United States. Smallpox is believed to have been completely eradicated from the face of the earth. Thus, there are few if any reservoirs from which these epidemics could arise and spread.

(b) Mobility of the surviving population—and hence exposure to communicable diseases—would be severely constrained during the early stages of societal recovery as fuel and transportation assets were devoted to priority needs, such as the transport and distribution of food and other essentials.

(c) Sources of broad spectrum antibiotics may be capable of being created or augmented in a short period of time by conversion of some fermentation facilities and by importing from U.S.-owned facilities in Mexico. Veterinary-grade antibiotics, which are produced and stored in copious quantities, could be used by humans in an emergency.

(d) Perhaps *knowledge* is the single most important factor that would serve to mitigate the effects of epidemics and diseases. Knowledge will survive the attack. The great discoveries of Pasteur and Lister do not have to be repeated. We know that questionable water has to be boiled and that food must be well cooked. We know the importance of waste disposal and other sanitary measures. Moreover, simple guidance on those preventive measures is widely available.

As noted earlier, providing adequate life support for the survivors in the form of drinking water, food, shelter, personal cleanliness, and sanitation is the first big hurdle that postwar leadership must strive to overcome. If these efforts were successful, the spectre of pestilence and disease stalking the land in the aftermath of nuclear war would be a greatly diminished possibility. In contrast to attack injuries, where the availability of doctors may be the limiting factor in effective treatment, the critical element in treatment of communicable diseases appears to be the adequacy of medical supplies, particularly drugs and medicine.

Groups opposed to civil defense have mainly concentrated on arguing the utter futility of effective treatment of attack injuries, a position that although not necessarily true is assumed in the survival odds discussed in the introduction. Recently, Greer and Rifkin [16] speculated that there would be major immunological damage to the survivors through a variety of causes: fallout radiation, nuclear winter effects, ultraviolet radiation, attack injuries, psychological stress, and malnutrition. In their conclusion, Greer and Rifkin made the following statement: "Patients with AIDS show depression of T lymphocyte populations and reduced helper-to-suppressor T lymphocyte ratios similar to those anticipated in millions of nuclear war survivors." This statement was seized upon by the Institute of Medicine, an offshoot of the National Academy of Sciences, in a press release headed: "Nuclear war survivors likely to suffer from AIDS-like syndromes."

Comparing the possible immunological depression in nuclear war survivors to AIDS is particularly obnoxious because it misleads the public into thinking that radiation sickness is contagious and invariably fatal. Quite the opposite is true. AIDS (Acquired Immune Deficiency Syndrome) is caused by a disease organism, thought to be a virus, that continues to attack the body's immune system until death. Nuclear radiation, whether attack related or used in medical treatment, also depresses the immune system, but only temporarily. Unless lethally irradiated, the body rapidly repairs itself from such injury. There is no communicable disease organism involved.

How many survivors could be affected by radiation sickness but not fatally depends on many factors, including whether air bursts or fallout-producing surface bursts are used in the attack and the quality of fallout shelter available to the population. The survival odds discussed in the introduction indicate that not more than 1 in 6 or 1 in 4 are either injured or ill. The fraction suffering both injury and sickness is a much smaller number. These people are predicted to be alive at least a month after attack and thus are unlikely to become fatalities.

Greer and Rifkin's other synergistic effects are not convincing. For example, any possible damage to the human immune system from enhanced ultraviolet radiation could only occur many months to years after the war when the effects of radiation injury had been repaired. Moreover, the countermeasures to ultraviolet radiation, such as proper clothing and staying out of the mid-day sun, should be readily achievable. The number of survivors who would be exposed to all of the impacts postulated by Greer and Rifkin is vanishingly small.

ECONOMIC RECOVERY

Some observers believe that the great destruction resulting from nuclear attack would inevitably result in economic chaos and would prevent meaningful economic recovery. A more careful study of the evidence indicates that the essential resources for economic recovery would survive the attack and that economic recovery would be possible given proper management of resources and continued support of the population at large.

Experience following World War II indicates that rapid economic recovery can follow wartime devastation. Simon Kuznets, a U.S. Nobel Prize-winning economist, studied the economic recovery of European nations following World War II [17]. He looked at national economic statistics in terms such as gross national product and other indicators of overall economic performance. While he found recovery rates to be quite variable, nearly all nations had within five years reached a higher level of economic activity than in the prewar period.

The case of the two Germanys helps to explain some of the variability among nations. Both nations suffered devastating economic and political damage. West Germany had within five years achieved a level of economic activity of 117% of the prewar level, while East Germany achieved a level of 73% during the same period. West Germany had the advantage of economic and political support from the United States, including the Marshall Plan. East Germany suffered under repressive political and economic measures imposed by the Soviet Union, including expropriation of industrial plants as war reparations. Nonetheless, East Germany did eventually recovery to prewar levels.

Other nations in the Soviet bloc (including the Soviet Union) which did not receive Marshall Plan support also reached or exceeded prewar economic levels in the five-year period. The evidence thus indicates that given reasonably adequate political and economic institutions and policies, a nation can recover from heavy wartime devastation, and can do so in a surprisingly short time.

The level of physical damage in nuclear war could of course exceed that occurring in World War II (although the damage sustained in the Soviet Union and Germany might be comparable to that in nuclear war). Many defense critics picture a "moon landscape" over the entire United States, implying that every possible target would be attacked. Actually, the current estimated Soviet arsenal (about 12,000 warheads) is still not adequate to directly attack all significant U.S. targets. Counts of U.S. urban/industrial and military aim points show that there are at least two legitimate aim points for every warhead in the Soviet arsenal (assuming warheads of 1 MT yield or less). Also, it is likely that some targets (ICBM silos) would attract more than one attacking warhead to assure a high probability of damage.

The Soviet planner must therefore make choices as to what to attack. U.S. analysts who have studied this subject have reached the conclusion that Soviet targeting plans are designed to accomplish specific strategic objectives. Soviet doctrine calls for focusing attacks on high priority governmental and military targets. War-supporting industry is also included to the extent required to achieve a military victory. Thus, in all likelihood, a substantial part of the industrial plant of the U.S. would not be subjected to direct attack.

Perhaps the most publicized claims of defense critics derive from the nuclear explosion effects that can impact large regions of the country or the entire globe. These effects are judged by critics to invalidate any thoughts of an acceptable postwar economy or production system. Among the area and global effects are those mentioned earlier: mass fires, fallout radiation, and the "nuclear winter" hypothesis. Another effect that has aroused considerable concern is electromagnetic pulse (EMP), which can damage electrical and electronic equipment over large areas.

Mass fires would for the most part be restricted to areas of direct blast damage. While the required weather conditions for mass fires could exist in a few locations at the time of an attack, they would not exist everywhere at the same time. Also, most industrial areas are not as vulnerable to fire spread as forests or downtown areas of major cities because of the lower density of buildings, wider spacing of structures and other such factors that determine the likelihood of fire spread. People also can do much to reduce fire risks before and even after an attack. Thus major fire losses to industry outside blast damage areas are not inevitable or even likely.

Fallout radiation can affect industrial production by denying workers access to production facilities for a period of time until the radiation hazards naturally diminish. In a surface-burst attack, large areas of the United States could be subject to dangerous levels of radiation. In the absence of countermeasure actions, these radiation levels could deny entry to workers of some facilities for weeks to months. However, countermeasures such as firehosing contaminated surfaces (walls, driveways, etc.) have proved to be effective and such methods have been developed and tested. With the use of such measures, denial times could be reduced to a few days. In addition, if Soviet targeting following anticipated objectives, many industrial areas would experience quite low levels of fallout (see Figure 2).

The threat of "nuclear winter" has also received extensive publicity in the past few years. The smoke and dust created by the attack was supposed to cause dramatic temperature declines over the northern hemisphere. In the recent past, however, more careful studies have determined that the postattack conditions might now be better characterized as a "nuclear autumn." Such temperature declines would not be sufficient to cause a significant decrease in manufacturing and service activities. Agricultural production might be curtailed during the first postattack year; however, for reasons previously discussed, this effect would not jeopardize the population or the economy.

Electrical power systems are critical to early industrial recovery and production, so that the possibility of widespread damage to these systems from EMP is a matter of major concern. A high altitude burst could induce surges throughout the entire system. Moreover, lightning arrestors are unlikely to provide significant protection from these EMP surges. Major components of the system, such as transformers and generator units, are likely to withstand these surges in most instances. However, other equipment may not. Insulators can be damaged and circuit breakers can be locked out. System controls, which are increasingly solid state, would be damaged and could also cause the disabling of some generating units. However, due to their random locations, inadvertent shielding and other factors, not all of the sensitive components in a system would be damaged by EMP.

Even with a program of component protection, it must be anticipated that electric power systems will be inoperative immediately after attack because of operational upset. Loss of power is likely to be corrected within days or weeks after the attack, which would not appreciably delay the resumption of production in most areas and industries. The magnitude of the early repair effort could be coped with by the establishment of priorities for repair of systems. For example, power systems or lines supporting industrial areas that are heavily damaged need not be repaired until industrial capacity is rebuilt in the damaged areas. Priorities will allow concentration of manpower, repair equipment, and inventories of system components on the systems that need to resume operations at the earliest times.

While a strong case can be made for the survival of a large fraction of the industrial capacity in the United States, the same cannot be said for some of the individual components (e.g., petroleum refining, military end-item production, electrical and nonelectrical motors, industrial instruments, and others). As mentioned before, the Soviets might selectively attack certain types (sectors) of industry. Also, the facilities in some industrial sectors tend to be more concentrated in likely target areas than do other sectors and thus more subject to damage. One possible consequence is that a given sector may not be able to produce up to maximum capacity because of a shortage of steel, and so forth.

How serious a problem can this be? It depends to some degree on how far out of balance the entire industrial structure happens to be. To study this problem, economic models have been developed that incorporate data on the inputs and outputs among industrial sectors (inter-industry relationships). The models also consider the consumption requirements of end users (government and the population at large). For most attack scenarios examined, these models show that even with these imbalances, industry can produce more than enough to meet minimal consumption by end users as well as inter-industry consumption.

Production above that required for end user consumption (final demand) may be used for investment in new industrial facilities that will over time restore production capacity of the entire system to prewar levels and beyond. Some economic models also include consideration of investment. Using primarily historical construction time and cost data, these models predict the rate of industrial recovery over a period of years. Generally, results are in agreement with World War II experience. They suggest that recovery could occur to prewar levels within perhaps five to ten years.

There are, however, still uncertainties in these projections. If the Soviets concentrate on just a few industrial sectors they might drive down the remaining capacity below that needed to meet even minimal final consumption, let alone inter-industry needs. The economic models are really not designed to handle this problem, so we must look elsewhere for an answer. The models are based largely on historical data on what industries need in the way of inputs and what the end user consumes. This data only reflects past peacetime economic preferences; by no means does it represent the range of technological possibilities. The substitution of one product for another is one approach that has proved successful in prior wars. The Germans during World War II, for instance, reduced the amounts of scarce metals in their locomotives and even their artillery and kept on producing and fighting effectively for years thereafter. Reduction in end user consumption also has proved very successful both in peacetime and in wartime. The import of products we need is currently a way of life in the U.S. and may be possible to some extent in the postwar world, using some of our vast stores of food in exchange.

Adequate production and economic recovery depend on more than the survival of the physical plant and the labor force. Also required is the satisfactory functioning of political and economic institutions and policies and the continuing support of the population at large. The sensitivity of economic recovery to institutional and policy considerations has been studied using various economic models. These models attempt to estimate the impact of policies on the willingness of industry to produce and invest and the willingness of the labor force to work. Depending upon the assumptions made, the results can show a slowing or stalling of the economic recovery process. Other results show that correct selection of policies and their impact on the system, the results do tend to demonstrate how important these factors are likely to be. In general, specific economic recovery projections should be taken with a grain of salt. After all, economists find it difficult to predict the performance of the undamaged peacetime economy.

Widespread concern has been expressed by many economists and financial experts about the ability of the governent to carry out all of its resource management and economic stabilization functions. It has been pointed out that the government in all likelihood will lack the organization, policies, and information to manage the economy in detail. One example cited is the likely inability of the government to set reasonable prices on commodities in the postattack period due to lack of information on damage-caused shortages. Such price maladjustments could result in unwillingness of industries to produce and unwillingness of labor to work for unrealistic wages.

A variety of approaches has been suggested for handling these problems. The majority of approaches involve the reintroduction of market forces into the economic decision making process. While many of these approaches have merit, they have not been studied in adequate detail nor have they been included as part of official government guidance. In this latter regard, any detailed approach to managing the economy will only be officially adopted in the postattack period when the characteristics of the economic situation are apparent and a political consensus can be reached.

In the event of a massive nuclear exchange between the United States and the Soviet Union, the stark question of how to meet the basic subsistence needs of the survivors must be answered before the economic recovery can commence. This question must be dealt with mainly at the local and regional level. If it were met successfully for a significant period of time for most of the survivors, the process of economic recovery would be eased greatly. The Federal government could assist by maintaining private property rights, promoting the use of money to avoid inefficient barter arrangements, providing for appropriate price expectations, and reestablishing traditional operations in the provision of important goods and services. It appears that the physical resources for economic recovery are likely to survive. The challenge will lie in effective management and survivor morale.

ECOLOGICAL EFFECTS

There is still considerable uncertainty concerning the ecological consequences of nuclear war. Various ecological catastrophes have been postulated to follow a nuclear war, such as wildland fires, erosion, flooding, pest outbreaks, epidemic diseases, and the like. Careful studies of these possibilities [18][19] have concluded that longtime ecological effects would not be severe enough to prohibit or delay seriously recovery from nuclear attack.

Speculation that attack effects might cause drastic upsets in the "balance of nature" have in common two erroneous assumptions. The first is that changes that exist for a relatively short time can induce permanent ecological damage. This is not borne out by experience. For example, some of the atolls in the South Pacific have experienced repeated direct nuclear effects and fallout from weapons tests comparable to the worst that could occur in a nuclear war; yet, the tropical ecosystem has survived and recovered.

Long-term consequences require continuous pressure over centuries of time, of which the impact of human habitation is the outstanding example. People have cut the forests, tilled the land, irrigated deserts, dammed and polluted streams, overgrazed hillsides, flooded valleys, eliminated species of plants and animals, and introduced others. Man has radically changed the face of this continent. If he should suddenly disappear, it seems overwhelmingly probable that there would be a gradual return to older ecological balances.

The second fallacy of "doomsday" ecological forecasts is to assume that the impact occurs everywhere. Jonathan Schell, in his book, *The Fate of the Earth,* entitled his first chapter, "A Republic of Insects and Grasses." Because insect predators such as birds are known to be more vulnerable to fallout radiation than insects, he came to the conclusion that the insects would inherit the earth. But heavy fallout areas are rarely more than 20 to 60 miles from areas with low levels of fallout. Since the population of the various species is controlled largely by the available food supply, there would be an invasion of predators into the temporarily insect-rich areas.

On the other hand, there could be short-term ecological changes that could require governmental action in the early postwar years. Drought has been suggested [15] to result from changes in convective rain-producing air currents caused by smoke and dust. This drought could injure agricultural crops and increase the fire hazard in forests. On the other hand, worldwide fallout could increase rainfall over normal amounts by acting as a "cloud-seeding" mechanism. This would have adverse effects in flood plain areas but would delay the onset of fire hazard from radiation-killed trees in areas of moderate-to-heavy fallout. Failure to log dead trees (which would be useful for housing and firewood) would sooner or later result in forest fires and erosion. Over a period of several years, silting could destroy the usefulness of reservoirs and irrigation works. Finally, degraded sanitation and public health measures in damaged urban areas could create conditions favorable to outbreaks of disease-carrying insect and rodent populations. All these consequences, however, are subject to human planning, intervention, and control.

LATE RADIATION EFFECTS

Longer-term radiation effects would take their toll in the years following a nuclear war. They include thyroid damage, bone cancer, leukemia, and other forms of cancer of the types that occur today. Radiation does not induce new forms of cancer, it increases the frequency of occurrence of those which result from other causes. A physician examining cancer patients in the postwar world would not be able to discriminate between those caused by the fallout radiation and those which would have occurred anyway. The radiation exposure would increase the incidence of various types of cancer so that the net effect would be observable on a statistical basis. There is no danger that the increased incidence would be great enough to pose a threat to the survival of the society.

During a symposium held in 1969 [20], the chairman of the National Academy of Sciences Division of Medical Science summarized such long-term biological effects of a nuclear attack by stating:

> "20,000 additional cases per year of leukemia during the first 15 to 20 years postattack followed by an equal number of miscellaneous cancers, added to the normal incidence in the population for the next 30 to 50 years, constitute the upper limited case. They would be an <u>unimportant</u> social, economic and psychological burden on the surviving population." (Underlining added for emphasis)

This estimate was based on a surviving population of 100 million persons who had an average exposure of 100 roentgens, a realistic possibility. If (because of inefficient use of fallout shelter or careless exposure to fallout radiation afterward) the average exposure were higher than 100 roentgens, the expected consequences would be correspondingly higher.

Perspective is provided by comparing the death expectancy among the survivors due to late radiation effects with the death expectancy from various causes in today's society. In the comparison it is assumed all the fallout radiation-induced leukemias and other cancers among the survivors result in death, which is extreme and not to be expected.

If 40,000 people die each year from leukemia and other cancers following a nuclear attack in a society of 100 million population, the average chance per individual of dying from these causes in a single year is 4 in 10,000. This 4 in 10,000 risk of death is faced by the average individual in today's society who:

- — Smokes 300 cigarettes, or
- — Travels 160,000 miles by commercial air, or
- — Travels 24,000 miles by car, or
- — Spends 10 hours a day rock climbing, or
- — Lives 5 and one-half days after his 60th birthday.

A 1985 review of the potential late radiation effects has been performed by Bochkov and Oftedal [21]. Their conclusions were:

> "In summary, a general nuclear war would presumably expose populations of industrial and densely populated areas around the world to levels not less than 1.0 Gy (100 rad). The rest of the world would be exposed to delayed fallout. Based on the explosive force of 10,000 Mt, survival in the target areas would be about 50 percent. It might be expected that there would be 100 million survivors in each of the target areas of North America, Western Europe, the USSR and various scattered smaller areas. About 400 million survivors would be irradiated with doses leading to a 17 percent increase in the present cancer incidence, from 15 percent to about 18 percent. This means that about 12 million cases of cancer due to radiation would arise in target areas. In the rest of the world an increase of about 1 percent from 15 percent to 15.2 percent might lead to some 7 million extra cases. Cancer would thus add to the suffering of the postwar world."

These authors also point out that because most cancer deaths occur among the elderly, the effect of a 17 percent increase in cancer mortality "would not have a marked effect on the average life span."

GENETIC DAMAGE

In common with late-radiation and ecological effects of nuclear war, the genetic effects of radiation are widely misunderstood and consequently feared. The specter of a vast increase in congenital defects among our descendants is awesome. Perspective is hard to develop partly because any threat to our children is so laden with emotion.

But a great deal is known about the genetic effects of radiation. Dr. H. J. Muller, an American geneticist, received a Nobel Prize for this work in radiation genetics. He established that gene mutations produced by ionizing radiation are not different in their effect from the mutations produced by other agents.

Thus, any nuclear war-produced genetic damage would not be manifested in unfamiliar ways, such as the birth of two-headed monsters. Rather there might be a statistical increase in the number of the various types of genetic-related disabilities that occur in the world today.

Extensive laboratory and field studies have been undertaken. The latter include studies of the survivors of Hiroshima and Nagasaki. Another approach is the doubling dose method, in which estimates of radiation effects in humans are based on the spontaneous mutation rate seen in humans and in experimental animals (usually mice) and on the dose needed to double the rate in the experimental animal.

According to Oftedal [22] writing in 1985,

> "In Hiroshima/Nagasaki, it has not been possible to demonstrate genetic effects in children born to parents, one or both of whom were exposed to bomb radiation. The question may be discussed whether the effect might be too small to be registered, or if circumstances limit the possibility of insight, or if the findings really demonstrate that humans are less sensitive to genetic harm from radiation than are, for example, laboratory mice."

In other words, the doubling dose method would predict significant genetic injury in the children of Hiroshima/Nagasaki survivors that has not been found. Thus, even though some radiation-induced genetic effects may become apparent in generations following a nuclear war, these consequences would not threaten the survival of society or impede the progress of recovery.

SUMMARY AND CONCLUSIONS

On the question of whether the United States would recover following a massive nuclear attack, the jury is still out—and most probably always will be. Everyone hopes and most people believe the question will remain in the abstract. The probability of nuclear war seems very remote, and we will never know for sure whether recovery is possible unless nuclear war actually occurs.

No nation can realistically hope to be better off after a nuclear exchange than it was before. One superpower might iunflict more damage on the other than it sustained itself, but any such "victory" would be a Pyrrhic one.

The reasons for avoiding nuclear war are very strong. They include:

- Prospects of losing a major fraction of the population.
- Prospects of losing an even larger fraction of industry.
- Prospects of facing a difficult and uncharted road to recovery involving the hazards and obstacles previously discussed.

Does this assure that nuclear war will never occur? Unfortunately, it does not.

The basic justification for civil defense is very simple. It would:

(1) reduce the number of lives and the amount of property that would be lost in a nuclear attack;
(2) help the survivors stay alive; and
(3) facilitate recovery.

If a nuclear war should occur, the United States would be far better off with an effective civil defense than without it.

The argument that a nuclear war could eliminate the human species or bring an end to civilization as we know it has not stood up when exposed to light of objective and scientific examination. New hypotheses for doom and disaster no doubt will arise and they also must be examined and evaluated. But no prudent society can afford to allow myths to continue to paralyze its preparedness programs.

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