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PROCEEDINGS OF THE SYMPOSIUM ON POSTATTACK RECOVERY FROM NUCLEAR WAR, HELD AT FORT MONROE, VIRGINIA, NOVEMBER 6-9, 1967

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Office of Civil Defense, and
Office of Emergency Planning

Postattack Recovery from Nuclear War

FOREWORD

Postattack-recovery problems were the subject of a symposium held at the Hotel Chamberlin, Fort Monroe, Virginia, 6-9 November 1967. It was jointly sponsored by the Office of Civil Defense, the Office of Emergency Planning, and the National Academy of Sciences through two of its advisory committees -- one on civil defense and one on emergency planning. A total of 36 papers were presented.

Among the major objectives of the symposium were (a) an interchange of information on the current state-of-knowledge in postattack-recovery research; (b) better understanding, within and among all the disciplines involved, of the problems of the recovery period including their relative magnitude and importance, their difficulty, and the research needed: (c) an opportunity for participants to learn something about the problems and programs in disciplines other than their own. The objectives are spelled out in the first paper of the symposium.

The papers presented are reproduced on the following pages, grouped according to the sessions in which they were delivered: introduction, sustenance, health, long-range effects, economics (two sessions), and societal vulnerabilities. A final session consisted of a summary statement by each session chairman.

In general, when speakers wished to give quantitative data on recovery, they used the results of two hypothetical attacks that are described in the second paper. Even if the United States suffered somewhat larger attacks, it appeared to be the consensus that crippling postattack problems of food, health, ecology, and long-term effects on man were unlikely. As for economic recovery, current studies concluded that recovery could be fairly rapid, provided there were no management problems. Thus it appeared that the most serious of the post-attack-recovery problems would be in management techniques -- for government as well as for the economy -- and in the motivations, the incentives, and the behavior of all levels of the population. There appeared to be more doubt and less optimism in these areas than in any of the others.

It is probably superfluous to point out that the views expressed by the speakers were not necessarily those of the agencies they represented nor of the symposium sponsors. Also, no attempt has been made to seek out official government-policy statements from the agencies bearing responsibility for post-attack-recovery planning and research. Statements of such a nature, as well as general comments on the symposium, may be addressed to any of the Planning Group members.

We repeat our thanks to speakers and session chairmen who gave so freely of their time, and without whose efforts nothing could have been accomplished. We also are taking this opportunity to express our gratitude to Mr. Waldo Dubberstein for the informative and entertaining talk he gave at the symposium dinner.

The Planning Group

F. Lloyd Eno - Office of Emergency Planning
Jack C. Greene - Office of Civil Defense
Richard Park - National Academy of Sciences
James C. Pettee - Office of Emergency Planning
Lauriston S. Taylor - National Academy of Sciences

April 1968

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INTRODUCTION

Lauriston S. Taylor, Chairman

THE OBJECTIVES OF THE SYMPOSIUM

Jack C. Greene
Office of Civil Defense

It is my purpose, on behalf of the symposium Planning Group, to elaborate a bit on the background of the symposium and its objectives.

The Planning Group engaged in a considerable amount of thinking and debate to evolve detailed concepts of what this symposium should try to accomplish and what it should encompass. I would like, as much as possible, to save you from a similar, fairly painful process by providing the results of our deliberations to you. Hopefully, then we will be off to a running start in addressing the problems at hand.

First of all, the focus here is on the post-nuclear-attack period -- a part of the problem that, relatively, has been slighted in most nuclear-attack studies, and for two good reasons: (1) understandably there has been preoccupation with the task of keeping people alive during and immediately after an attack (unless the people survive, postattack problems would be academic), and (2) there just were not many research data on post-nuclear attacks to talk from. Much conjecture had occurred, some of it interesting and some of it highly dramatic -- as, for example, Nevil Shute's <u>On the Beach</u> -- but there was very little information available based on serious research.

Whatever the explanation for the delay, the importance of coming to grips with the postattack part of the problem is receiving increased recognition. It is patently futile to save people from an attack, if it should occur, only to lose them afterward to starvation or disease. The failure to take preattack measures required to ameliorate the postattack conditions that could thwart national objectives would be fully as irresponsible as the failure to take the preattack measures required to mitigate the direct-attack effects. So, it is this area of the amelioration of postattack problems that we have set ourselves to address in the symposium.

In sharpening the definition of the symposium goals, the first technique of the Planning Group was to apply "the power of negative thinking." By agreement, three items were ruled out as explicit objectives:

First, we would not engage in a comprehensive or exhaustive analysis of the postattack consequences and the countermeasures required following a particular hypothetical attack, i.e., this was to be a symposium discussion of types of problems, not a more elaborate or differently focused civil-defense exercise -- an exercise such as CDEX-67, which many of us have been involved in during the last few days.

Second, we did not plan an evaluation of the current methods of doing research; or of damage-assessment procedures; or of particular computer programs for postattack economic analysis. This is not to say that useful criticism, leads, and ideas for improvements might not occur. We hope they will, but they are not programmed in, and whether or not they come depends largely on you.

Third, and finally, just as we had determined not to evaluate analytical procedures, we resolved also that development of doctrine or policy, or the formulation of recommended changes in existing plans and programs, were not proper goals. Doctrinal and policy changes do and should occur as a result of research and the acquisition of knowledge. Our concern here, however, is to elicit and elucidate the existing knowledge and to examine its implications so that the responsible, policy-making officials may become more fully familiar with the technical and scientific elements of their problems.

Having agreed on what was not wanted, it was easier to agree on what was; that is, what questions to address. The following statement -- the one that appears on your program -- resulted. It is short, and I will repeat it:

> "What is the current state-of-knowledge as to the magnitude, character, and tractability of the various categories of problems that would face a population surviving a nuclear attack? Can these problems be ordered in importance, i.e., which are crucial and which, if any, might be played down? Which require research and of what kind?"

It follows that neither a comprehensive nor exhaustive treatment of the various subjects is desirable and clearly would be impossible in the half day allotted to each session. Rather, the goal is consideration of each subject as a part of the total system for post-nuclear-attack recovery.

Let me illustrate this point by reference to the problem of keeping people alive and healthy after a nuclear attack, and the difference in focus between a symposium concentrating on the subject of postattack health and this one. The former might address these questions:

> "How should the health professions organize? What plans for augmenting and utilizing medical and environmental-

health resources should be developed so as to minimize the loss of life following an attack and to maximize the health status of those who survive?"

The health questions for today's symposium are more properly framed as follows:

"How important is the total health component of the overall problem of survival of society in a post-nuclear-war environment?
"How does it relate to and compare with the other elements of the survival problem?
"What can be done about it, and what difference does it make?"

In addition to the difference in focus, there is another important difference to keep in mind -- namely, the participants. The participants in a symposium devoted to postattack-health problems would be made up largely of physicians and public-health specialists, and the best single descriptor for them would be "health specialist." There are physicians and sanitary engineers here today, but also there are economists, psychologists, physicists, engineers, operations researchers, and others, but the best single descriptor would probably be either "postattack researcher" or "postattack planner." Thus, if a speaker wants to communicate with more than a small segment of his audience, he must avoid excessive use of the jargon or any other idiosyncrasy of his profession.

Having agreed to limit attention to the critical problems -- and what the focus should be -- the next question was the criteria for selection.

Three elements of a postattack society -- or any society for that matter -- that are absolutely essential are sustenance (food and water), protection from the elements (housing and clothing), and avoidance of epidemic diseases.

There seems little reason to question the availability of sufficient water -- at least for drinking purposes. And, although housing and clothing sooner or later might present difficult problems, there seems little reason to expect that surviving supplies would be greatly out of proportion to the surviving population. Thus "sustenance" (with the emphasis on food), and "health" were scheduled for Sessions II and III.

The next question in the hierarchy of problems appears to involve the potential productivity of the damaged economy with the associated direct and indirect damage to economic and social institutions. Could this economy, in effect, get up to speed in time to replenish supplies of essential consumer goods before they became exhausted?

So two more of the potential agenda candidates were selected. One was given the broad heading of "Economics" -- Session V -- and the other was titled "Societal Vulnerabilities" -- Session VI. A special evening sessi n, "Prospects for Economic Recovery," was added as background for, and in support of, the Economics Session.

Under a strict application of the tough criterion, "Does, or does not, a potential problem appear to pose a major threat to the viability of the surviving society?" the Planning Group would have stopped at this point. But many people apparently have been intensely worried about certain longer-term effects of a nuclear war, appearing to believe, in effect, that most of the attack survivors would die sooner or later from strontium-90, cesium-137, and/or carbon-14; or that the effects of radiation and fire on the ecology would be so devastating that the environment would become too hostile for rehabitation. So, Session IV, entitled "Special Topics on Long-Range Biological and Ecological Effects" was scheduled.

No doubt some other planning group would have used a somewhat different approach; but I doubt that the list of critical problems identified would have been very different.

In dealing with the subject matter that the speakers were asked to discuss, points can frequently be best made through illustrative use of numerical data. Let me continue to refer to the health question to explain what I mean.

A useful assessment of the health problem requires an appreciation of the number and location of people likely to need medical attention under various attack and shelter conditions. And, in looking at treatment effectiveness, one needs to know something about the expected physician/patient ratio, and the survivability and accessibility of hospitals, drugs, and vaccines. Such estimates are generated at the Office of Emergency Planning's National Resource Analysis Center. Analyses of hypothetical attacks and calculations of surviving resources truly provide our only stand-ins for reality; there is no actual nuclear-attack experience that is relevant. Thus, although necessary, perforce they are somewhat arbitrary, and are used only as points of departure for the sessions.

Finally, Session I (the Introductory Session), was rounded out by the addition of two papers. Mr. Strope will illustrate a not-implausible sequence of events that could culminate in a nuclear attack. Even if a nuclear attack should occur (an event considered by most people to have a very low probability), the conditional probability of an "out-of-the-blue" simultaneous attack on a major proportion of the large population centers is considered by most professionals also to be a very-low-probability event. Nevertheless, from our experience, this "out-of-the-blue" simultaneous attack is the image that appears in the minds of many people when a possible nuclear attack is mentioned.

The other paper in the Introductory Session, by Dr. Pettee, will provide the details of the two example attacks so that the audience will have the same starting point as the speakers, who were supplied the data earlier.

EXAMPLE ATTACKS

James C. Pettee
Office of Emergency Planning

Proceeding from the awesome experience of witnessing the simulation of a scenario which illustrates the series of events which might lead up to a nuclear attack, we turn our attention to a summarization of what the situation might be like if a nuclear attack had in fact occurred. Case-study descriptions of two different hypothetical nuclear attacks on the United States are presented. They were provided to the speakers as a common frame of reference so that discussions might be related to explicit attack-case problems. Two different attack cases are presented for at least three different reasons. They offer the speakers some choice in their selection of illustrative material; they help preserve an air of uncertainty about the specific results of any actual attack which might occur; and they should discourage any possible tendency for the symposium to become absorbed in an exercise-like concentration on the problems associated with a single-attack problem case.

The two cases summarized here are from unclassified hypothetical attack problems established in the past. One is called CIVLOG 64. This attack design was generated in the Department of Defense for exercise HIGH HEELS III which took place in 1963. The results were then used during 1964 in the preparation of the CIVLOG exercise conducted in 1965 among the NATO emergency-planning representatives. The other attack problem is a heavier one than the CIVLOG attack. This attack, called UNCLEX for "unclassified exercise," was designed in 1966 by the Office of Emergency Planning in accordance with the unclassified general statement in the National Plan as to what the enemy attack objectives might include if a nuclear attack on the United States should occur. This case problem was developed in response to a requirement for a heavier unclassified attack pattern than was otherwise available. Most of the older, unclassified attack patterns, such as those for the Operation Alert exercises in the late 50's, were so light as to be misleadingly unrealistic.

The general magnitude and structure of the two attacks are shown in Figure 1, entitled "Weight of Attack." The CIVLOG problem is depicted on the left and UNCLEX on the right. The size of the left hand bar in each case represents the total number of weapons: 445 for CIVLOG and 800 for UNCLEX. The size of the center bars represent the respective total yields: almost 2000 megatons for CIVLOG and about 3500

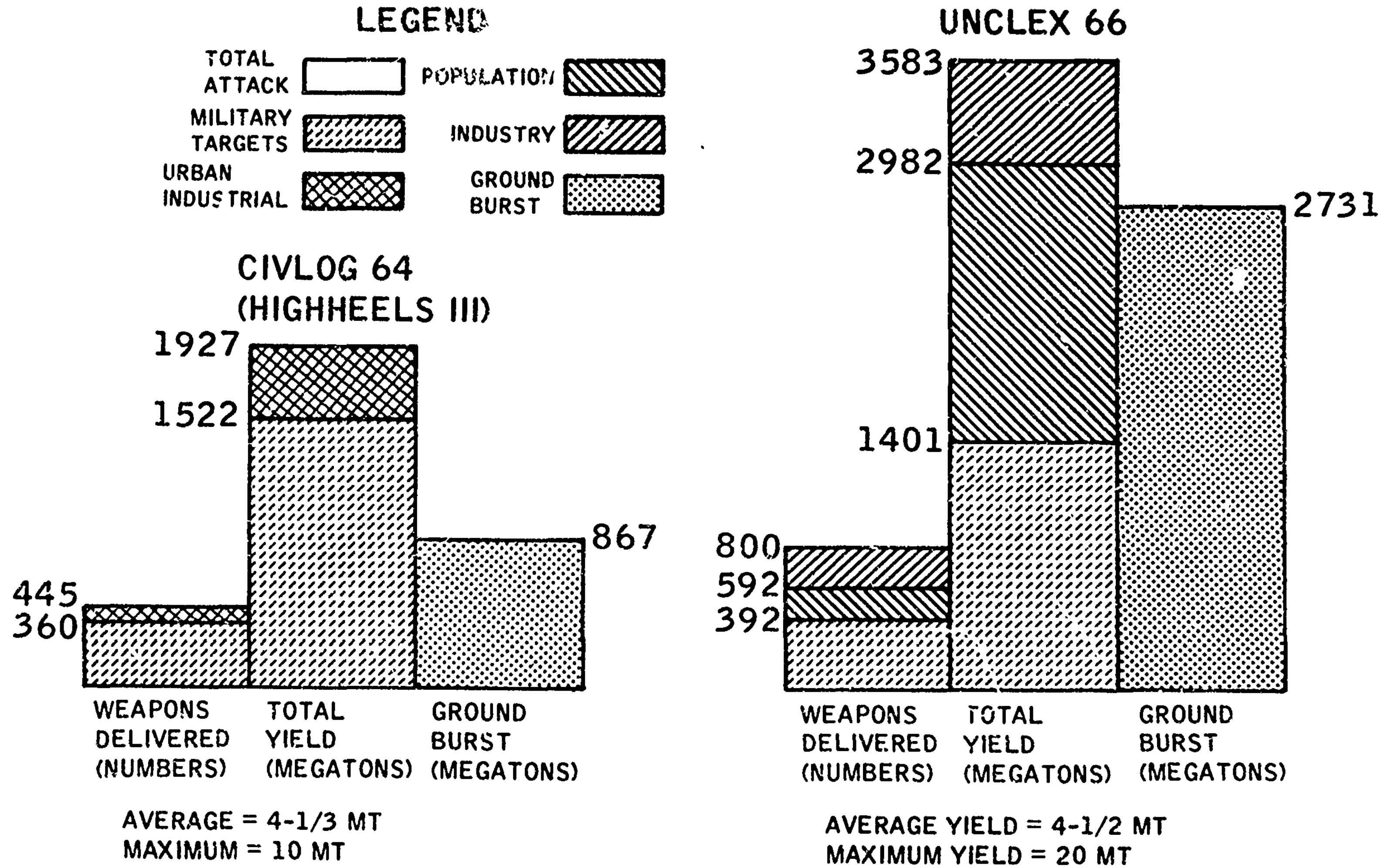

Figure 1. Weight of Attack.

megatons for UNCLEX. Both the average and maximum weapon sizes indicated for the respective attacks are comparable. Also they would be classed as intermediate as weapon sizes go.

The internal composition of the first and second bars reflect the targeting objectives identifiable in the respective attacks. The CIVLOG attack is shown to be largely directed at military targets. The small remainder was devoted to urban and industrial targets in combination. In the UNCLEX problem, however, one-half of the weapons including about two-fifths of the yield are devoted to the military, while one-quarter of the weapons with almost one-half of the yield are directed at population and the remaining quarter of the weapons with only about one-sixth of the yield are directed primarily at the most lucrative of the expected remaining industrial-target concentrations. The HIGH HEELS/CIVLOG attack may be thought of as a sort of truncated attack in which it was primarily the military part which had been delivered.

The third bars in each of the two sets represents the total yields of the ground-burst weapons in the respective problems. Less than half of the CIVLOG yield is in ground-burst weapons. This reflects the desire to maximize assurance of damaging military targets by calling for more air-burst weapons to increase the area of effective damage for each weapon assigned. Over three-quarters of the UNCLEX yield is in ground-burst weapons. The somewhat smaller effective blast area from ground-burst weapons is accepted in the attack design when population casualties are the targeting objective. The slight reduction in blast casualties would easily be more than offset by the lethal effects of the fallout radiation even though it cannot, with assurance, be directed at any particular area.

From summarizing the indications of the amount of fallout produced in these hypothetical cases, we turn to the question of how the resulting fallout is distributed over the nation. This is reflected in Figures 2 and 3, which are maps for CIVLOG and UNCLEX, respectively. The contours on these maps represent the respective levels of the maximum Equivalent Residual Dose (ERD) in roentgens accumulated from the respective attacks. Except as modified by shielding this is the total dose which would be received in the area between the time of first arrival of fallout and the time when additional increments of exposure would be fully offset by the body recovery from the previous exposure. The model used for ascertaining the amount and distribution of the fission fragments causing the fallout radiation is based on the so-called "WSEG-10" model which serves adequately for general magnitude problems. More precise but cumbersome analytical models are available for more specialized problem analysis.

The edges of the solid block areas on these are formed at the 10,000 R ERD contours. The unsheltered dose at any point within those

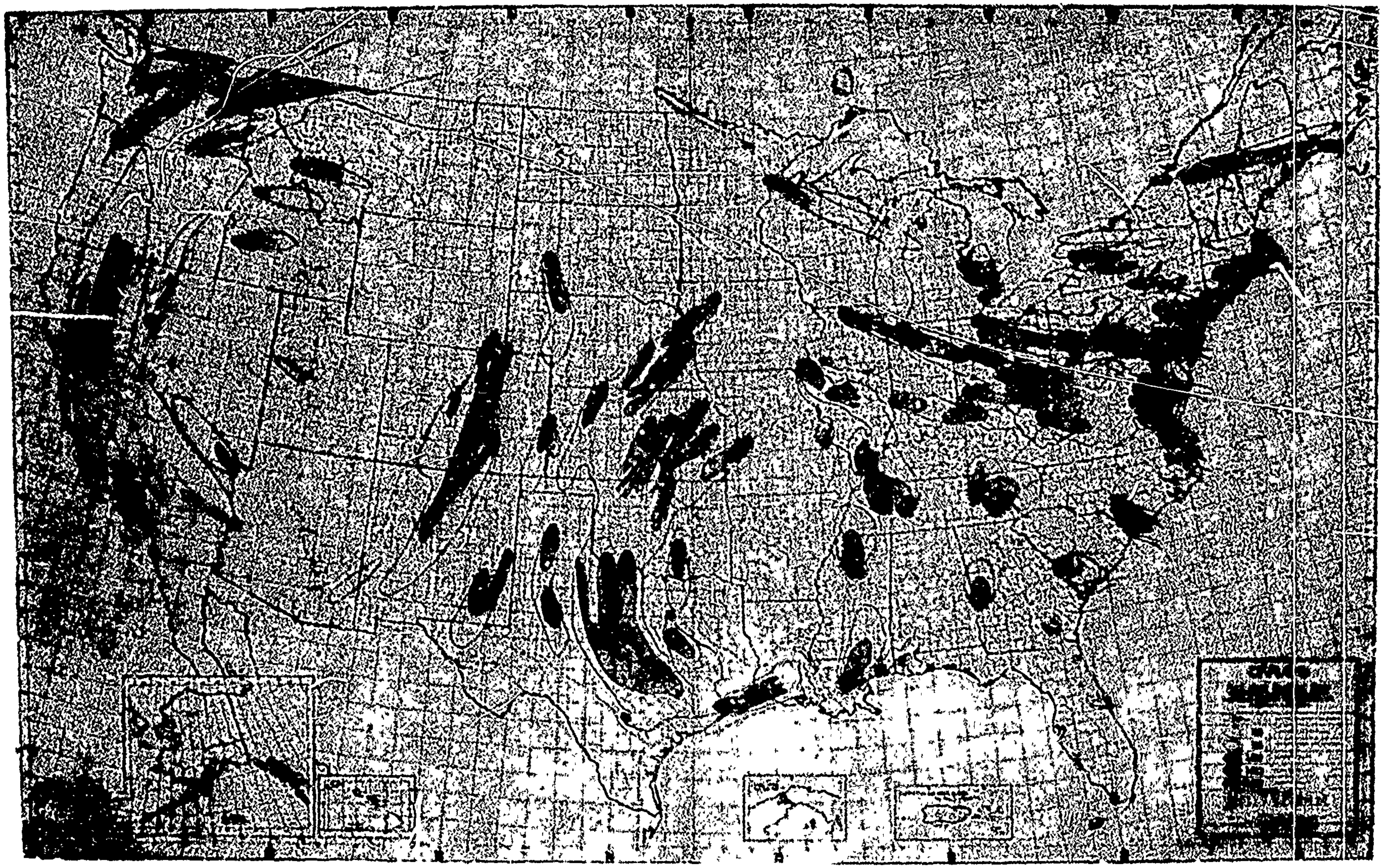

Figure 2. CIVLOG Map.

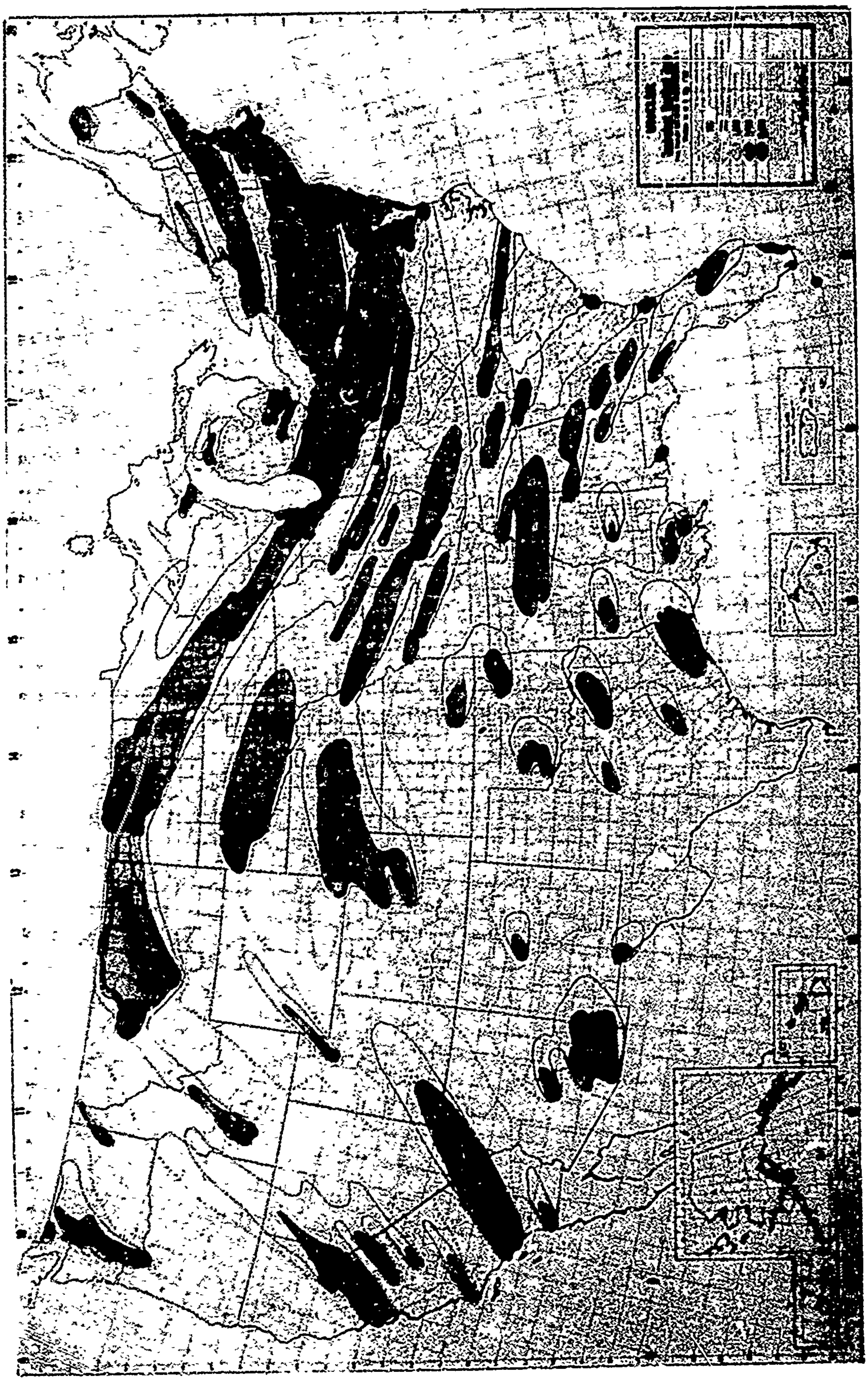

Figure 3. UNCLEX Map.

areas exceeds 10,000 R. These are surrounded by the dark-hatched areas in which the dose ranges down to 3000 R at the edge. The light-hatched areas carry the dose level down to 1000 R. Inasmuch as the median lethal dose for man is taken to be about 450 R, the shaded areas are those in which systematic use of adequate shelter is required for survival. In the clear areas on the map the solid line is the 300-R contour and the dotted line is the limit of the area in which 100-R dose is received.

The winds used for the CIVLOG exercise were the actual winds of September 26-29, 1963 -- the dates of the HIGH HEELS exercise. The map reveals the characteristic whorls with a counter-clockwise low over Utah and a clockwise high over Arkansas. The weather used for UNCLEX was that of July 8, 1966, a day when the winds were moving generally across the whole nation with no cyclonic center being manifested on the map.

Next, we consider the casualty levels of these attacks as shown in Figure 4, entitled "Impact on Population." Casualties were completed for both attacks with the READY model of the National Resource Analysis Center. This model uses the casualty inducing factors for the direct effects developed by the Dikewood Corporation for the Office of Civil Defense (OCD). No estimate is included of any increase of casualties from firespread. The shelter assumed to be available and used was that revealed in the OCD fallout-shelter survey. Little warning was assumed for both problems; hence, shelter availability for the population was counted as that in the same standard location (census tract) of residence. This carries the implication that the attacks commenced at night when the people were at home.

The population impact for each attack is depicted by a bar the height of which represents 100 percent of the preattack population. For the CIVLOG attack the total casualties constitute about three-eights or less than 40 percent of the population. This total is about evenly divided among those killed outright, those fatally injured and those injured who are expected to survive. The casualty level for the UNCLEX attack is almost twice the level indicated for the lighter, military-oriented CIVLOG attack. In this case about two-thirds of the population are killed or injured. In this case the potentially surviving injured constitute only about one-quarter of the total casualties. As with the CIVLOG case the fatally injured include about one-third of the total casualties. The relatively smaller share classed as surviving injured is made up by the increase in the share of total casualties killed outright in the UNCLEX problem. The increase in that category to almost half of the total casualties reflect the population targeting included in the UNCLEX attack.

The relative importance of direct effects and fallout as the cause of injuries in each case is represented by the scale across each bar

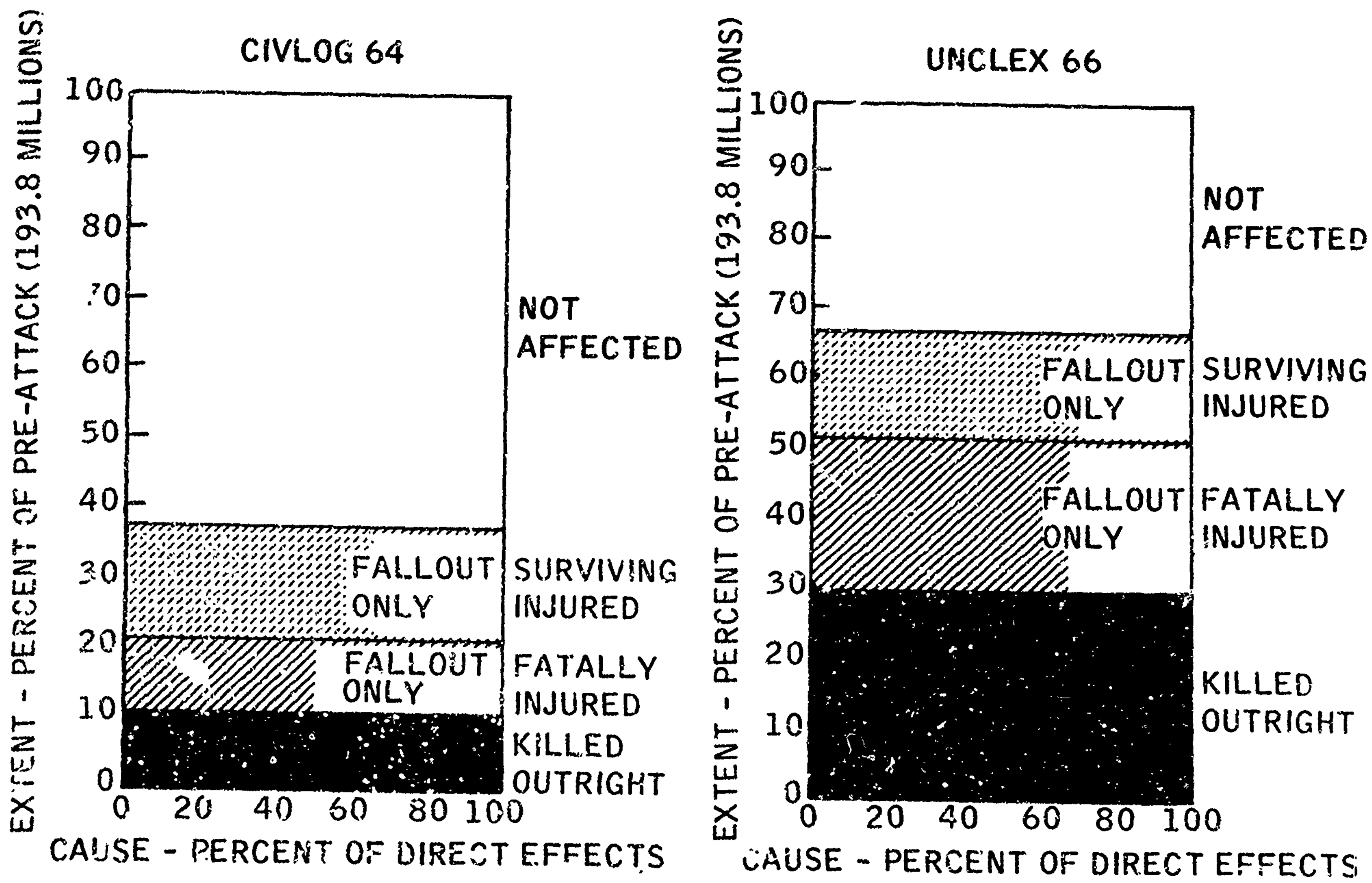

Figure 4. Impact of Population.

which represents the percent of the total induced at least in part by direct effects. Direct effects include not only the concussion from overpressure but also physical displacement, collapse of buildings and flying debris. They also include the effects of the direct gamma and thermal radiation from the fireball. The balance of cause of injury in each case is that caused by fallout only. As would be expected from the attack directed in part at population, the direct effects are responsible for a much larger portion of the UNCLEX injuries, both fatal and potentially surviving.

The next subject to be considered is the condition of the population with respect to consumption and production. This is reflected in Figure 5 entitled "Status of Population." It is a line graph for which time, up to one year, is the base and the population expressed in millions is on the vertical scale. A preattack population of 1938 million is used. The status of the survivors over time is shown in two lines for each of the attack problems. Because the survival level is so much higher for the CIVLOG problem, that pair of curves is entirely above the pair for the UNCLEX attack.

The upper or solid line in each case represents the total number of living persons at the particular point in time after the attack. As the fatally injured people die, this curve goes down. In general this is the base for most consumption requirements on the economy.

The lower or dotted line in each pair represents effective survivors. These include people not yet exposed or sick or who have recovered from sickness or injury imposed by the attack. The principal significance of this curve is the measure provided of the segment of the surviving population from which the labor force and armed forces can be recruited.

The shape of these curves is governed by a formula established some years ago for the Federal Civil Defense Administration and the Office of Civil and Defense Mobilization. It was developed by Max M. Van Sandt, M.D., of the Public Health Service, for deriving a time-phased intrepretation of the attack-casualty-status estimates to serve primarily as a basis for estimating medical caseloads in nuclear-attack exercises. Continued usage has tended to ascribe more validity to the assumed projection factors than was ever originally intended. The importance of the concept for planning, however, requires its continued use pending systematic development of more realistic criteria. When developed, it should include a procedure for assessing the consequence of the particular level of casualty care available where needed during crucial periods.

The final presentation deals with the estimated survival of manufacturing capacity. It is shown in Figure 6 entitled "Impact on Production Capacity." While dealing with production, this chart relates

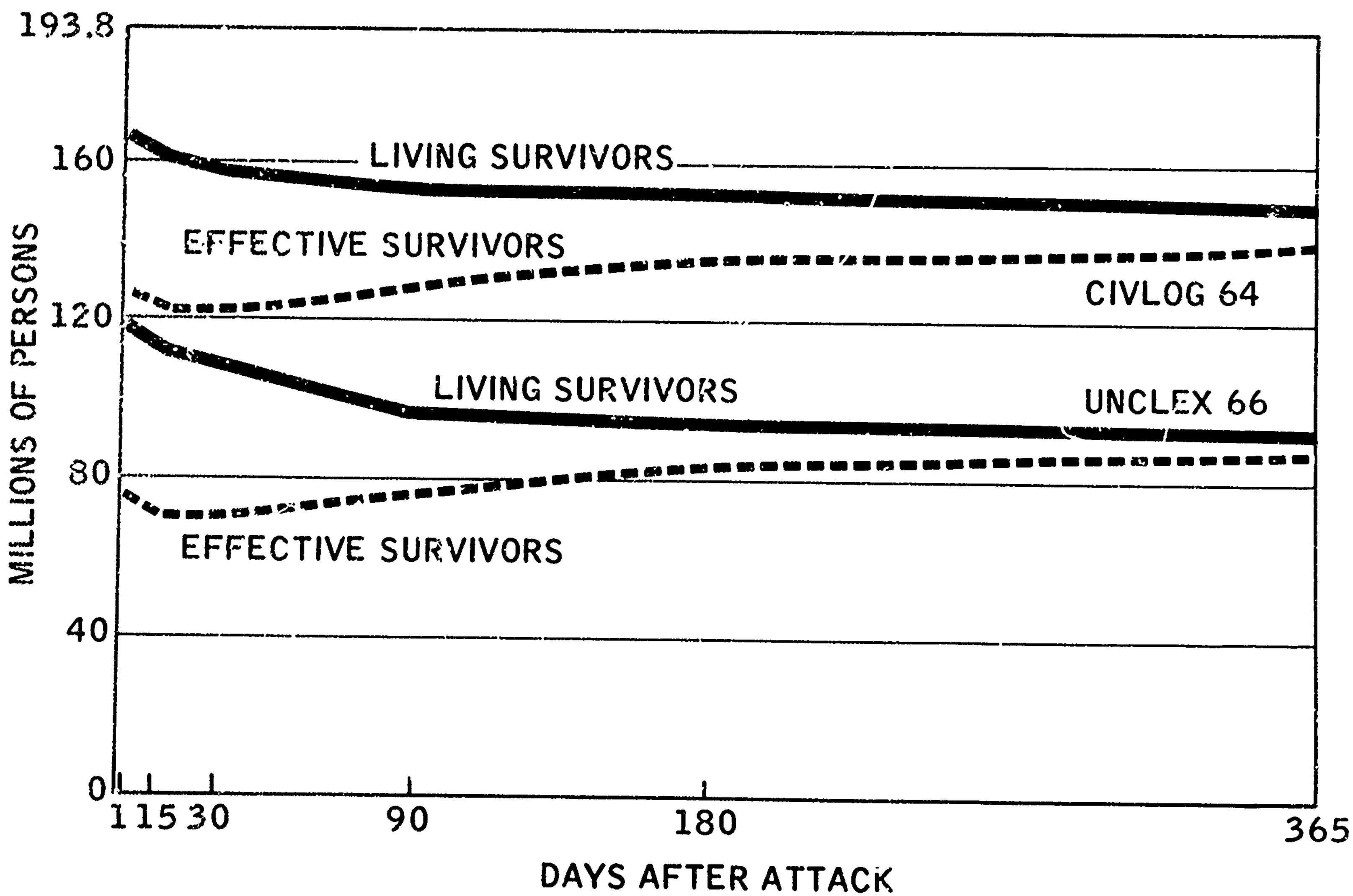

Figure 5. Status of Population.

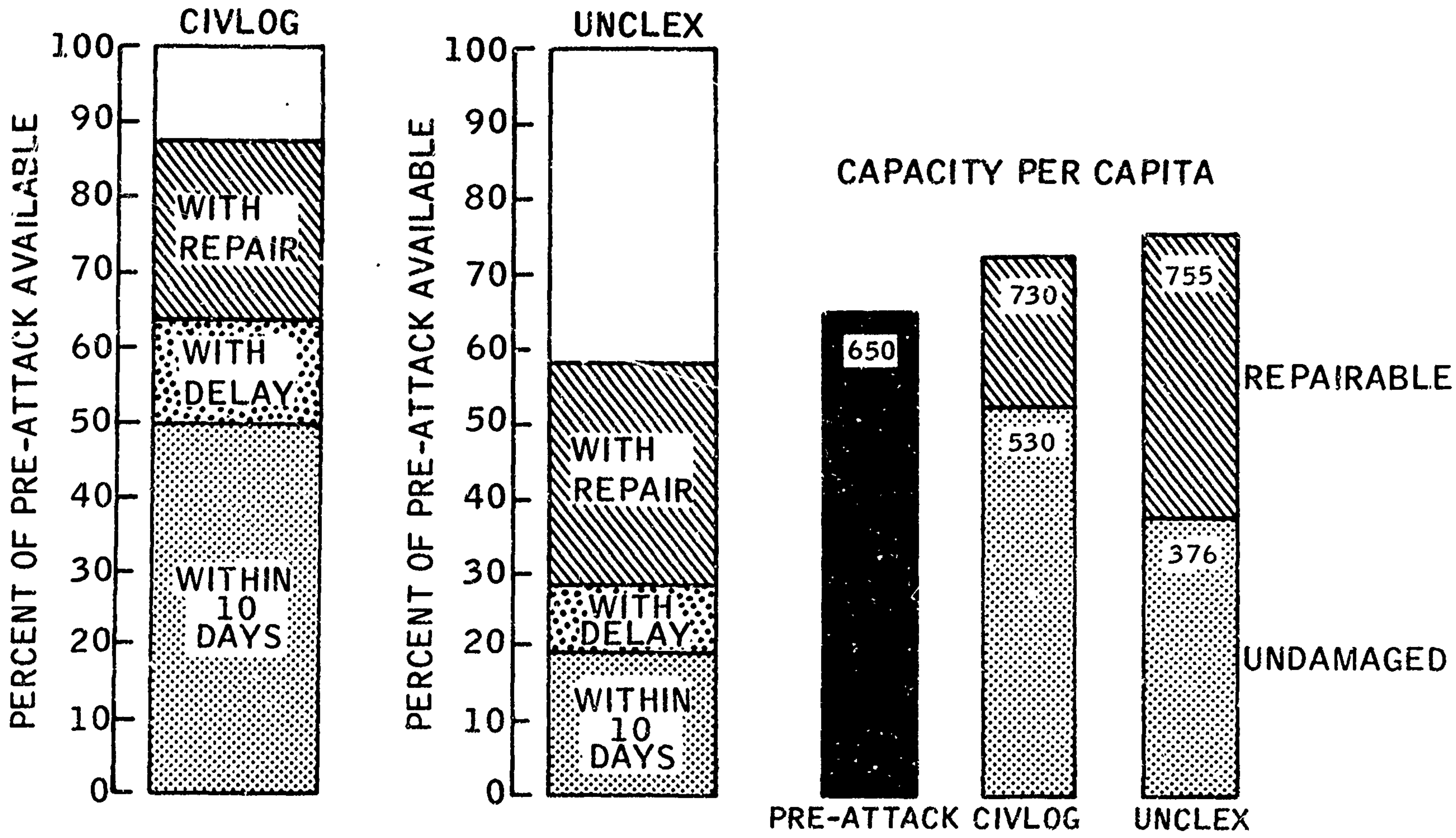

Figure 6. Impact on Production Capacity (1961 Large Plant Manufacturing Value Added).

to postattack production only in a twice-removed sense. First of all it deals only with surviving capacity. It does not show whether or to what extent actual use of the indicated capacity either would be wanted or could be supported. No statement of demand is developed and no measure provided of the availability of manpower, electric power, raw materials or other essential items of production support. In the second place the capacity representation rests on the assumption that it is adequately reflected by the manufacturing value added in the large establishments (100 or more employees) as reported in the 1961 census - the latest year for which data were available for this analysis. Thus, any actual capacity unused in the reporting establishments in 1961 is not reflected. Likewise the capacity in smaller establishments is not reflected.

With these caveats in mind about the difference between capacity and production and the deficiency of the 1961 production data as a statistical measure of the preattack capacity, we may proceed with the best information at hand.

The two bars on the left of the chart reflect the postattack availability status of the over-all total manufacturing capacity for the respective attacks. Availability "within 10 days," as shown at the bottom of each bar, represents the capacity of those establishments where there is no direct damage and where any fallout radiation was minimal enough to assure that even without any decontamination the plant could be in operation within 10 days after the attack without undue hazard to the employees. The addition of "with delay" brings the total up to include all undamaged surviving capacity. The increment is the measure of capacity denied, pending decontamination measures or simply waiting out the denial time until fission decay has lowered the radiation hazard to employees to tolerable levels. For the CIVLOG attack about half of the indicated manufacture capacity is available early and, if delay is disregarded, a total of about five-eights escapes direct damage altogether. For UNCLEX both figures are about half as great, indicating the severe consequences for manufacturing of the attack directed in part at it.

The third increment of shading in the bars represent the amount of capacity suffering moderate damage or probable fire in the area. Either is presumed to interrupt production but to leave the essential elements of the facility in good enough shape to be susceptible of repair at less than new construction cost. Such damaged but repairable capacity was substantial in both examples, ranging between one-quarter and one-third of the preattack totals. The economic impact of making anything like so extensive an amount of repairs would itself be a major burden on the reduced postattack economy. Hence, in a rationalized postattack economy such repairs would be ordered piecemeal in anticipation of requirements for the restored national capacity.

The unshaded remainders in each bar represent preattack capacity which was severely damaged or destroyed in the attack and hence permanently denied. This included only one-eighth of the preattack capacity for CIVLOG, whereas for UNCLEX about two-fifths are lost, reflecting the industry orientation of the targeting in the latter case.

The three bars on the right-hand side of the chart are designed to relate industrial capacity to the population. The first relates these items in the preattack base used for both problems. It shows that in the base year the indicated industrial capacity stood at $650 per capita for the over-all national totals. Considering only the undamaged surviving industrial capacity without regard to radiation denial, the per capita level related to survivors become $530 for CIVLOG and $376 for UNCLEX. Thus, undamaged industrial capacity has been subjected to a bigger reduction than population and the more so for the more severe attack. If survivors are compared to the total surviving industrial capacity, however, including what is repairable as well as the undamaged, the population loss turns out to have been the greater.

In summary, this presentation has consisted of a general exposition of the major characteristics and dimensions of the effects of two quite different attack problems. The purpose has been to provide a specific framework for subsequent symposium presentations when it is desired to relate them to specific illustrative cases. It was also intended to supplement the presentation of the scenario in creating the atmosphere and general frame of reference for the whole series of symposium discussions.

SUSTENANCE

This session was planned and organized by Mr. Alec G. Olsen. Because he was unable to attend, Mr. George H. Walter presided over the session, and Mr. Bruce M. Easton prepared and presented the summary.

FOOD CROPS AND POSTATTACK RECOVERY

A. F. Shinn
Oak Ridge National Laboratory

INTRODUCTION

The swiftly changing world-food situation has brought a dramatic drop in our commodity reserves. At the same time the level of nuclear threat to the U. S., particularly from the Soviet Union but also from Communist China, has been increasing. The recent decision to install a limited missile defense implies a national commitment not only to deter attack but to survive and recover if deterrence fails. Such a decision should be accompanied by an examination of the desired future size and location of our commodity reserves.

Livestock and grains comprise our major commodity reserves. In an emergency, the grains would be of overriding importance because of the large number of calories they could supply, whereas the livestock would be primarily important for meeting protein needs. This paper gives the status of U. S. grain reserves, suggests ways to use them in an emergency, and recommends sources of protein which would be emergency backup supplies in the event of a severe depletion of livestock.

FOOD COMMODITY RESERVES

During the early part of this decade our grain-storage space was virtually filled to capacity. With the exports of recent years, especially to India in 1966, our reserves of various grains have shrunk to half or much less than half of their peak quantities. The National Agricultural Advisory Commission's Subcommittee on Food and Fiber Reserves has suggested reserve levels for major food commodities[1] but no official minimum levels exist at present.

In June 1966, Secretary of Agriculture Freeman discussed the vastly changed wheat situation.[2] His concern for increasing the carryover from one year's crop to another was reflected in the increased acreage allotment for the 1967 crop. Despite this action, our July 1967 carryover of wheat declined to 426-million bushels as compared to 535-million bushels on July 1, 1966.[3]

The National Resource Analysis Center (NRAC) of the Office of Emergency Planning has made numerous studies jointly with the U. S. Department of Agriculture (USDA) of the vulnerability of our food supply and food-processing facilities. They issued the statement on January 5, 1967, that, as of December 30, 1966, the need had not yet been established for a nationwide food-stockpiling program against the contingencies of nuclear war. Their studies indicated that while there would likely be transportation problems, it appeared that total postattack transportation capabilities and fuel supply would be adequate to move needed food stocks from surplus areas to anticipated deficit areas. Even though the option was left open to modify the above policy if new information suggests changes, it follows from the above statement that they believe our present food supply on a national basis is adequate to meet postattack needs.

The National Advisory Commission on Food and Fiber, in their report published July 1967,[4] recommended establishment of a national security or strategic reserve, including emergency stocks for food aid. The Commission recommended that the reserve be isolated from the market except as offsetting sales and purchases are required to maintain the quality of the reserve stocks. The Commission also suggested establishment of the normal carry-over size for various commodities.

A number of bills to create a food stockpile have been introduced in Congress. The most recent one (Purcell, HR 12067, defeated November 1967) was designed to create an emergency food stockpile by government purchase of commodities at market prices for storage and subsequent release contingent upon the relationship between government crop-support price and market price. An alternative to this may be Senator George McGovern's idea to make loans to farmers to store grains on their farms until needed. All bills to establish food stockpiles have apparently had price-controlling connotations, without adequate isolation of the stocks from the market, and none has been acceptable to Congress. Nevertheless, the mood of Congress seems to be that some kind of reserve bill is needed. In the next section we will examine the size of our present food stocks.

THE NATIONAL FOOD SUPPLY AS OF JULY 1, 1967

The major sources of food are diagrammed in Figure 1 much as was done for a previous report.[5] The statistics on the food supply came from official government sources. The major change which has occurred is a reduction of the total normal food supply to 16 months on July 1, 1967, from a comparable 21 months on July 1, 1965.[5] "Normal" here is defined as food potentially available for human consumption during one month,

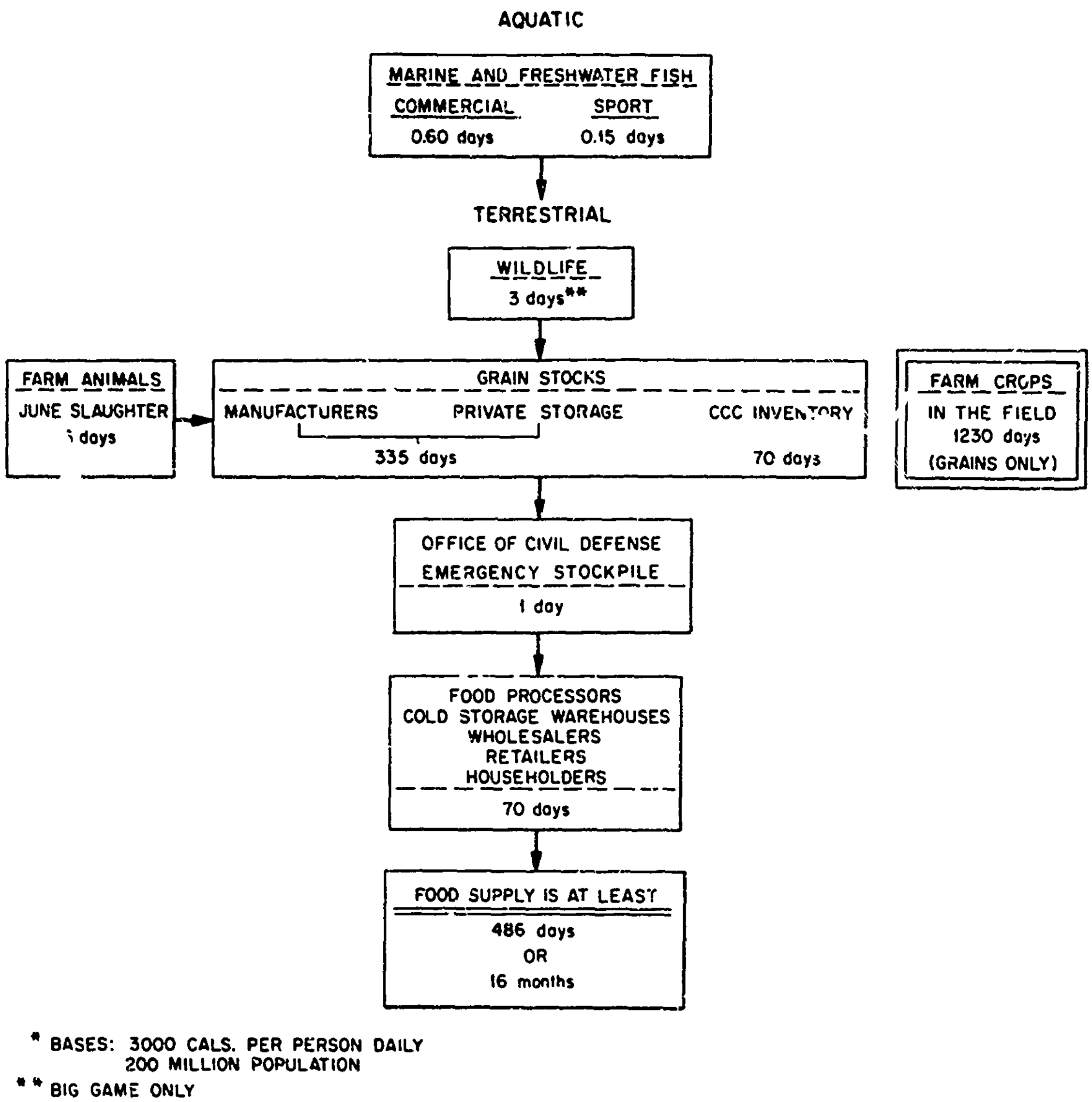

Figure 1. Estimated National Food Supply, July 1, 1967.

following normal harvesting methods -- that is, a month's production of livestock products. Livestock feed grains are assumed available for human consumption, despite the possibility that forage or range feeding in a nuclear emergency may be slight. The strong implication then is that the livestock population might have to be reduced drastically in an emergency, a contingency discussed later. This reduction could considerably expand the normal food stocks by an amount directly proportional to the percent reduction in livestock and the salvage efficiency.

Food represented as fish, wildlife, farm animals, food processors etc., is virtually unchanged from that of mid-1965. No new estimates have appeared from the last category, but since the data for it were from 1957, 1962, and 1963, it would seem worthwhile for the USDA to do the research necessary to update their report and make it more accurate.[6]

Although our stocks actually on hand total 16 months at mid-year 1967, Figure 1 shows that 41 months of food and feed grains were in the field at that time. This is an impressive supply and the harvest of it would be nearly completed before the time of the CIVLOG attack in the last week of September.

The season of the attack is an important consideration for vulnerability and damage assessments in agriculture. In general, most crops are planted by the end of June. In the case of corn, for example, the problem from a spring attack might well be the increased radiosensitivity of the young plant in contrast to an older stage, while a major problem from a summer attack might be denial of the mature crop to the harvesters because of fallout radiation; the main problem in an autumn attack might be difficulties in getting the corn into storage -- because of overmaturity for use as silage, or moisture-content problems -- after a delay resulting from fallout radiation.

Two important voids of information hamper estimations of the effects of various equivalent residual doses on crops. The first void is the general lack of data on the radiosensitivity of our crops at various developmental stages. Much of our information on radiosensitivity has been extrapolated for the vegetative plant from irradiation of its seeds. The second void is the dearth of data on the effect of the beta radiation from fallout adhering to the plant as opposed to the plant's exposure to gamma radiation. We have Davies and Russell[7] to thank for their data which so strikingly demonstrate that injury to crops in nuclear warfare may be much more serious than previously imagined. Although ~ 4000 rads of acute gamma radiation will kill mature spring varieties of barley and wheat, they found that 2000 rads averaged over all the stages of the growth they irradiated reduced the yield of both crops by one third. But this dose given during the first month of growth -- 2- to 4-leaf stage -- would result in complete inhibition of grain production, and even 500 rads at this time resulted in grain yields reduced by one fourth in wheat and one half in barley. The autumn CIVLOG attack comes too late to appreciably affect any of our major grains, yet it is important to remember that only 1000 rads in the first 4 to 6 weeks of spring grain growth may reduce the yield of wheat by 50 percent and that of barley by 95 percent.[7]

Research on the radiosensitivity of various species is further complicated by the variation in radiosensitivity among the varieties of a single species. A several-fold difference in yield of varieties of wheat exposed to gamma radiation was demonstrated by Donini, Mugnozza, and D'Amato.[8]

Our only emergency food stockpile -- in the sense that its stocks are semipermanent and are insulated from the market -- is that held by the Office of Civil Defense for use in community fallout shelters. Five pounds of food supplying 10,000 calories are stocked for each person using a National Fallout Shelter Survey (NFSS) shelter.[9] This amounts to about one day's food for our total population at mid-year 1967.[10]

SEASONAL CHANGES IN STOCKS OF GRAINS AND SOYBEANS

Comparisons of our major food stocks, the grains and soybeans, show that the mid-year stocks have steadily declined in the 1965-67 period by an over-all 24 percent (Figure 2).[5,11]

The seasonal changes in stocks of grains and soybeans are shown in Figure 3, where the stocks of grains and soybeans are seen to be maximum about January 1 and minimum about July 1. The same situation obtains for food inventories in food-processing and cold-storage plants as well as for daily food processing.[6] During 1966, the difference between the January maximum and July minimum number of days of food in grain totaled 21 months. But why were 21 months of food consumed in only a six-month period? This occurs because the 21 months were calculated using all grain for humans in this country, whereas most of the feed grains were consumed by animals and much was exported to other countries.

The reserve levels recommended by the National Agricultural Advisory Commission[1] are drawn in Figure 3 for comparison with the stocks. Both food grains and soybeans fell below the recommended level in 1966 and in 1967. Our 1967 carry-over stocks of wheat amounted to 426-million bushels,[3] feed grains to 37-million tons,[12]

	GRAINS	JULY 1, 1965	JULY 1, 1966	JULY 1, 1967
FOOD	WHEAT	125	81	63
	RYE	2	3	3
FEED	CORN	263	243	233
	OATS	19	17	15
	BARLEY	7	7	8
	SORGHUM	95	76	47
	SOYBEANS	25	25	37
		536	452	406

Figure 2. Days of Food in the Major Items of Stocks.

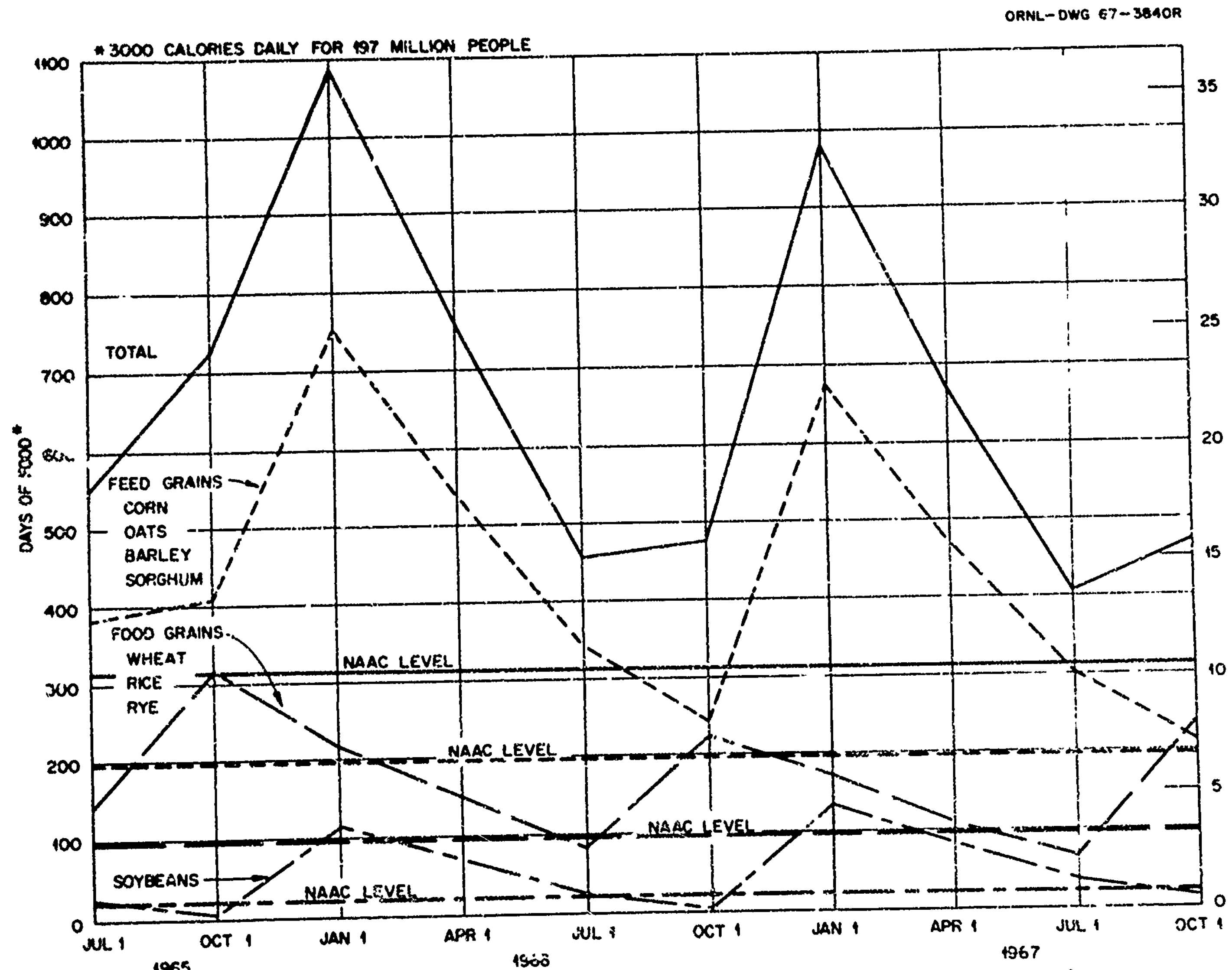

Figure 3. Quarterly Stocks of Grains as Days of Human Food.

and soybeans to 91-million bushels;[13] these amounts are 68, 82, and 91 percent, respectively, of the recommended reserve levels.

THE NATIONAL-EMERGENCY FOOD-CONSUMPTION STANDARDS

Few persons outside of agriculture realize the extent to which the USDA has organized to be ready to fulfill its postattack role in maintaining a viable agricultural industry. A hierarchical organization of defense boards runs from national to regional to state, and finally to county level. The defense boards' standard for immediate postattack food consumption calls for an average daily caloric intake of 2200 calories. The present average daily intake is about 3170 calories. A daily intake of 2200 calories would probably be adequate for a month or more, or perhaps even beneficial in view of the estimates that 20 percent of all adults[14] and 20 percent of all children[15] are obese. The research by Professor Doris Howes Calloway at the University of California, Berkeley, is directed towards determining the optimum food intake for man and will likely result in data of direct use for setting optimum emergency food-consumption standards.[16]

There is a need for research to develop simple, cheap, quick tests for the determination of vitamin deficiencies, especially for Vitamin B_1. Vitamin C appears to be the only vitamin for which such a test is now available: a lingual test for the tissue concentration as determined by the time to decolorize a standard dye solution.[17] In view of the importance of Vitamin C in human performance, it seems highly desirable that the challenge by Williams and Deason to scientists to conduct research on an individual's Vitamin C needs[18] should be taken up with the intent of putting the results to practical use in a postattack environment.

Our food reserves should be sufficient to insure that we do not have to stay on a lower calorie diet so long that it reduces productivity of workers, as occurred in Germany in World War II.[19] The allowance of 2200 calories for workers in the bridge-building works in Dortmund permitted only about half the amount of peacetime work. Young German miners furnished 2800 calories produced 7.0 tons of coal daily per man. At 3200 calories their output rose to 9.6 tons, and at 3600 calories it levelled off at 10 tons daily -- almost a 40 percent increase in production. Obviously, postattack recovery rate is likely to be strongly influenced by the available calorie supply. The Canadian worker, Sackville, suggested that 3000 calories daily are actually needed for emergency group feeding,[20] and the British worker, Hollingsworth, recommended no less than 2800 calories daily.[21]

It seems likely that in a postattack period all survivors will be working relatively hard under a stressful situation. Under such conditions it would seem wise to plan to abandon a relatively low caloric intake as soon as possible.

VULNERABILITY OF FOOD SUPPLIES

The results of the NRAC studies of the vulnerability of agriculture are contained in the HAZARD-65 study of the hazards of a nuclear attack on the conterminous U. S. A.[22] In essence, HAZARD-65 is an updated version of the estimation: Nuclear Attack Hazard in the Continental U. S. for 1963 (NAHICUS-63). Three important unclassified conclusions which emerged from the HAZARD-65 studies are listed below.

1. On a nationwide basis, adequate transportation and fuel would survive for distribution of food from areas of surplus to areas of deficit, but local transportation problems would occur.

2. More grain would survive the postulated attacks than people to consume it.

3. More livestock would survive postulated heavy attacks than people to eat it.

Conclusion 1 may need continuing reevaluation as the trend for more rapid turnover of wholesale food stocks becomes a widespread pattern and thus we become more dependent on transportation to maintain wholesale stocks. Conversely this trend might lead to a lower vulnerability of the stocks themselves since they would be stored closer to points of production and generally be farther from urban target areas than the wholesale locations. With immediate postattack transportation problems in mind, it might be well to effect an optimum geographic placement of our grain stocks.

Conclusion 2 might be substantially altered by an increased number of survivors from a nuclear attack if advanced civil defense or ballistic-missile defense were installed in the future.

Conclusion 3 might change either as the result of a more dangerous attack on livestock -- such as a biological attack -- or as the result of a future improved defense of the population, perhaps combining ballistic-missile defense and advanced civil defense. Hence, a more detailed inquiry has been made into the status and vulnerability of three alternate sources of protein: soybeans, augmentation of the lysine content of grains, and freshwater fish. The results of this inquiry are given in the last section.

Postattack Distribution of Food

Plans could probably best be developed through a series of postattack exercises involving USDA state and county defense boards whose members know their own regions well and thus should be able to anticipate difficulties peculiar to them. Although the boards carry out some exercises each year, I do not believe any have systematically tackled problems of transportation and distribution in detail. A thorough case study by Billheimer[23] dealt with the CIVLOG-65 five-megaton air burst near San Jose and its effect on Santa Clara County. His study revealed that adequate postattack food was both available and accessible by means of the surviving transportation and distribution network. Similar studies should be performed by local defense boards throughout the U. S.

In certain areas of the U. S., huge distribution centers are springing up, tending to concentrate wholesale food stocks in target areas. A case in point is the mammoth food distribution center in Philadelphia, Pennsylvania. Located on 358 acres in south Philadelphia, the center is "a larder for the Philadelphia area's 4½ million people, and for an estimated 14 million ... customers in this part of the nation."[24] The same trend is evident overseas; for example, a single distribution center in the Netherlands serves 407 large food stores,[25] and the famous Parisian market, Les Halles, will soon be replaced by the nearby market at Rungis which will distribute 20 percent of the total perishable products marketed in France, and will supply more than 8-million consumers.[26] The postattack implications of such concentration of distribution facilities need to be evaluated.

Optimum Geographic Location of Stocks

The optimum placement of grain stocks would seem to be near areas of predicted population survival. This would largely obviate the possible and difficult problems of long-haul transportation and its usually associated distribution complex. The late President Kennedy suggested a 46-million-dollar program to so relocate grains, but neither this idea nor the idea of having a strategic food reserve have proved acceptable to Congress. The alternative is to have plans ready for transportation and distribution of stocks as necessary.

OUR PROTEIN SUPPLIES

The sources of U. S. dietary protein are depicted in Figure 6.[27] In 1966, 39 percent of our total protein intake came from livestock, poultry, and fish, and, with dairy products and eggs included, the

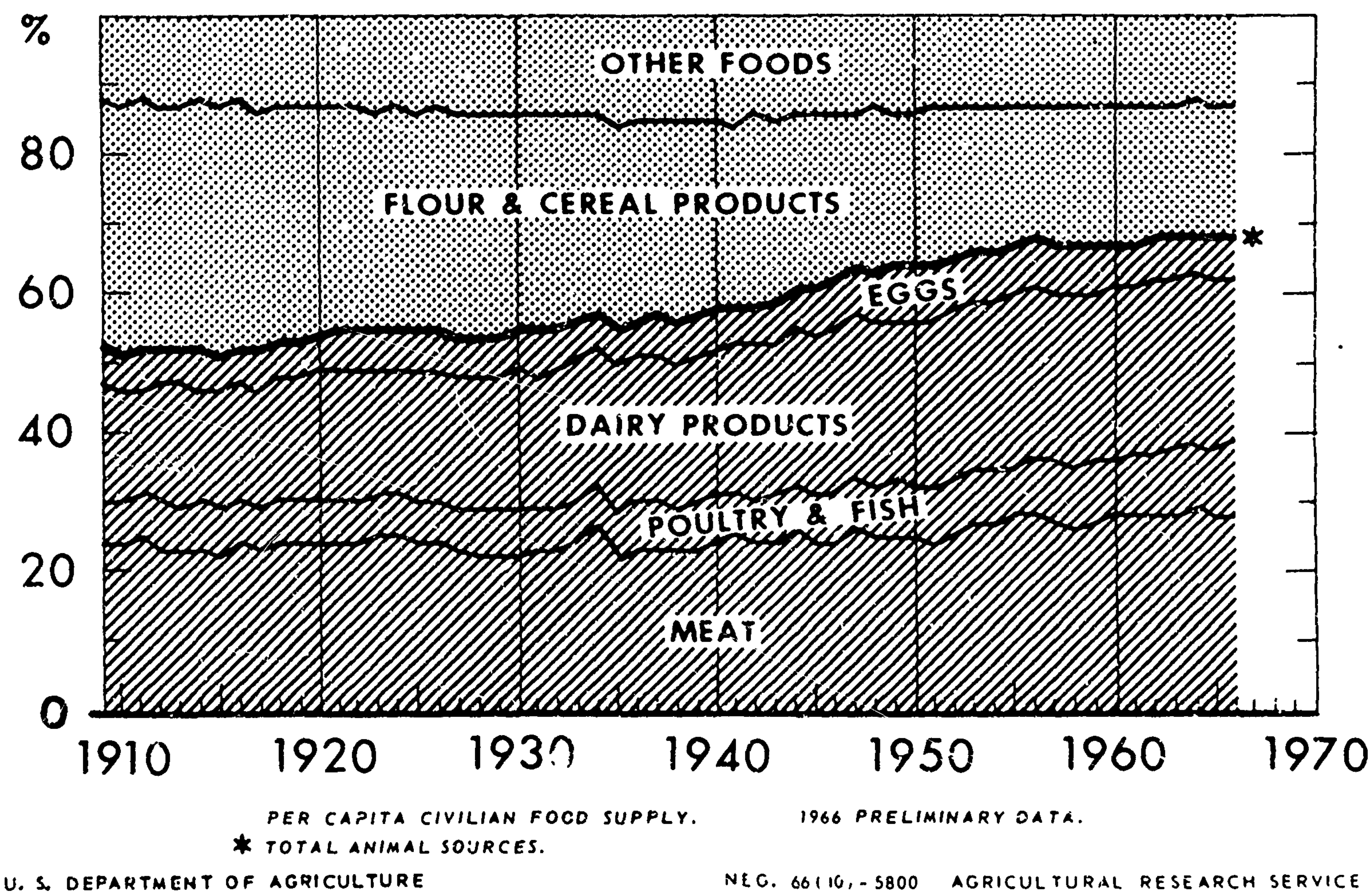

Figure 4. Sources of U. S. Dietary Protein.

figure becomes 66 percent. Both livestock and poultry numbers may be severely reduced by a nuclear attack. Three alternate means of meeting our protein needs without a food stockpile are (1) the use of soybeans for human consumption, (2) supplementation of soybeans and grains with the amino acids methionine and lysine, respectively, and (3) the use of inland freshwater fish. Although these sources are used as a human protein supplement, their utilization has been minimum in the past. On the other hand, the use of each for human food has been accelerating under the stimulus of the world need for good-quality protein.

Reduction of Livestock Supplies in an Emergency

Our food supply may be visualized in one of three conditions: (1) unharvested in the field, (2) in transit -- the so-called pipeline -- as harvested, or in some stage of processing, or ready for consumption, and (3) in storage. The normal supply for consumption would include the usual harvest which, in the case of livestock, was taken as the slaughter for one month for Figure 1. A reduction of livestock supplies might result from an emergency harvest of livestock for any of the following reasons:

1. Salvage of injured livestock.

2. Salvage of livestock exposed to heavy irradiation.

3. A decision to stretch food supplies as much as possible by using food grains for human consumption, thus necessitating a slaughter of livestock.

4. A decision to shift the economy to a lower level of food cost so that more calories could be bought per dollar spent, again necessitating a slaughter of livestock.

In both these last two cases, enough livestock should be retained to rebuild the industry.

In view of the several possibilities for a reduction in livestock supplies, the three alternative sources of protein have been investigated and are discussed below.

Soybean Production and Vulnerability of Processing Mills

Figure 5 is a map of the production of soybeans by counties as given by the most recent Census of Agriculture.[28] The locations of soybean-processing mills are superimposed on the production map.[29]

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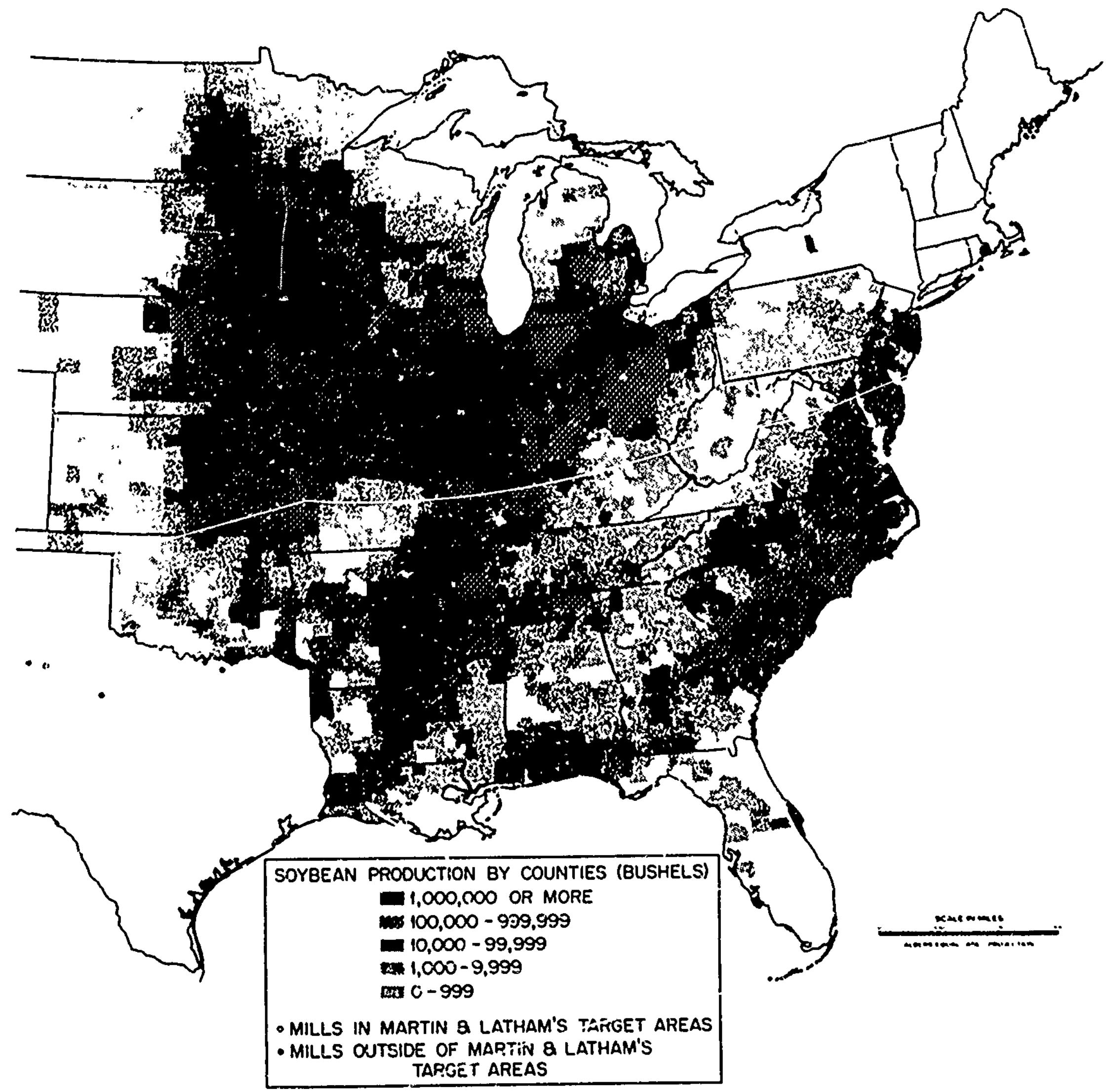

Figure 5. Soybean Production and Processing Mills, 1964, Showing Results of a Nuclear Attack on Soybean Mills.

Heavy production of soybeans occurs in the corn belt states and along the Mississippi River, and it is obvious from the map that most mills are located in or close to the major areas of production.

An estimation was made of the physical effect on soybean-processing mills of 9,000-megaton mixed military-industry-population nuclear attack postulated in Martin and Latham's Strategy for Survival.[30] The results are listed in Table I. Of the 132 mills, 87 (or 65 percent) sustained overpressure of less than one psi, meaning that they could continue operation in spite of minor damage from broken glass and some light structural damage.[31] Only 35 (27 percent) mills were completely destroyed. Assuming that the mills are destroyed in proportion to the total U. S. capacity, and with only 90 percent of capacity used in 1966,[32] the net loss in processing capacity would only be approximately 17 percent. Because of the targeting, the effect of the CIVLOG-65 attack is somewhat less, but that of UNCLEX is essentially the same as that for the much heavier Martin and Latham attack.

TABLE I.

RESULTS FOR THE SOYBEAN PROCESSING INDUSTRY OF

THE 9000-MEGATON MARTIN & LATHAM NUCLEAR ATTACK

Overpressure (psi)	Damage to Mill	Number of Mills
< 1	Negligible	87
1-2	Light	3
2-7	Medium	6
7-12	Heavy	1
12-200	Extreme	0
> 200	Nonrepairable	35
Total		132

The soybean is used for both meal and oil production, but for human food in a postattack period it might be most economical to process it as a full-fat soybean without removing the oil. A simplified five-step process for producing full-fat soybean flour has been recently developed.[33] For potential application of this process in an emergency, USDA state defense boards in the soybean-producing states could be supplied with several sets of the three machines -- cracker, dehuller, and grinder -- for this process. The total cost of the three machines has been estimated to be about $200.[34] With these machines, five men could produce 300 pounds of soy flour in an eight-hour day, which would be enough to supply the daily requirement of protein -- 35 grams -- for more than 800 adults.[34]

The chief use of soybean oil is for human-food items such as margarine and cooking oil, and the chief use of soybean meals is in livestock- and poultry-feed rations. Thus, if livestock and poultry were either badly damaged by a nuclear attack or deliberately reduced in number, the soybean meal and oil would be available for human food.

If an oilseed meal is consumed in combination with grain, the amino acid deficiency of each is compensated for by the other. For example, two parts of ground cereal grain combined with one part of well-processed soybean flour -- or cottonseed or peanut flour -- provides a mixture with more than 20-percent good-quality, complete protein.[35]

Lysine Supplementation of Grain

Lysine supplementation of postattack grain supplies has been suggested as a means of meeting protein needs.[36] Bacteriological fermentation is the method of choice for manufacture of lysine in the U. S. because of the higher costs for chemical synthesis. Only one company in the U. S. currently produces lysine: Merck and Company, Inc., at Elkton, Virginia. This facility is far from any of the targets listed by Martin and Latham,[30] but two former producers of lysine have their plants in potential target areas: Chas. Pfizer Company, Terre Haute, Indiana, and Du Pont, Niagara Falls, New York. A makeshift facility for chemical synthesis -- Du Pont's process -- would probably not be feasible because of the requirements for specialized equipment,[37] but feed-grade lysine could be produced on such a basis by the fermentation method. Feed-grade lysine would have some odors and flavors which might be objectionable to humans,[38] but they would likely be tolerable in a nuclear emergency.

The government has considered adding lysine to wheat flour for shipment to underdeveloped countries, and if the demand increases sufficiently it may trigger enlargement of current facilities or the construction of an additional production facility. An incentive offered to encourage location of such a plant away from potential target areas would have a high value for emergency food production.

Freshwater Fish

The use of soybeans for a postattack protein source is principally recommended as an emergency measure. Human consumption of soybeans and grains in amounts sufficient to furnish adequate protein for adults might produce flatulence and diarrhea. In addition, young children could not ingest the large quantity necessary to supply their protein needs. A child of four years of age and weighing 37 pounds (17 kg) needs the same minimum intake of protein as an adult, yet normally eats only half the quantity of food.[39] A source of high-quality protein more concentrated than that of grains is needed by developing youngsters, and an alternative to livestock and poultry to meet this need is fish.

In the wake of a nuclear attack it is likely that our marine fisheries would be largely out of service for a lengthy period by reason of ship and harbor damage, and more critical needs for petroleum fuel. Our inland freshwater fish would be conveniently close to major markets and emergency harvesting of the available species could yield more than one-billion pounds of such fish as alewives, catfish, and trout. This amount would supply 20 days of daily 10-gram protein supplements for the entire U. S. population, or, more importantly, 50 days of the supplement for the 77-million[40] people 19 years of age or younger. Moreover, the widespread production of freshwater fish in ponds and reservoirs could quadruple this supply.[41]

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LIVESTOCK AND POSTATTACK RECOVERY

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INTRODUCTION

The primary function of the livestock industry in the United States is to provide high-quality nutrients for human consumption. Man's performance and growth are dependent on an adequate supply and balance of nutrients from food and the inclusion of animal products in the diet helps to insure the supply of the necessary nutritional requirements of our population. Most of the people in the world are involved in food production which is insufficient for their needs, while in the United States, only 6 percent of the people are involved in a remarkable productivity of food which more than adequately meets the needs of the population.

Much of the success of the livestock industry depends on providing livestock with needed nutrients by the adaptation, through least-cost computer programs, of the latest scientific knowledge. Many of the feed ingredients are by-products which are unusable by man and it is a matter of economic concern only when animals are given food which could be consumed directly by man. Animals are therefore the practical means of utilizing over 40 percent of our agricultural land since this area is only suited for grazing by these highly developed scavengers.

After major disasters, food production and food supplies have played important roles in recovery. In the past, the people of all countries ravaged by war have suffered from lack of food. Since World War II, we in the United States have enjoyed an abundant productivity and have generously continued to supply food to needy people throughout the world. Considering the ever-increasing needs of other countries, who would or who could help supply our food needs to promote an effective recovery from a major disaster such as thermonuclear war? The objectives in this paper are to consider livestock as a food reserve and to determine the state of knowledge available to predict the role of livestock in postattack recovery.

LIVESTOCK AS A FOOD RESERVE

Livestock products in 1965 provided 40 percent of the energy, 68 percent of the protein and 83 percent of the calcium in our diet, as shown in Table I. The demand for these products has increased to the extent that we are now importing 3 percent of our total consumption. Most of these livestock products were from cattle which were valued at over 16-billion dollars in January 1967, as shown in Table II. This large inventory is necessary to provide enough females for the slow repopulation rate of an average of 0.8 calf per adult female per year. Since milk cows make up only 14 percent of the total cattle numbers, most of the emphasis will be placed on beef cattle as a food reserve. The importance of considering cattle as a significant food reserve for the United States is further emphasized by considering the value of 16-billion dollars in constant inventory in comparison with an average carryover of less than one-billion dollars' worth of wheat out of an annual wheat production valued at about 2-billion dollars the past few years.

The concept that it is wasteful to use livestock as food producers due to the waste of food energy is valid only if these feedstuffs could be used directly by man. Swine and poultry are more efficient than cattle and compete more for grains and the more expensive protein sources which might be used by man, but cattle and sheep are fed more on roughages, grain by-products, and synthetic-protein substitutes which are not suitable for man (Table III). Poultry and swine numbers can also be rapidly replenished in comparison with the long repopulation time necessary for sheep and cattle as shown in Figure 1. These repopulation times were developed with increase in animal numbers as the total goal and with very little attention given to quality of production.

Livestock as a food reserve played an important role in the survival of the people in northern Europe during prolonged periods of food shortages after World War II.[1] In contrast, Japan had few livestock reserves and depended heavily on grain shipments from the United States to prevent starvation of an estimated 10-million people during the first winter after World War II.

Livestock products have a much shorter shelf life than grains and similar dry supplementary foodstuffs. However, the advantages of live storage, coupled with the large value and large number of livestock, make livestock well worth considering as a substantial food reserve of excellent quality. In addition, these animals can also help to screen out dietary undesirables such as radioactive fallout and other pollutants.

TABLE I.

U. S. CONSUMPTION OF MAJOR FOODS AND NUTRIENTS SUPPLIED IN 1965 *

Item	Pounds per capita	Percentage supplied Energy	Protein	Calcium
Meat and fish **	203	19.2	38.6	3.3
Eggs	39	2.2	5.8	2.4
Dairy products	364	12.6	23.8	76.7
Fats and oils	51	16.4	.1	.4
Citrus and other fruits	158	3.3	1.1	2.0
Potatoes and sweet potatoes	101	2.8	2.4	.9
Vegetables	196	2.7	3.7	6.2
Dry beans and peas, nuts, soya flour	16	2.9	5.1	2.6
Flour and cereal	145	20.9	19.1	3.3
Sugars, sweeteners	112	16.3	---	1.0
Coffee, cocoa	15	.8	.5	1.1
Total animal products	629	40.5	68.2	82.6
Total crop products	787	59.5	31.8	17.4

* U. S. Department of Agriculture. Agricultural Statistics 1966. U. S. Govt. Printing Office, Washington, D. C., pp. 581, 583.

** Retail equivalent pounds: Beef 88; pork 52; poultry 41; fish 14; veal 5; and lamb and mutton 3.

TABLE II.

LIVESTOCK STATISTICAL DATA *

Species	Number in millions	Total value $ billions	Usual market weight lbs.	Usual market age months	Annual No. offspring per female	Reproduc. age months
Cattle	108	16.2	950	18	0.8	24
Swine	51	1.7	200	6	14.0	12
Sheep	24	0.5	90	9	1.2	12
Poultry	428	0.5	3.5	3	200.0	6

* Bell, M. C., 1967 ORNL Civil Defense Research Project Annual Report.

TABLE III.

MILLION TONS OF FEED CONSUMED BY LIVESTOCK IN 1964

Item	Dairy cattle	Beef cattle	Swine	Poultry
Roughage	64.4	119.0	2.4	0.7
Feed grain	25.7	25.0	46.7	25.0
Protein supplement	4.8	6.4	7.0	11.2

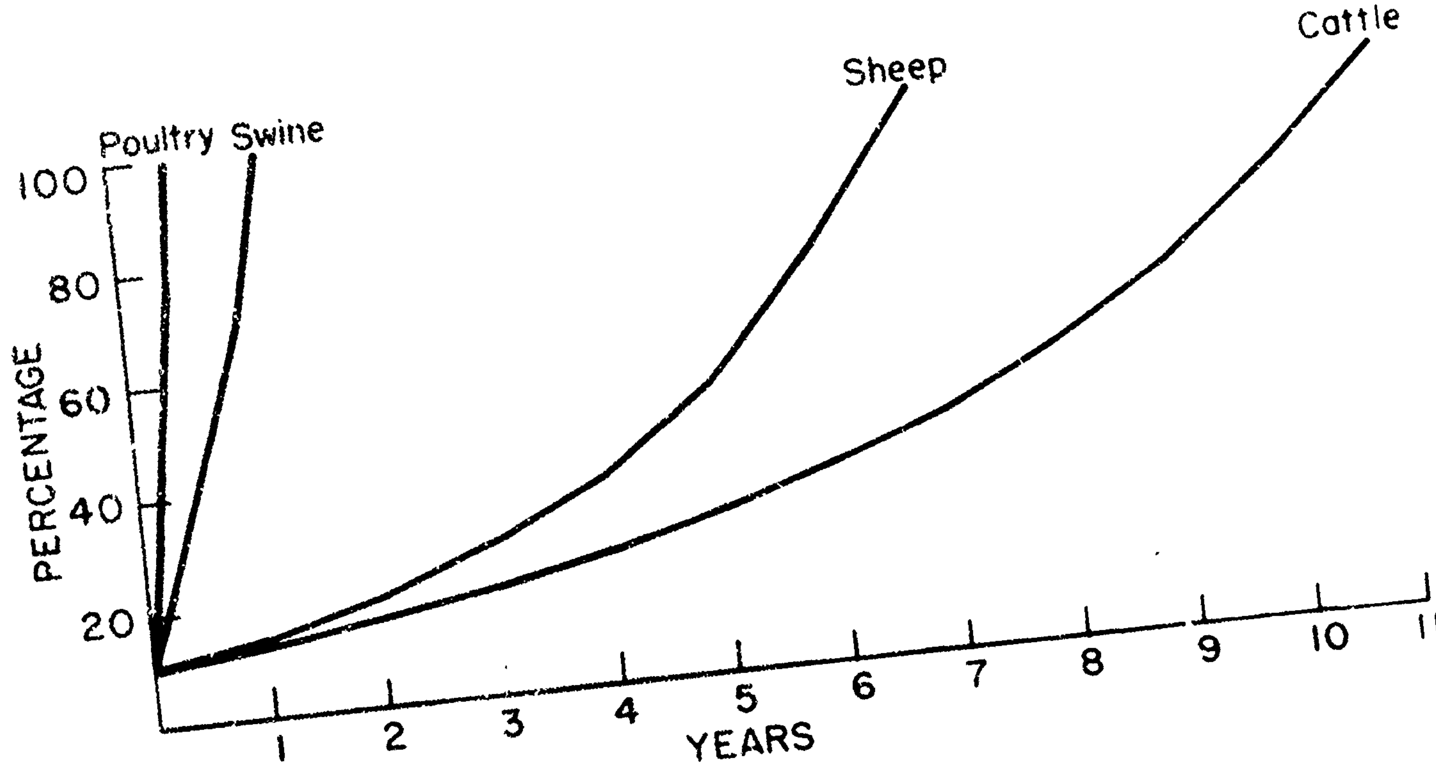

Figure 1. Years Required to Rebuild After 90% Loss of Female Breeding Stock.

FALLOUT RADIATION EFFECTS ON LIVESTOCK

A NAS-NRC report[2] considers gamma radiation as the major hazard to livestock from effects on the hematopoietic system. These conclusions were based on a low retention of fallout on forage crops and should be reevaluated in view of recent data[3,4,5] to include effects on the gastrointestinal tract and skin. The estimated gamma radiation $LD_{50/30}$* for mature food-producing animals is 550 rad in 4 days, except for poultry which has an $LD_{50/30}$ of 900 rad. These values vary with dose rate, species, and radiation characteristics; swine even build up radiation resistance of 164 percent of the controls at 20 days after a preconditioning dose.[6]

Most of our cattle and sheep remain on pasture throughout the year and receive supplemental feed during the winter months. The possible gastrointestinal injury and retention of fallout on plants and animals appear to be the major areas lacking in valid information which can be applied to livestock and forage crops under a variety of conditions. The data presented by Rhoads[5] on plants, and Engel[7] on animals, along with the information on the Alamogordo cattle,[8] demonstrate that the direct surface damage from fallout is due to beta injury and not to gamma irradiation. Also the data presented by Miller[3] on the retention of volcanic ash of particle size comparable to early fallout, and the data of Ward and Johnson[4] on world-wide fallout, show that plant contamination is of considerable significance. Under heavy fallout conditions, grazing animals could ingest large quantities of early fallout which might be lethal. Although meaningful field studies would be difficult to perform, they are clearly needed for realistic damage estimates. Much of the laboratory results are not directly applicable to field conditions for food crops and livestock production. The limited field-test results using aerosols of iodine[9,10] and the distribution of glass or fused particles[11] on forages provide us with some useful information in this area.

Data on the estimates of gastrointestinal damage due to ingested radioactivity are very limited. Reliable dosimetry of radiation from sources of mixed beta and gamma emitters to the gastrointestinal tract is difficult due not only to the variable anatomical and physiological factors but also to the variable mass and water content of the ingesta. Based on data from dogs and goats,[12] it has been predicted that the major gastrointestinal damage from mixed fission products will be

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* A dose lethal within 30 days to 50 percent of those exposed.

limited to the large intestine of both single-stomach animals and ruminants.[8] However, sheep fed levels of cesium-praseodymium-144 which was lethal to about 25 percent of the animals showed gross lesions primarily in the omasum and a few lesions in the rumen.[13]

No experimental data were found on effects of feeding cattle fission products at levels high enough to produce gross damage to the gastrointestinal tract. Variables to consider in ingestion studies include direct retention of fallout by pasture forages; dust blown onto the forages;[4] rain splash; and level of grazing. Ruminants under ideal grazing conditions consume soil at the rate of less than one percent of dry-matter intake, while in overgrazed pastures soil ingestion may amount to 14 percent of the dry-matter intake.[14,15] Swine and poultry depending mostly on supplemental grains would ingest much smaller amounts of contaminated soil.

Although the skin injury of the Alamogordo cattle was of little consequence to the productive life of the cattle exposed to the early fallout from the first atomic-bomb explosion, it was the only positive damage reported on these cattle. Estimates of radiation dose to these cattle was 37,000 rads to the skin surface from the beta activity and 150 rads to the whole body from gamma activity.[8] Most of these animals were sacrificed because of anaplasmosis infection, and the scar tissue from beta injury was probably more susceptible to insect carriers of the infectious anaplasmosis. In a postattack-recovery period, it would probably not be possible to continue the insect-control programs; therefore, livestock with skin and other injuries would be highly susceptible to screw worm and similar infestations. Information has been found in only one preliminary report on the effects of exposing cattle skin to beta radiation; much more data are available on swine and small animals.

Radiation effects on livestock need to be considered not only from the separate effects of whole-body, gastrointestinal, and skin damage, but also on the combined additive effects of these insults on the survival and productivity of grazing livestock. Productivity of the survivors would probably not be affected markedly and the unproductive culls could still be used for meat as they now are used in present livestock management practices.

Dairy cows surviving whole-body gamma radiation near the $LD_{50/30}$ level showed no effect on milk production except when feed intake was depressed and the return to normal lactation was rapid immediately after irradiation.[16] Reproductive performance of the Alamogordo cattle and growth of their offspring was not different from comparable groups of nonirradiated control Hereford cattle.[8] Survivors from a group of over 200 cows whole-body irradiated in 1960 and 1961 at our Laboratory have shown no difference in performance of offspring in comparison with the untreated animals.

Limited information shows that some of the animals dying of whole-body gamma irradiation develop bacteremia. The salvage of these animals for human food has not been recommended even though cooking would probably be sufficient to provide a wholesome and safe food. Normal meat inspection regulations prohibit the use of meat from animals with elevated temperatures characteristic of lethal radiation exposures. Livestock exposed to gamma irradiation at $LD_{50/30}$ levels are recommended for use as meat for the 2-week period after irradiation since temperature elevation usually occurs about 14 days postexposure.[2]

CIVLOG-65 ATTACK EFFECTS ON LIVESTOCK

The effective residual dose (ERD) for this hypothetical attack has been discussed in preceding papers. When these map contours are combined with the livestock census data, the National Resource Analysis Center (NRAC) printout showed an 89 percent survival of livestock as shown in Table IV. In obtaining an estimated survival of 89 percent of the livestock, only gamma-radiation sensitivity has been considered. No data are available on the interactions of blast effects, skin damage, gastrointestinal damage, and disruption of feed, water, and care with the gamma radiation, but these interactions would probably double the death losses. This 89-percent-survival estimate is comparable to the 87-percent-survival estimate for the population. One primary difference is that people can take the necessary action to reduce exposure and continue the necessary activities to provide their needs. In contrast, much of the livestock depending on man for their daily needs would be denied these inputs for several days as inferred from the data in Table V. The livestock most susceptible to this would be those depending on feed, water, and temperature control. A lack of water would be expected to increase the loss of livestock suffering from radiation sickness which characteristically increases the loss of body fluids.[17]

As discussed above, cattle are the main livestock reserve and they are least protected from fallout. The 1959 distribution of cattle is shown in Figure 2, which is still a fairly characteristic distribution. Since 1959, total cattle numbers in the United States have increased by 16 percent with an actual decrease in the number of milking cows and some changes in the percentages by states.

Death losses of cattle would vary with the concentration of livestock which varies from one cow per 20 acres on some range land to a concentration of 80,000 head on 300 acres in one Colorado feed-lot. The 1,000-rad ERD contours on this attack pattern primarily cover the heavy concentration of 2.6-million head of cattle in Colorado, have no effect on the 7.3-million head of cattle in Iowa, and would probably kill over 20 percent of the widely dispersed 10.2-million head of cattle in Texas.

TABLE IV.

CIVLOG-65 (U. S.) SURVIVAL OF LIVESTOCK AND POULTRY *

Item	Number in millions	Survival %
Milk cows	15	88
Other cattle	93	89
Swine	51	89
Sheep	24	89
Poultry	428	90

* National Resource Analysis Center and U. S. Department of Agriculture.

TABLE V.

CIVLOG-65 (U. S.) LAND ACREAGE AVAILABILITY *

Item	% Available for use in days**				
	1	4	10	30	180
Cropland	46	70	82	93	94
Pasture	51	74	85	93	94
Woodland	27	57	78	92	93

* National Resource Analysis Center.

** 50% probability.

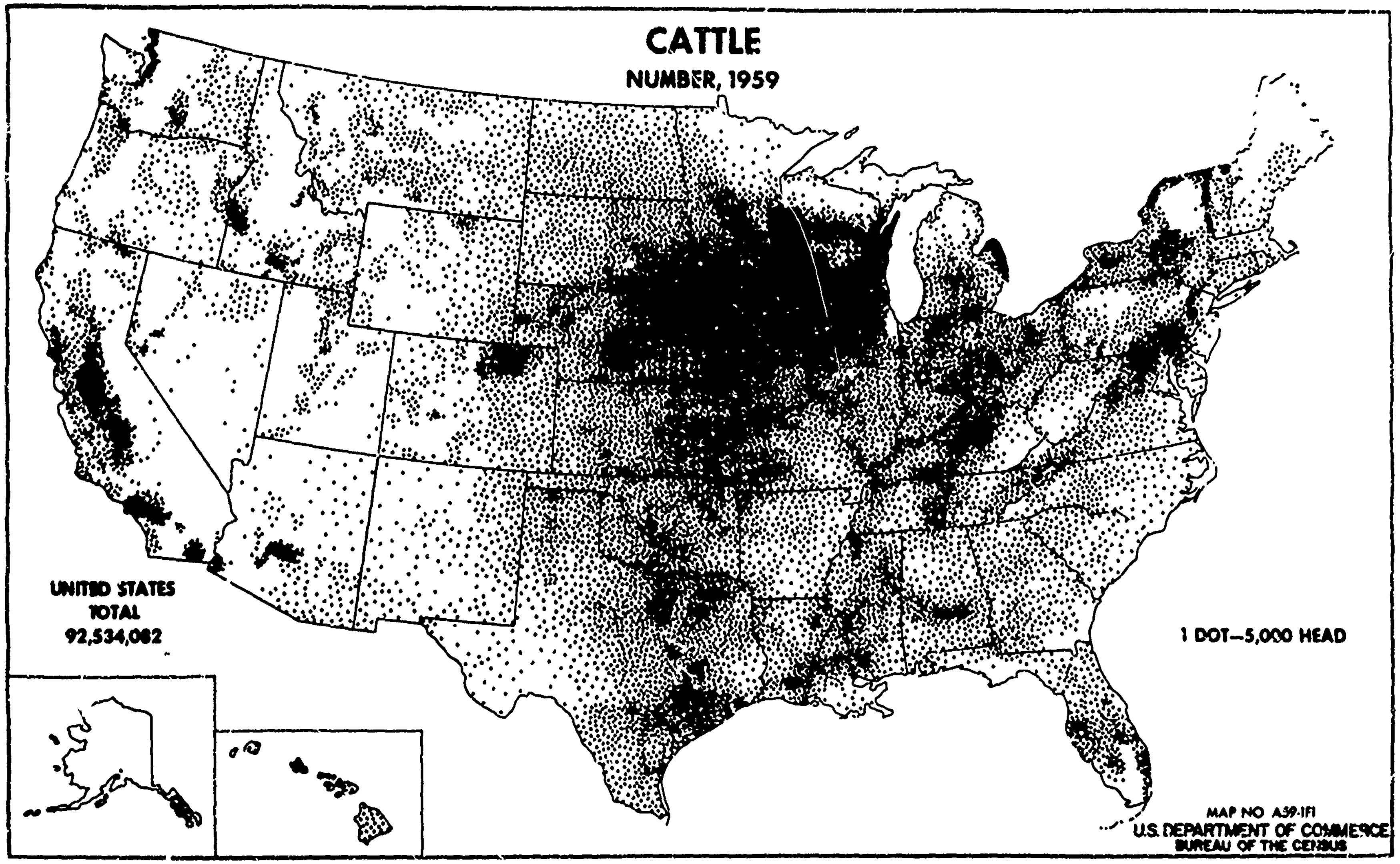

Figure 2. Cattle Distribution in United States.

Although the primary emphasis in this paper is on fallout-radiation effects, consideration should be given to blast effects as discussed by Damon et al,[18] from their shock-tube research on cattle. An LD_{50} reflected pressure of 43 psi of 184-msec duration was obtained for 180-kg steers and those injured but surviving 24 hours recovered. No data were found on the interaction of radiation, thermal burns, and blast effects.

COUNTERMEASURES AND RECOVERY

Shielding

To increase the livestock survival, it is recommended that advantage be taken of existing natural and man-made facilities to reduce exposure of livestock to fallout radiation. No survey data were found to be able to state the percentage of each class of livestock confined in buildings, but it is estimated that almost all of the poultry, over half of the swine, and about half of the dairy cows would be under cover that would protect them from fallout directly. In contrast, most of the 93-million cattle other than dairy cows would not be under a roof at any season of the year. Some of the animals could get protection from rough terrain, wooded areas, and existing barns and sheds normally used for crops and equipment. An assessment of the value of these factors is now being considered,[19] in addition to previously published information.[20]

Mills and Evans[21] have made an assessment of methods for protecting the more valuable animals through mutual shielding by close confinement of the animals as illustrated in Figure 3. The protection factor (PF) for most farm buildings may be small but these would at least reduce or prevent the skin damage from fallout such as that suffered from the Alamogordo cattle.[8]

Feed

The principal contaminated feeds of concern to livestock producers are the forages for grazing livestock. Providing uncontaminated stored feed for these animals, as recommended by the NAS-NRC report,[8] is an ideal solution if the animals are in confinement. For grazing livestock the main problem is that at the time critical for the survival of livestock ingesting contaminated pasture, there would be an undue exposure hazard for man as inferred from Table V. If time permitted, it might be better to confine the animals for which no cover is available in a small fenced area with water and no grazing for a few days in order to provide mutual shielding and to reduce the ingestion of fallout until decay has reduced the activity to a level tolerated by livestock. This recommendation is not practical for much of the range area.

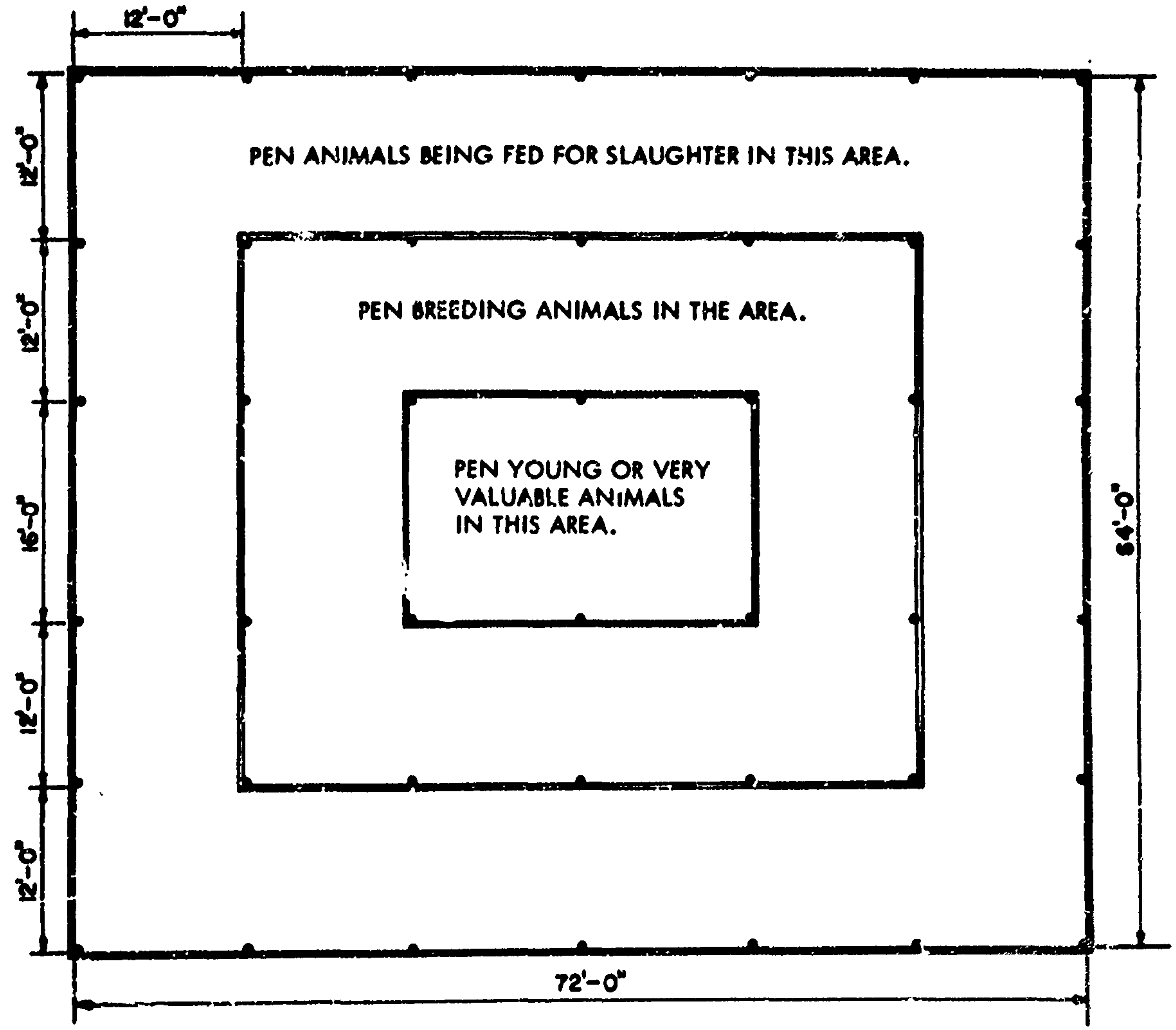

Figure 3. Livestock Confinement for Mutual Shielding.

Feeding livestock to reduce the amount of radioactivity in animal products is recommended, with milk producers and those soon to be slaughtered having the top priority for stored uncontaminated feed. These practices recommended for the long-term recovery phase could include the feeding of extra calcium to reduce strontium absorption; extra potassium to reduce cesium absorption; and extra iodine to reduce iodine-131 uptake by the thyroid. These feeding countermeasures will probably reduce uptake by 50 percent; however, precautions should be taken that these measures do not limit trace minerals required for normal body functions.[22]

Livestock Products

Livestock are good screeners against radioactive fallout, but even more progress can be made in reducing the human exposure by processing milk to reduce strontium-90[23] and meat to reduce cesium.[24] These practices would be considered only in regard to the long-term problems of reducing the exposure of man. Iodine is the principal short-half-life radioisotope and storage of milk to take advantage of natural decay is the easiest decontamination method.

Repopulation

In this era of specialization, care should be taken to effectively utilize the skills of the efficient livestock producers, balanced with the needs and availability of the necessary inputs of feed, water, and power facilities. Rebuilding rate is much faster for poultry and swine that require high-protein, complex, mixed feeds in contrast to a slow rebuilding rate for cattle and sheep which can be fed on less-expensive feeds not used by man (Figure 1). Fortunately, the framework for meeting disasters to agriculture has already been established through the county, state, and regional defense boards. In livestock-feed-deficit areas where only 3 to 10 days' supply is maintained at times, these defense boards would be prepared to request and recommend action for salvage and recovery of the livestock industry.

LIVESTOCK RESEARCH NEEDS FOR POSTATTACK RECOVERY EVALUATION

Needs are summarized as follows to determine:

1. Shelters available for livestock;
2. Retention of simulated fallout on cattle and forages;
3. Amount of unabsorbed radioactivity characteristic of early fallout consumed in 4 days or less to establish $LD_{50/30}$ to the gastrointestinal tract for cattle and sheep;

4. Interaction of combined insults which might be characteristic of insults to livestock in a fallout field. These include: blast and thermal effects; gastrointestinal, skin, and whole-body exposures; and deprivation of feed and/or water;
5. Wholesomeness of food products from lethally irradiated animals; and
6. Guidelines to help establish levels of radioactivity in livestock products which would be acceptable for human consumption in postattack recovery.

SUMMARY

After major disasters, food supplies and food production have played important roles in recovery. Livestock in the United States valued at $19 billion are a major food reserve item of significance to postattack recovery. Our food reserve of cattle, valued at $16 billion, thrive on feeds not suited for man and they also help to screen out dietary undesirables such as radioactive fallout. Livestock-survival estimates for CIVLOG-65 are similar to human-survival estimates. These estimates of survival of livestock might be much lower if consideration is made for the interaction of gamma radiation with other insults such as: blast and thermal effects; gastrointestinal and skin damage; and deprivation of feed and/or water.

The productive life of livestock surviving a thermonuclear attack would probably not be materially affected provided the necessary production inputs were supplied. Guidelines are needed to help establish levels of radioactivity in livestock products which would be acceptable for human consumption in postattack recovery.

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FACTORS LIMITING POSTATTACK AGRICULTURAL RECOVERY

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The guiding principle of the practice of epidemiology is to study the chain of factors that contribute to the epidemic in an effort to break that chain at its weakest link. One considers the probable reservoirs of infection, the host, the probable methods of spread of infection, the extrinsic, usually environmental, factors and the intrinsic factors such as host susceptibility. Of interest is the fact that one of the least important factors is the identity of the disease agent.

A study of those factors limiting postattack agricultural recovery is a straightforward exercise in epidemiology. Blast and thermal effects can be considered as single host agents, and radiation a multiple host agent because of its ability to migrate in the biosphere. There is a fourth disruptive agent for agriculture which, although a product of radiation, can be considered separately. This is denial time. Although it is more important in this study to consider the disruptive agent, it is equally true that the elucidation of the weak links is much more important than the character of the agent.

Many studies have been made on the impact of nuclear war on agriculture. In most if not all an empirical approach was used; that is to say a statistical appraisal of the geographic distribution of probable weapon strikes was made against the agricultural input-output capability of the weapon effects area. This was then expressed in terms of regional and/or national totals. The results of one such study (CIVLOG 65) are as follows:

Industry	Percent Remaining D+30
Meat packing	40
Meat products	46
Dairy products	40
Canned and frozen foods	51
Prepared flour	20
Grain-mill products	47
Bakery products	31
Sugar	44
Agricultural chemicals	46
Fertilizers	56

Industry	Percent Remaining D+30
Pesticides	20
Farm machinery and equipment	72
Food-products machinery	43
Metal cans	29
Pressed and blown glassware	61

Once the statistical analysis is completed for all industry it is possible to study the interdependency problem. It was noted, for example, that, although 70 percent of U. S. industry survived, the uneven pattern of lost and surviving assets would not permit production at 50 percent of the preattack level. It can be seen from the above table that the food industry was hard hit. Although not noted in the industrial analysis, commodities at the farm and ranch as well as grain storage survived much better than the capacity to process these commodities. For example, livestock survived 89 percent.

The U. S. Department of Agriculture (USDA) has defined 8 Food Groups. These are purely arbitrary and suit the needs of USDA State and County Defense Boards in food listing.

1. Meat and meat alternates.
2. Eggs.
3. Milk and dairy products.
4. Cereal and cereal products.
5. Fruits and vegetables.
6. Fats and oils.
7. Potatoes.
8. Sugar, syrups, honey and other sweets.

In addition, they use a ninth category, that of "wholesale food distribution facilities."

If one is to appreciate the disruptive effect of an attack on our food supply it is necessary to understand the relative disposition of these 9 categories.

Group 1. Meat and meat alternates include red meat, fish, and the processed meat products. Although in the past, meat packers were located in major centers like Chicago, this is no longer true. They have moved closer to the source of supply. Even though refrigeration is required, it is cheaper to ship the processed product to the population centers than it is to ship the live animal to these centers and pay the high cost of labor in these cities. Some of these centers still remain, such as Omaha, but the industry is becoming less vulnerable. It is, on the other hand, more dependent on specialized transportation. Fish, particularly sea food, is and will continue to be highly vulnerable since the commercial fleets operate out of the large ports which are obviously high-risk areas. Processed meat production takes place in the large population centers and is therefore in the same category as the population itself -- and can be expected to survive in the same ratio.

Group 2. Eggs, including poultry, are located in widely scattered areas and the processing industry is located near them. The broiler industry, however, is heavily centered in the southeast in a feed-deficit area. In addition, as noted in Dr. Bell's paper, poultry require the kind of feed which places them in direct competition with the surviving population. It is ironic that poultry are quite radioresistant, are for the most part in shelter, and yet, because of production practices, may not survive the disruptive effects of the attack.

Group 3. Milk and dairy products are really in two categories as far as vulnerability is concerned. With the advent of bulk tank transportation, fluid milk is hauled distances of 500 miles and more for processing. Most of this transportation is to serve the major metropolitan centers which, if destroyed, would create surplusses in one area and deficits in another several hundred miles away. On the other hand, a disruption of transportation routes could delay for some time the delivery of milk to such a metropolitan area. Finally, fallout over the milk production area might prevent dairymen from leaving shelter and thus might have serious if not permanent effect on dairy cows.

The dairy cow in this country is a completely artificial animal. Nature never intended that a cow, any cow, produce 100 pounds of milk a day, and yet many of them do. These animals are bred for production, fed for production and housed for production. They are so dependent on man that neglect even for a few hours may mean disaster. For a dairyman to miss even one milking can mean mastitis. Untreated mastitis for these cows can mean death in a few days. If she survives the mastitis that means a drastic reduction if not cessation of production for that lactation. For a cow that has recently started to milk it means she may be out for a year. If possible a dairyman could put his calves in with the cows before he himself goes into shelter in order to prevent this consequence but it is common practice for commercial operators to sell the calves to a calf feeder a few hours after birth.

Group 4. Cereal and cereal products includes flour milling, dry-corn milling, cereal preparation, rice milling, wet corn milling, bread and other bakery products, cookies and crackers, malt and malt liquors, liquors and macaroni and related products. This, too, is a mixed category as far as vulnerability is concerned. For example, the production of high-quality flour is concentrated in just two cities; Minneapolis/St. Paul and Buffalo. On the other hand, anyone with a hammer mill and a fine screen can grind flour from which bread can be made. Cereal production is concentrated in a few major centers but bakery products are produced in the smallest of towns. We can all be thankful that distilleries are widely scattered as are the breweries.

This entire group shares a very serious problem, however. They are for the most part completely automatic, computer-operated complexes operating in the field of biochemistry and electronics. Many of them have incredibly complex special purpose machinery which is dependent on so many other industries for parts and services that one cannot do an independent analysis of this industry.

Group 5. Fruits and vegetables are for the most part relatively invulnerable. Fallout over the production area could deny access to the crop at the time of harvest and cause a serious disruption in supply, but many of the vegetables grow in areas where the farmers reap two and three crops a year. For the most part the recovery would be fairly fast.

Group 6. Fats and oils. In the vegetable-oil industry there are two categories: crushing and refining. The crushers are located near the source of supply and thus are widely dispersed and relatively invulnerable. Many of these plants used to refine the oil as well, but this practice has changed and the refineries are now less dispersed, larger, and located in or near large population centers. Since they are vulnerable, the use of oil for baking and cooking will certainly be curtailed. The animal fats fall into the same category as meat since renderers are dependent on and located near the parent industry. Likewise marine fats and oils are vulnerable, since this industry too is located in the major ports near to the source of supply.

Group 7. Potatoes are perhaps the least vulnerable of all. The crop can be left in the field for some time with little damage, it can be stored in warehouses for a long time, it is easily decontaminated by washing and peeling and is very nutritous. Commercial potato production is naturally located in areas best suited to large yields. However these areas are widespread enough so that transportation should be considerably less of a problem than with some of the specialty crops like citrus.

Group 8. Sugar, syrups, honey and other sweets. The major industry in this category, sugar, is quite vulnerable to attack. The U. S. must import a large percentage of its domestic requirement, usually in the form of cane. The cane refineries are located in major sea ports and are therefore highly vulnerable.

Group 9. Wholesale food-distribution facilities are normally located in the population centers so they, too, can be expected to survive in about the same ratio as the population.

It can be seen from the foregoing that both extrinsic and intrinsic factors are involved. Those that can be considered as intrinsic are the location of the industry in high-risk areas, and the effect of denial time on the industry. Those that can be considered to be extrinsic are the dependency on other high-risk industries, and the effect of denial time on the basic inputs.

Dr. Shinn has referred to the fact that varying the time of the attack would result in very different effects on the ultimate availability of food crops. He referred to the effect of radiation on plants of a specific age. There are additional factors involved. Planting times are critical for many areas where the growing season is short. It will be interesting indeed to observe the effect of the recent disruption in China. The crops were planted late by the Red Guard who were largely unskilled in agricultural methods. It is not likely that a similar situation would occur in this country in a postattack period. Ninety-five percent of all farm machinery is on the farm and the farm population is expected to survive considerably better than the general population. Nonetheless a delay in planting could occur and an assessment of the Chinese situation might determine which of the two factors was the most important.

It is possible to identify other factors which merit additional study. The availability of seed for planting has been said to be adequate under various postattack situations. One cannot really evaluate the seed situation on a statistical basis alone. In an effort to achieve highest yield in the face of widely varied climatological conditions and soil types, literally hundreds of varieties of many species have been developed by the USDA. Incipient, recurring disease has caused the development of many more varieties. These varieties are so specific that a change can occur from one side of a river to another. A shortage of a specific variety in a specific area can lead to markedly reduced yields.

Any veterinarian engaged in large-animal practice will tell you that by far the largest majority of the problems he is called upon to treat are caused by errors in management and not infectious or contagious disease. By far the largest majority of management errors concern feeding practices. One can feed an animal dozens of different nutrients so long as the same mixture is fed daily. To change the feed without causing an untoward physiological result takes a considerable period of time with a gradual changeover. To do it rapidly results in constipation, diarrhea or bloat. Any of these conditions, if untreated, can cause death. As with the dairy cows, our feeder-cattle of today are highly complex, man-dependent animals. If one attempts to analyze the effects of an attack on the feeder-cattle industry, one must take into account the effect of denial time.

In every hypothetical-attack pattern studied it has been shown that the two overriding limiting factors are fuel and electricity. Fuel on the farm and fuel for transportation, electricity on the farm and electricity for food processing; these are the keystones of production. In this paper a few examples of the many other factors which merit serious study have been outlined. It may be that these extrinsic and intrinsic factors cannot be reduced to computer language. This fact does not reduce the problem, it merely makes the job more difficult. In the opinion of the author a panel of specialists in the biological and economic field could perform such a study without considering the cause of the disruptive agent. Once all of the weak links have been identified, those in policy-making positions would at least be in a position to study the alternatives open to them.

HEALTH

W. Palmer Dearing, Chairman

In planning and organizing the session, Dr. Dearing was assisted by Dr. Henry C. Huntley and Dr. Robert Price.

A SIMULATION MODEL

OF AN

EMERGENCY MEDICAL SYSTEM

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INTRODUCTION

A computer simulation model has been developed to determine the effectiveness of alternative medical-support systems in the immediate postattack period. This model allows an in-depth examination of the problems of allocating scarce medical resources among overwhelming demands caused by the direct-effects caseload.

The model is intended to describe all essential elements of an emergency medical-support system in a community. Limiting study to a community is reasonable, in that lack of communications and transportation in the postattack period would tend to isolate groups of survivors. The inputs are the casualty types resulting from a specified attack. These are treated by the medical resources -- personnel, facilities, and supplies -- according to predetermined rules of triage or treatment priorities. The resources may be varied through input data to test the impact of the level of medical stockpiles, packaged disaster hospitals, etc. on the measure of system effectiveness: survivors added by the emergency medical system. Secondary output, available at the option of the user, include utilization of medical personnel and other specified resources.

The simulated community consists of several geographical areas, called grids. One of the grids is the hospital grid, which contains the total hospital capability of the community; the others contain emergency-medical-treatment centers. Casualties originate in all grids. A treatment table, consisting of prognosis data, treatment times for injuries, and priorities, is stored in the computer's memory. The table is consulted and available resources applied to casualties (in batches) in the order of their preassigned priorities for treatment. Provision is made for the treatment level to be altered depending upon

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the availability of personnel. The appropriate prognoses are applied to the injured, deaths and survivors are estimated and recorded, and available resources depleted. The nonhospital grids are processed, then the hospital grid, and finally, transfers to the hospital from the nonhospital grids. Grand totals for the run are prepared and printed out as well. The current model is applicable only to the first few days postattack.

The remainder of the paper discusses model-input data, operation of the model, output data, design of the simulation experiments, and results of simulation runs.

SIMULATOR INPUT

The input data required by the simulation program consist of the following items:

Injury Caseload

The injury caseload is prepared outside the model. Each injury is defined in sufficient detail to allow specification of care requirements and prognoses under a variety of treatment options, as described further below.

It was originally anticipated that detailed information would be available from ongoing studies concerning specific types of injuries as a function of shielding and weapon parameters. These studies were not sufficiently advanced to provide the required data.

For case studies with the model, injury data have been developed for a California city subject to a 1-MT airburst over a military target about 12 miles northwest of the city center. A burn and mechanical injury spectrum was estimated using Dikewood curves[1,2] and assumptions regarding resident construction and population. Dikewood casualty curves yielded estimates of the total number of injuries only (no detailed indication of injury types or of multiple injuries). Accordingly, 49 injuries not involving radiation exposure have been derived as representative of the likely injury spectrum; combination injuries -- radiation plus the above -- and pure radiation injuries have also been selected. Protection data, i.e., shielding posture, and the population data base were developed from conventional sources (National Fallout Shelter Survey, U. S. Bureau of the Census Data, the Office of Civil Defense (OCD) Five-City Study, Community Shelter Plans, etc.). No significant fallout was present. Data on a second city were obtained from a recent report by Bio-Dynamics, Incorporated.[3] This report treats a New England city which was subject to fallout in addition to direct effects.

Prognoses

A medical prognosis is required for each injury. The prognosis is an estimate of the probability of death from an injury as a function of both the kind of treatment employed and the time delay before treatment. The generation of these input data is a significant contribution of this research. Numerical values were estimated by Dr. Warner Wells of the University of North Carolina School of Medicine.

The prognosis for each injury as a function of time takes the general form illustrated in Figure 1.

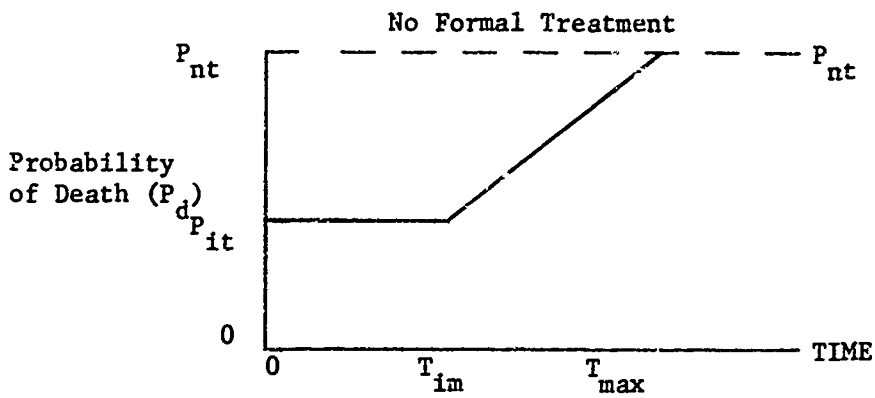

Figure 1. Injury Prognosis.

As can be seen, the prognosis function is composed of three segments: (1) time zero to T_{im}, during which a specified treatment is maximally effective and probability of mortality is lowest; (2) T_{im} to T_{max}, during which the prognosis steadily decreases; and (3) beyond T_{max}, when the probability of death with treatment equals that with no treatment.

The Preferred and Actual Level of Treatment

Several levels of treatment are available in the model. These range from surgical teams to no treatment, and include treatment by physicians, medical self-help personnel, and hospital care, etc.

One of these defined levels of treatment is specified as the "preferred" treatment for each injury type. The preferred treatment is the lowest level which will not greatly reduce the chances for survival of the injured person.

Availability of personnel and supplies effects the actual treatment provided to the injured in the model. Thus, it was necessary to establish as input a table of the decision rules and alternative prognoses for various treatment options for each of the injury types considered. The decision rules specify for each injury type (1) the preferred treatment and (2) alternatives to be used when the preferred treatment is not available.

As treatment personnel become saturated and waiting lines form, the time which a casualty must wait for treatment increases. The program calculates the waiting time; if it exceeds T_{im} (that initial period during which a delay in treatment does not alter survival probabilities), then the prognosis under conditions of delayed treatment is calculated. This prognosis is compared with the prognosis calculated using the level of care downgraded to the next lower level. If the probability of death is less using the lower level of care -- which may be the case if the lower level of care will be available sooner -- the casualty is assigned to the next lower level of care.

The procedure is illustrated in Figure 2. Assume the calculated time to treatment under the preferred level (hospital care) is T_A, with corresponding prognosis A. Since $T_A > T_{im}$ prognosis under the downgraded level (physician care in an emergency center) is calculated; if $P_B < P_A$ then treatment is provided by physicians outside the hospital.

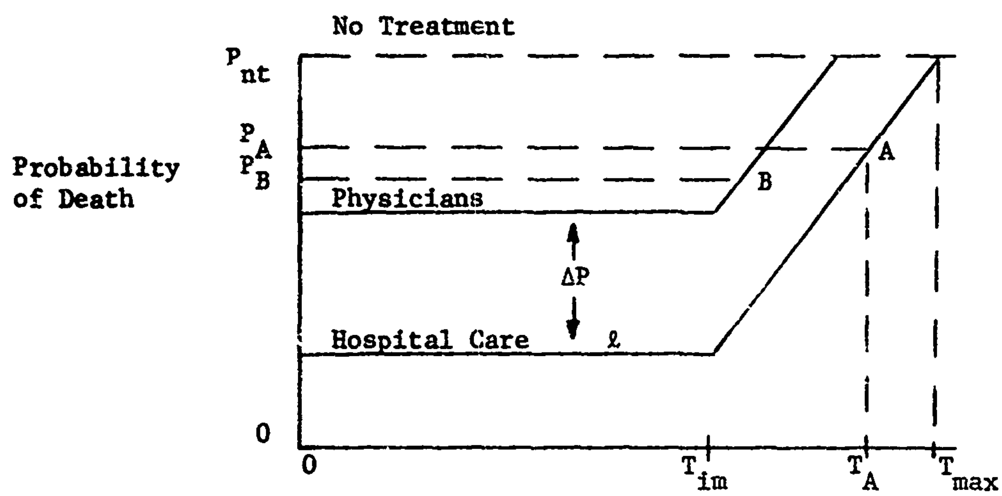

Figure 2. Injury Prognosis for Two Levels of Treatment-- Hospital Care is the Preferred Treatment.

If this downgraded care level is also saturated to a point where the prognosis cannot be improved by downgrading, the next higher quality of treatment level is examined. If all levels of care are saturated to a time greater than T_{max}, the injured are transferred to the hospital.

In the hospital, injured are treated at the preferred level of treatment unless that level is saturated, in which case, alternatives are examined as above.

Priority Rule

An essential aspect of disaster medical treatment is triage,[4] the sorting of the injured into categories according to treatment priorities. Effective triage will increase the number of survivors subject to the constraints of limited medical resources.

Two schemes have been employed for determining the priority for treatment of each injury category. These are described in detail in the section on results in this paper. Both schemes reflect plausible reasoning and well-known principles regarding the response of queuing systems to various queue disciplines. The basic approach involves consideration of ΔP_ℓ (the degradation in probability of survival owing to downgraded care), T_T (time required for treatment) and T_{im} (the time period during which delay of treatment does not degrade the prognosis). A highest priority patient would be one with minimal T_{im} and T_T, and maximum ΔP_ℓ. The priority function, which ranks injury categories in order of priority for treatment within each preferred treatment level, is:

$$\text{Treatment Priority} = \frac{\Delta P_\ell}{T_{im} + T_T}$$; high values mean high priority for treatment.

An alternative priority scheme was used in one supplementary run to provide some insight into the sensitivity of model response to decision rules. The alternative gave the highest priority to injuries requiring the shortest treatment time; it is in accord with the well-known queuing-theory conclusion that such a priority scheme maximizes the number of patients treated. In the data used in this study, long treatment times are associated with relatively more life-threatening injuries; the shortest treatment-time priority scheme should therefore tend to maximize survivors added.

The Abstraction of the Community

The community is defined by a group of subareas, called grids. Within each grid the casualties are treated by the medical facility contained therein. Every grid has some medical facility, even if only medical self-help personnel in a fallout shelter. The quality of treatment in each facility may vary widely. One grid contains the entire hospital capability in the community.

Medical Resources

Estimates of existing and surviving treatment facilities, personnel, and supplies and equipment are made for each community studied.

1. Treatment facilities are of two types, i.e., hospital and emergency-treatment facilities. The hospital facilities include operating rooms, specialized personnel, and medical supplies. General and specialized hospitals and the 200-bed packaged disaster hospitals correspond to this facility definition.[5] Emergency-treatment facilities may be located at a stocked fallout shelter, a physician's office, a medical-arts building, or a drug store.

2. Treatment personnel are defined in the simulation model as follows:

   (a) physicians -- all physicians, including osteopaths, regardless of specialty;

   (b) allied medical personnel -- professionals, excepting physicians, associated with the medical field. Included are dentists, veterinarians, nurses, x-ray technicians, etc. Persons trained in medical self-help[6] could be separately recognized within the model. Current prognosis input data equate them with allied medical personnel.

3. For supplies, equipment and services provision has been made to record inventories of expendable items as they are used in treatment. Sixteen medical treatment packages required for classes of injuries have been derived based on the MEND[7] recommendations.

   The model assumes a functioning hospital having potable water, electricity, etc. No provision is made for degrading prognoses for lack of anything except medical supplies or personnel. The supplies available at emergency-treatment centers contain at least the equivalent of medical kits stocked in fallout shelters.

OPERATION OF THE SIMULATION PROGRAM

Figure 3 gives a highly simplified version of the logic of the simulator program. For every grid and at each level of preferred treatment, the simulator considers the injury category with the highest priority, then the next highest, and so on. If no treatment is the preferred level of treatment, either because the injury is minor or very severe, the proper prognosis is applied and entries are made in the appropriate records. If a surgical team is the preferred level of treatment, the cases located in a nonhospital grid are immediately transferred to the hospital, since surgical teams are only available in the hospital grid. Limitations to travel (fallout fields, vehicles, fuel, etc.) are not considered.

If the case is to be treated within the grid -- hospital or nonhospital -- the model first determines whether personnel are available at the preferred level. If personnel and appropriate supplies are available, the prognosis is applied, deaths are recorded, supplies are depleted, and personnel time clocks are advanced to record the times spent in treatment.

If personnel are not available at the preferred level, a check is made for persons at the next lower treatment level. If personnel are not available at the lower level, a check is made for the availability of higher level personnel. If all three levels are occupied, the case is transferred to the hospital. A lower level of care than the preferred level degrades the prognosis; a higher level leaves the prognosis unchanged.

After determining the level at which treatment will be administered, a check is made for the availability of supplies. If treatment is to be given without prescribed supplies, the prognosis associated with the treatment level is reduced to a point midway between the prognosis with supplies and that with no treatment. An option available in the program provides that if the required medical supplies are exhausted, preselected casualty categories are transferred to the hospital. This option has not been used in the current studies because early runs indicated that the hospital would be overloaded with casualties from the hospital grid and such transferees would not be treated in any event.

After the analysis for all nonhospital grids is completed, the hospital grid is processed through the same program logic. Hospital transfers are finally processed and totals for the run are the output.

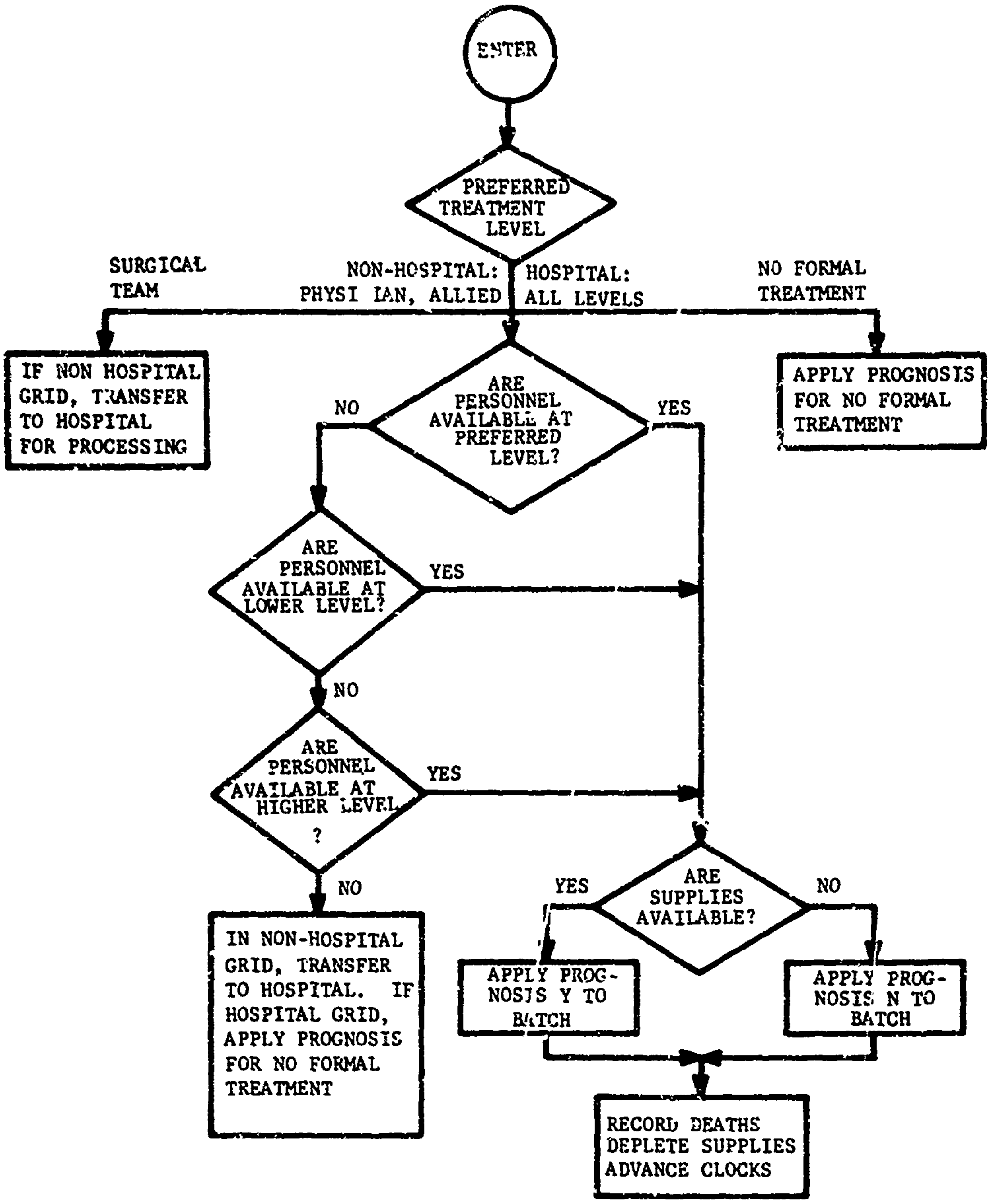

Figure 3. Simplified Flow Chart of the Simulation Program.

Output of the Simulation Program

The simulation output contains for each grid, including the hospital grid, and for the total community:

1. The number of injured by preferred treatment levels.
2. Treatment actually furnished to the injured: level of medical treatment with or without supplies, downgraded treatment, upgraded treatment, no treatment, sent to hospitals, etc.
3. Disposition of casualties -- survivors or fatalities.
4. Medical treatment packages initially available, used, and remaining.
5. Medical personnel utilization -- for each treatment level, the hours available and the hours used.

DESIGN OF THE SIMULATION EXPERIMENT

General Description

The model has been used in a number of case studies. A balanced set of factorial simulations has been employed to explore the complex interactions among injury spectra, resources, and prognoses. The effect of availability of resources on survivors -- including the level of resources available and their dispositions -- was studied. Thus, the quantity of supplies available in the hospital and in the several grids was varied independently. The number of medical personnel available and their disposition -- grouped into hospitals or dispersed through the grids -- was varied. These factors represent elements of the system which are controllable to some extent by planners.

Other significant factors which could be studied, but have not been as yet, include variations in prognosis data (except for one run which varied the ratio of T_{max} to T_{im}) and treatment times. Prognoses data determine the estimates of survivors, other things being equal. Treatment times are highly significant, since with the saturated queues and limited personnel likely in a postattack situation, the effect of halving treatment times is equivalent to a doubling of available personnel.

The Basic Factorial Study

The experiments were designed to analyze important additional factors, such as different casualty spectra which might result from a warned versus an unwarned population, and the kinds of problems likely to result from differences between cities or attacks. Accordingly, two separate casualty spectra have been prepared for each city, based on the assumption of warning or no warning; further, one of the simulated cities was subjected to an air burst and the other to a surface burst.

Table I presents a summary of the factors and levels included in the factorial design.

TABLE I

FACTORIAL STUDY OF SYSTEM PARAMETERS

Factor	Level (1)	Level (2)
Cities	A	B
Supplies (grid)	Best estimate of those actually available	2 X best estimate
Supplies (hospital)	Best estimate of those actually available	2 X best estimate
All medical personnel (surgical teams, physicians and allied)	Best estimate of those actually available	2 X best estimate
Physicians	Most in hospitals	Dispersed
Casualty spectra	Minimum (warning assumed)	Maximum (no warning assumed)

Bounds of System Performance

In addition to the balanced set of runs, special runs were made to determine the upper and lower bounds on system performance for each city and for each casualty spectrum within each city. The boundaries were estimated by simulating the system first with zero resources, and second, with the maximum resources allowed by the computer program. The resources included all classes of medical personnel and medical supplies.

Under conditions of zero resources, the casualties received the prognosis associated with no treatment. The maximum resources allowed by the program were many times as large as the levels likely to prevail. Processing the simulation with these practically unlimited resources resulted in a relatively large percentage of injured receiving treatment prior to T_{im} at the preferred level of treatment. This provides an estimate of the lower bound on the number of deaths attainable by an ideal system.

Sensitivity Analyses

Additional runs were made to test the sensitivity of results to variations in the ratio to T_{max} to T_{im} and to alternative methods for determining the treatment priority associated with each injury category.

For the factorial study, $T_{max} = 2\ T_{im}$ was assumed for every injury. One additional simulation run was made in which T_{max} was set at 4 times T_{im} for each injury. These runs were made with all resources -- i.e., supplies and personnel -- set at the low level and personnel dispersed. The relationships determined in this way are obviously rough approximations since the relationship between T_{im} and T_{max} may differ for every injury category.

Many alternative schemes might be devised for stipulating the treatment priority of each injury. In addition to the priority rule discussed previously, a second rule, assigning highest priorities to cases requiring the shortest treatment time, was chosen. Under the latter rule the maximum number of patients are treated during the simulation period.

RESULTS OF THE SIMULATION RUNS

The results of 32 runs representing all combinations of five factors, each set at two different levels, are reported here for City A (without radiation casualties). The discussion of results is based on these runs since the results for City B are quite similar.

Tables II and III give the number of deaths for each of the 32 runs on City A. Table II gives the results of the 16 runs with the high casualty spectrum developed on the assumption of an unwarned population. The 63,832 injured developed under this assumption were classified by study personnel into the 49 specific casualty categories recognized by the simulator.

Because of the balanced design of these 32 runs, 16 runs may be averaged with one factor at its high level and the other 16 with the factor at its low value. The average value of this single factor may then be computed by taking the difference between these two averages.

TABLE II

SIMULATED NUMBER OF DEATHS FOR VARIOUS SUPPLY AND PERSONNEL STRATEGIES

(High Casualty Spectrum)

			ESTIMATE OF HIGH NUMBER OF CASUALTIES					
			ZERO RESOURCES 28,814		MAXIMUM RESOURCES 23,788			
			GRID SUPPLY LEVEL HIGH		GRID SUPPLY LEVEL LOW			
			HOSPITAL SUPPLY LEVEL HIGH	HOSPITAL SUPPLY LEVEL LOW	HOSPITAL SUPPLY LEVEL HIGH	HOSPITAL SUPPLY LEVEL LOW	ROW TOTALS	ROW AVERAGES
CITY A	PERSONNEL	GROUPED NORMAL	27,189	27,206	27,226	27,243	108,864	27,216
		GROUPED DOUBLED	26,684	26,708	26,718	26,744	106,854	26,714
		DISPERSED NORMAL	27,257	27,278	27,310	27,326	109,171	27,293
		DISPERSED DOUBLED	26,679	26,708	26,739	26,762	106,888	26,722
		COLUMN TOTALS	107,809	107,900	107.993	108,075	431,777	
		COLUMN AVERAGES	26,952	26,975	26,998	27,019		26,986

T A B L E III

SIMULATED NUMBER OF DEATHS FOR VARIOUS SUPPLY AND PERSONNEL STRATEGIES

(Low Casualty Spectrum)

			ESTIMATE OF LOW NUMBER OF CASUALTIES					
			ZERO RESOURCES 14,962		MAXIMUM RESOURCES 12,316			
			GRID SUPPLY LEVEL HIGH		GRID SUPPLY LEVEL LOW			
			HOSPITAL SUPPLY LEVEL HIGH	HOSPITAL SUPPLY LEVEL LOW	HOSPITAL SUPPLY LEVEL HIGH	HOSPITAL SUPPLY LEVEL LOW	ROW TOTALS	ROW AVERAGES
CITY A	PERSONNEL	GROUPED NORMAL	13,970	14,027	13,997	14,054	56,048	14,012
		GROUPED DOUBLED	13,724	13,796	13,751	13,826	55,097	13,774
		DISPERSED NORMAL	13,999	14,038	14,026	14,065	56,128	14,032
		DISPERSED DOUBLED	13,791	13,863	13,818	13,890	55,362	13,841
		COLUMN TOTALS	55,484	55,724	55,592	55,835	222,635	
		COLUMN AVERAGES	13,871	13,931	13,898	13,959		13,915

The design of the runs is shown graphically for the maximum casualty spectrum in Figure 5. Using the data in Tables II and III, the average effects of each single factor are computed and shown in Table IV.

TABLE IV

AVERAGE EFFECT OF FACTORS ON SURVIVORS ADDED
(GRAND AVERAGE DEATHS = 20,450)

Factors Varied	Survivors Added
All medical personnel doubled	376
Physicians distribution (grouped more effective on the average)	43
Hospital supplies doubled	41
Grid supplies doubled	36
Difference between case of all factors at best level and at worst level in factorial design	494
Difference between essentially infinite resources at zero resources	3,836

Upper and Lower Bounds on Medical Support System Performance

An initial analysis considered the number of deaths with zero resources -- all received the prognosis associated with no treatment -- and with the maximum possible personnel and supply resources. These figures are shown in Tables II and III for the high-and low-casualty spectra. Because of the balanced runs in this design, any factor can be evaluated by using half the runs at one level and the other half of the runs at the second level for the factor. It is therefore useful

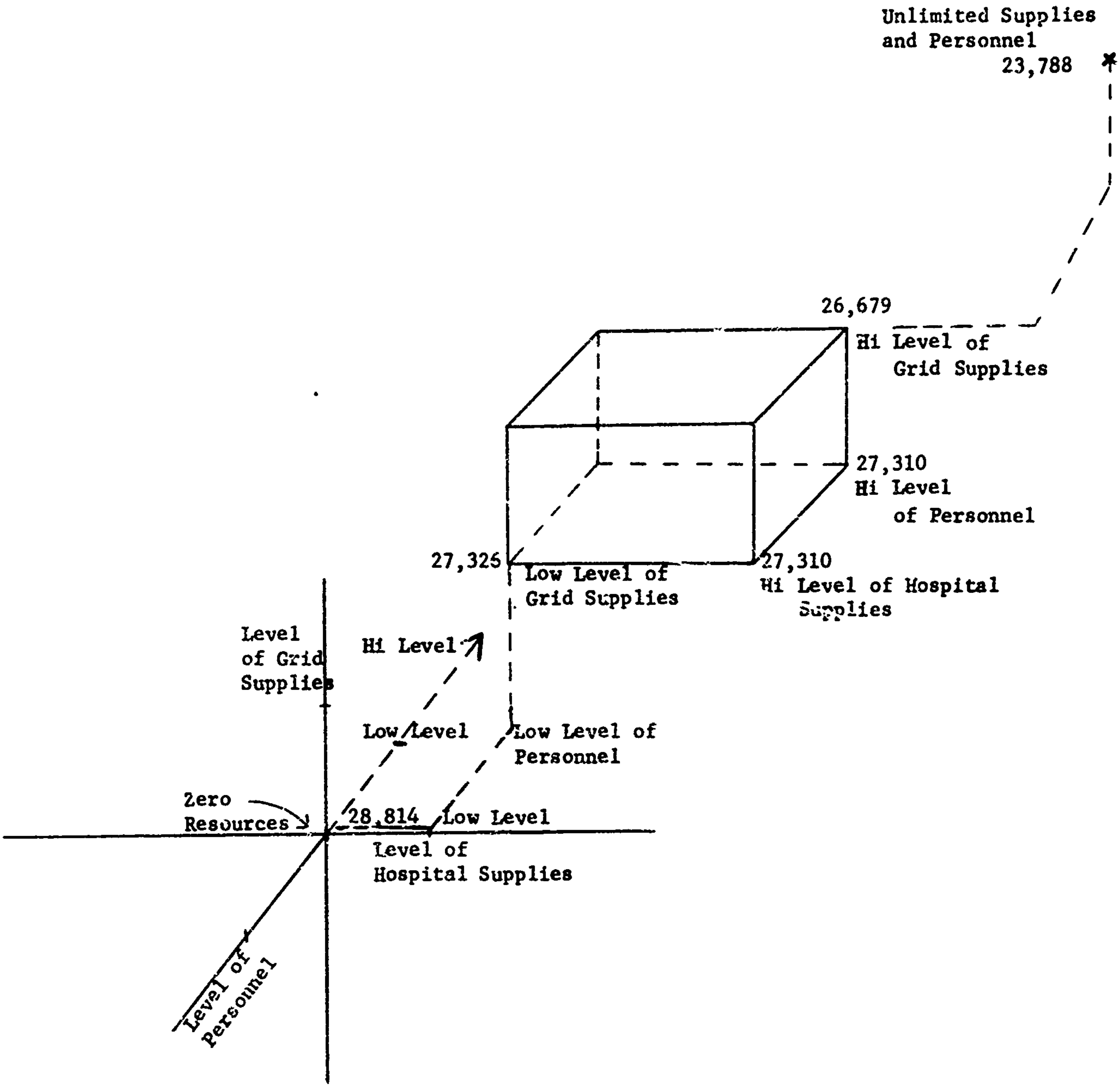

Figure 5. Deaths as a Function of Resource Levels.

to contrast the effect of zero and infinite resources in these runs averaged over the two spectra. For zero resources, the average number of deaths is 21,888 and for essentially infinite resources it is 18,052. All intermediate levels of resources fall in this range. Thus, the maximum range of average performance of the medical system is 3,836 survivors added, or about 2.5 percent of the number of injured.

The Effect of Increasing Resources

Numbers of medical personnel is the factor of overriding importance. Distribution of physicians, grid supplies, and hospital supplies is much less important; the effects of these three factors are approximately equal. The fact that the sum of the effects of the four factors (494) is almost three fourths of the average difference between the best combination and the worst combination of factors (326 and 647 deaths in Table II and 724 deaths in Table III) reflects the weak interaction among factors. Interactions will be discussed below.

Interactions Among the Factors

The second graphical illustration was made to display not only main effects of the factors considered, but also interactions among the several factors. Figure 6 is a graphic presentation of survivors added, plotted in a manner to show two-factor interactions. The effects of each factor alone are quite evident. The interactions are interpreted in the following way: if the low and high lines are not parallel there is a two-factor interaction between deaths and the variable plotted on the ordinate. In statistical terms, the conditional probabilities of death with respect to the two factors are not independent; that is, the two-factor interaction means that as one of the factors is varied from a low level to a high level, the effect of the other factor is altered. In Figure 6 the only interaction is between casualty spectrum and personnel levels. The graph has been scaled to represent survivors added, or the difference between deaths with zero resources and deaths with the given level of resources. Points on the graph are determined in the following way. For the high-casualty spectrum (results were given in Table II), the eight results when grid supplies were low were averaged to provide a level of survivors-added of 1,806. The eight results with grid supplies at the high level averaged 1,850. The intercept points for the low spectrum, from Table III, were determined in similar fashion and plotted on the same chart.

Figures 6, 7, 8, and 9 were constructed to illustrate each of the two-factor combinations. Each of the four intercept points is an average of one quarter of the runs.

The graphical analysis illustrated that a remarkable independence exists among the factors, i.e., lack of interaction. In only one of the

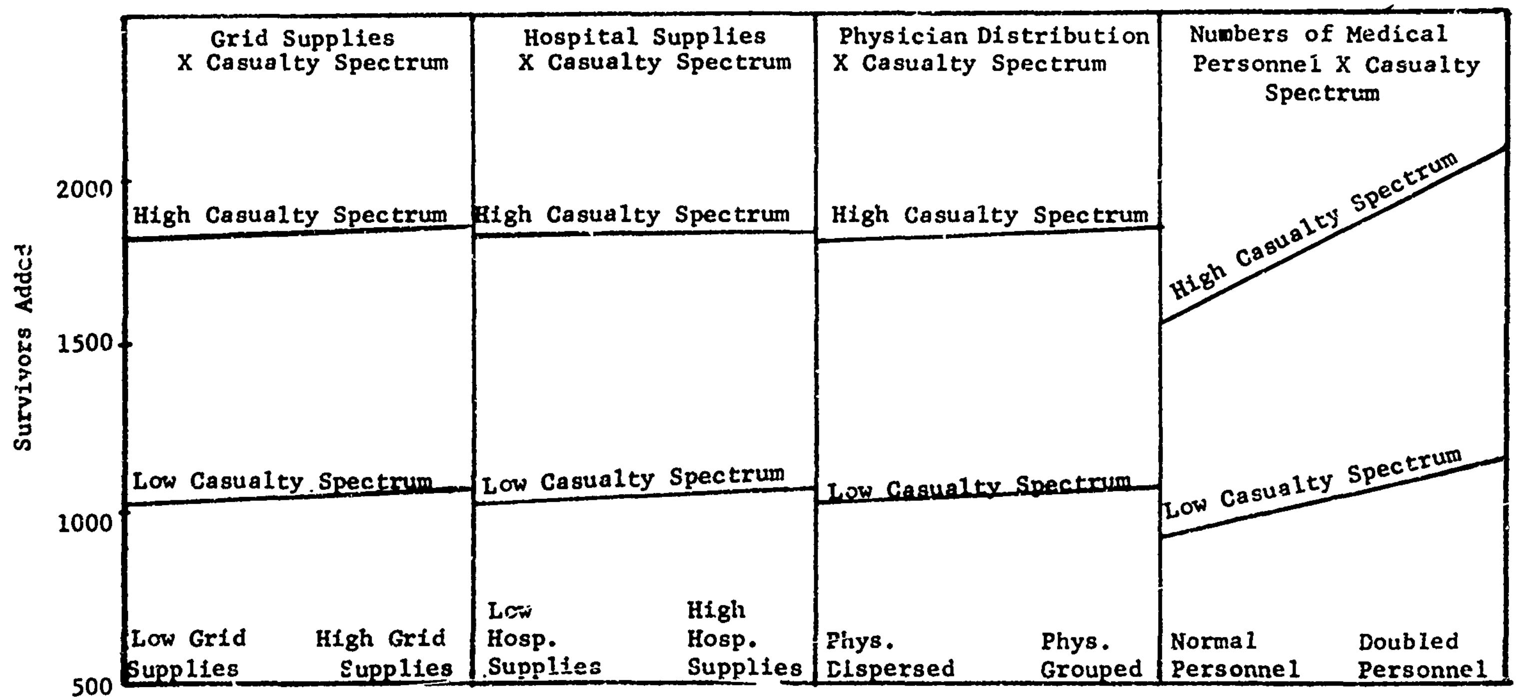

Figure 6. Response of the System (averaged over other factors) Illustrating Main Effects and Interactions Between Casualty Spectrum; and Grid Supplies, Hospital Supplies, Distribution of Physicians, and Numbers of Medical Personnel (City A).

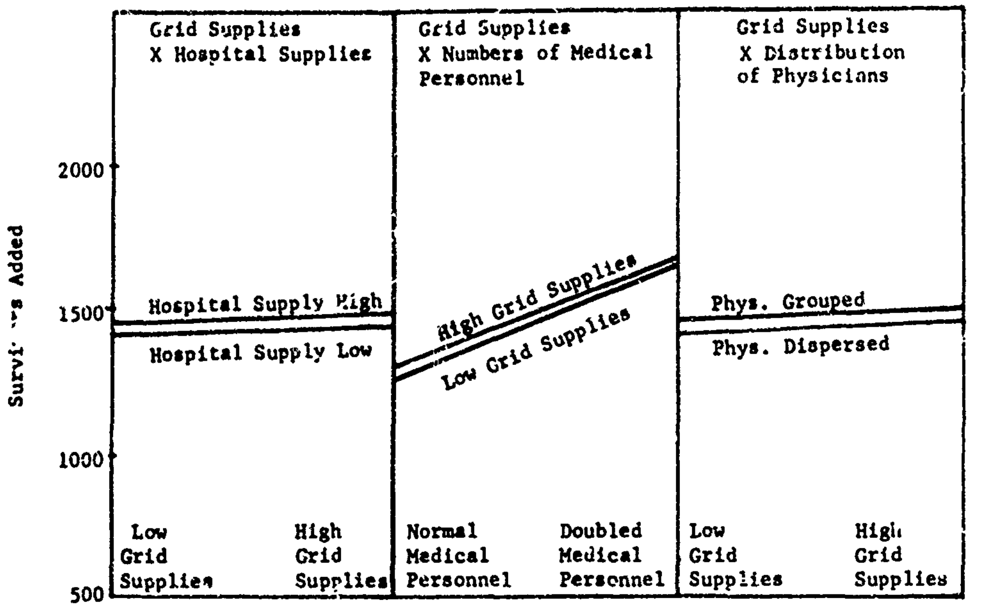

Figure 7. Response of the System (averaged over other factors) Illustrating Interactions Between Grid Supplies; and Hospital Supplies, Distribution of Physicians, and Numbers of Medical Personnel (City A).

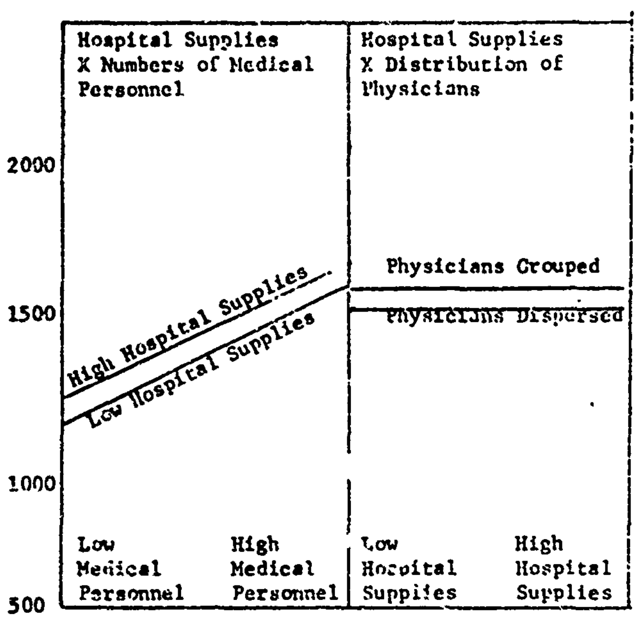

Figure 8. Response of the System (averaged over other factors) Illustrating Interactions Between Hospital Supplies; and Numbers of Medical Personnel and Distribution of Physicians (City A).

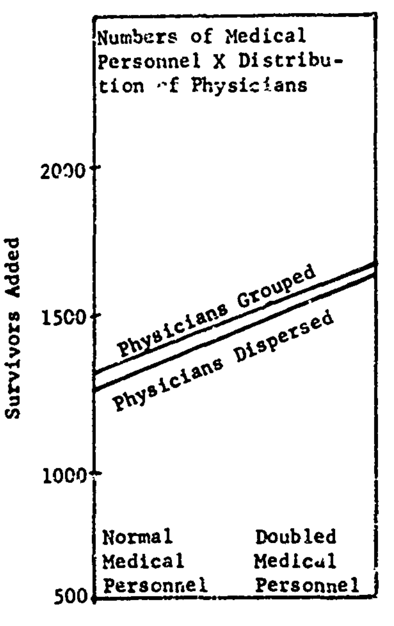

Figure 9. Response of the System (averaged over other factors) Illustrating Interactions Between Numbers of Medical Personnel and Distribution of Physicians (City A).

ten cases does any degree of interaction appear to be present. Figure 6 shows the effect of number of medical personnel at each spectrum. The lines are not parallel, indicating an interaction between personnel level and casualty spectra. With the high spectrum, the normal level of surgical teams completed treatment of hospital-grid casualties at 30 hours, leaving little time for hospital transfers -- i.e., transfers from other grids to the hospital. With twice the normal personnel level, hospital-grid casualties were treated within 16 hours, leaving 14 hours for treatment of hospital transfers. The same situation held for physicians. The low spectrum, on the other hand, contained more minor injuries and fewer of the more life-threatening injuries and thus placed fewer demands on these scarce resources.

Making treatment available to the large number of hospital transfers for whom the surgical team was the preferred level, and for which there was a large difference between prognosis with surgical treatment and that with no treatment, greatly increased the number of survivors. The additional personnel available for the low spectrum merely treated a large number of minor injuries with the result that relatively fewer survivors were added.

Variations in the T_{max}/T_{im} Ratio

As mentioned above, the sensitivity of system performance to variations in the T_{max}/T_{im} ratio was tested. This ratio establishes the slope of the characteristic prognosis curve shown in Figure 1. The desirability of such a test is apparent because of the uncertainty in estimates of prognosis curves. Estimates of changes in system performance resulting from variations of these parameters give an indication of the relative importance of improved input data. The conditions chosen for the sensitivity analysis were: (1) high casualties, normal resources, dispersed personnel and (2) low casualties, normal resources, dispersed personnel. These conditions provided the maximum deaths in the set of runs described earlier (Table II). The same system was run again with T_{max} set at 4 times T_{im} for each injury category instead of the normal 2 times T_{im}. Deaths in this case numbered 26,958. System performance improved more than half as much -- from changing the T_{max}/T_{im} ratio -- as it did from doubling all available resources. Results from varying T_{max} in City A data are given in Table V.

TABLE V

SENSITIVITY OF DEATHS TO THE RATIO OF T_{max} to T_{im}

(City A: Normal levels of resources, dispersed personnel)

Prognosis curve	Resources: Supplies	Resources: Personnel	High casualty spectrum: Deaths	High casualty spectrum: Survivors added*	Low casualty spectrum: Deaths	Low casualty spectrum: Survivors added*
$T_{max} = 2\ T_{im}$	Normal	Dispersed	27,326	1,488	14,065	897
$T_{max} = 4\ T_{im}$	Normal	Dispersed	26,958	1,856	13,965	997
$T_{max} = 2\ T_{im}$	Doubled	Grouped	26,684	2,130	13,724	1,138

* Relative to the simulation run with no resources.

Varying the Priority Rule

In order to test the sensitivity of the system to varying priority rules, a rule was chosen which treats injuries with the shortest treatment time first. It can be proven mathematically that this rule maximizes the number of patients treated prior to any specified time, or equivalently, minimizes the average waiting time. Using the prevailing levels of resources as a base case, the same data were rerun with no change except the priority rule. With the shortest treatment time given priority, 26,846 deaths were estimated as compared with 27,326 under the other priority rule. This finding is especially significant since a relatively large decrease was achieved relative to that obtainable by increased resources. In other words, there is as much to be gained by proper allocation of resources as there is by increasing the level of resources; this may be the most significant finding of the study.

TABLE VI

SENSITIVITY OF DEATHS TO TREATMENT PRIORITY RULES

Priority for treatment	Resources: Supplies	Resources: Personnel	High casualty spectrum: Deaths	High casualty spectrum: Survivors added	Low casualty spectrum: Deaths	Low casualty spectrum: Survivors added
High $\frac{\Delta P_\ell}{T_{im} + T_T}$ first	Normal	Dispersed	27,326	1,488	14,065	897
Shortest treatment time first	Normal	Dispersed	26,846	1,768	13,144	1,818
High $\frac{\Delta P_\ell}{T_{im} + T_T}$	Doubled	Grouped	26,684	2,130	13,724	1,138

Utilization of Supply Packages

The effect of the availability of supplies in nonhospital grids was analyzed using the same four baselines employed to analyze personnel levels: zero, normal, twice normal, and relatively unlimited supplies. Only three of the sixteen available medical-treatment packages were used in the nonhospital grids despite the fact that almost every type of package was available. The three utilized were treatment packages for fracture of the upper leg, head injury, and fracture of the lower leg or foot. Other treatment packages were not used in grids because the more serious injuries were classified as surgical-team-preferred level and transferred to the hospital. Less serious injuries, such as ambulatory burn patients, were classified "no treatment" as the preferred level and hence consumed no supplies. In the real world, such patients would consume medical supplies, however small the quantity. In the simulation runs, the two kits for treating fractures were always assumed to be available in unlimited quantities. (They were set at the maximum allowed by the program to begin with.) The packages for treating head injuries were completely consumed at the normal level and doubled level. Maximum availability of the head-injury kit resulted in still greater usage. A slight increase in survivors resulted from increased supply levels. Tables II and III summarize the effect, in terms of system fatalities, of different strategies for utilization of supplies and personnel.

The consumption of supplies in the hospital grid was also examined. At the level of supplies estimated to prevail normally, available stocks of six of the 15 kits were exhausted on hospital-grid patients. With the supplies doubled, five types were exhausted. With essentially unlimited supplies, none were exhausted. Additional supplies were used to treat hospital-transfer patients, with no marked increase in survivors.

Casualty Disposition as a Function of Medical-Resource Levels

Table VII summarizes the caseload results of the key runs -- i.e., zero, normal, twice normal, and maximum or relatively unlimited resources -- for the treated and untreated injured. Deaths are seen to decrease steadily as a function of resource levels to the lower limit of 23,788 with relatively unlimited resources. Even with the maximum resources allowed by the program, 36,168 injured went untreated. This group consisted of those who were assigned treatment but were not treated within the 30-hour limit set for personnel availability, and those for which "no treatment" was the preferred level -- i.e., the extremely serious and very minor injuries.

More elaborate systems, in terms of resources, left somewhat fewer untreated, but the effectiveness in terms of survivors added diminished.

For instance, doubling the level of resources increased the number treated by 5,069, but increased total survivors by only 647. This is partly because the added resources are used for those with less initial chance for survival and lower increment in survival probability (ΔP_{ℓ}) by treating them at their preferred level, rather than at a downgraded level. This results from the priority rule used.

Total survivors increased only about 8 percent in comparing the zero-resource system to the most elaborate. The percent treated but who die fluctuated slightly but it may be surmised that as resources increase, better care is afforded to those who are treated. In spite of this, however, as more high-risk patients are given treatment the percent of total deaths which are treated climbs steadily.

TABLE VII

CASUALTY DISPOSITION AS A FUNCTION OF MEDICAL RESOURCE LEVELS*

(Based on the High Casualty Spectrum)

Disposition	Resources			
	0	Normal	Twice Normal	Maximum
Casualties	63,832	63,832	63,832	63,832
Treated	0	10,101	15,170	27,664
Deaths among treated	0	6,451	10,466	17,167
Untreated	63,832	53,731	48,662	36,168
Deaths among untreated	28,814	20,875	16,213	6,621
Total deaths	28,814	27,326	26,679	23,788
Survivors	35,018	36,506	37,153	40,044
Treated	0	3,650	4,704	10,497
Untreated	35,018	32,856	32,449	29,549
Percent Survivors	55	57	58	63
Percent Treated who die	0	64	69	62
Percent of total deaths				
Untreated	100	76	60	28
Treated	0	24	40	72

* Includes those for whom "no treatment" was the preferred level and those for whom the system was unable to provide treatment.

CONCLUSIONS

The apparent lack of interaction among the variables studied implies that the addition of resources of any type tends systematically to increase survivors, independently of the level of, or changes in, the other resources. In the case study reported, however, system performance was relatively insensitive to resources levels, within the feasible limits of policy control. The most effective measure was doubling all medical personnel -- an unrealistically optimistic strategy -- with an average effect of about 375 survivors added. All other measures were comparable in effectiveness, in the average range of 30 to 50 survivors added.

The sensitivity of the system to resource levels partially results from the conditions of extreme overload, e.g., saturated queues. The overwhelming majority of injured will not be treated. Many would have a very low priority for treatment, if triage is employed correctly, because of their low probability of survival. While more elaborate systems treated more of the injured, survivors were added at a much lower rate since those with lower probabilities of survival were being afforded the additional treatment.

Variations in both ratio of T_{max} to T_{im} (of the prognosis curve) and the treatment-priority rule affected system performance relatively more than did resource variations. The decision-rule variables may be thought of as shifting the entire set of factorial results to a lower level of deaths.

Improved prognosis data and treatment requirements for radiation injury, alone and combined, would vastly improve the model output. Also, other measures of effectiveness than survivors/deaths should be investigated. For example, "To what extent would surviving casualties, from case studies thus far, be limited in their contribution to post-attack recovery?" This task requires modification of the current computer simulation process to specify the injuries from which the survivors recovered and the treatment they were afforded. An analysis of these data will provide estimates of the degree of activity limitation of surviving casualties.

The model can use resource and casualty data for other communities and other attacks and for natural disasters. Using the model, alternative prognoses data could be tested, so long as they differ only in the probability levels, or such parameters as ΔP_{ℓ}, T_{max}, or T_{im}. The preliminary nature of the prognosis data used, and the results of its being varied in the study lead to the conclusion that the effect of alternative prognosis data should be tested, either as estimated by other medical specialists or through systematic data collection, e.g., from accidents or disaster situations.

The simulation of emergency health systems for much larger geographic areas or population groups is also feasible with the preparation of appropriate input data. This might be accomplished either by multiple runs or by upward scaling of the results. The extremes of system performance and the relative independence of the factors studied suggest the possibility that the conclusions of the study could be extrapolated for consideration of the national emergency health system and its response to a national attack.

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PREVENTING THE PREVENTABLE

David J. Sencer
Public Health Service

My problem this morning is what to say. Primarily, I find it difficult because I don't really believe this conference is necessary. I guess I am enough of an idealist to have sufficient faith in mankind to believe that what we are discussing here will not take place. However, I guess I am also enough of a pragmatist to believe that we could plan for even the remotest of possibility when mankind's fate is at stake.

I would like to confine my remarks to the problem of communicable-disease control in a recovery phase. In contrast to many of the speakers, I will probably end up as a Pollyanna rather than a Pandora opening a box of black and white plagues, and massive epidemics.

To the extent that I disparge my own remarks, I would like to call attention to the fact that communicable-disease control in the recovery era will be more dependent on the things discussed in the sessions on morale and societal vulnerability than on the technology of communicable-disease control. The state-of-the-art, if you will. exists in sufficient magnitude at the present time for the control of communicable diseases. But the ability to mobilize society and to motivate individuals will be the key to the success of any operation.

I guess that is enough of the philosophy of what the problems will be. What do we need to do to prevent, rather than solve, them? For most of the problems that we would face in such a situation are preventable. Many would be preventable by action today, others by good old-fashioned common sense if and when a recovery period should occur.

We can look at the problem from two different viewpoints: (1) the modification of the population, the human population, as a result of the attacking agent -- in this case, radiation. Or, (2) the modification of the total environment -- physical, biological, and social -- by the disaster, be it a hurricane Beulah or hydrogen bomb Adam. For radiation would greatly alter the course of disease in many individuals. Its effect on the total ecology of the disease is much less certain. For example, in a person severely irradiated, immune mechanisms will be lowered and resistance to common infections, such as the streptococcal and those responsible for skin infections, will be grossly altered; but the radiation won't alter the total number of streptococci in our environment. These effects might better be considered a personal medical-care problem rather than a public-health or a preventive-medicine matter.

The effect of radiation will be covered in much greater detail by people knowledgeable in this field in this afternoon's session, so let me confine my remarks to problems that may or may not be present as a result of a disruption of our total ecology.

The changes that we could expect following a disaster, I think, could be classified into three major ones, those, at least, which affect human ecology: (1) crowding, (2) displacement from a normal place of living, and (3) primitive-like resources but with twentieth-century mentality.

What would be some of the disease problems that would be brought about by crowding? It is interesting that during the second World War, the only major communicable-disease problem brought about by crowding was diphtheria, and this occurred in Germany as a result of the massive push together of people into narrow living quarters. I don't think we need to be concerned about diphtheria being a major health problem in this country, in spite of Dr. Huntley's remarks about not enough people being immunized. We do maintain a high level of immunity in our population. We estimate that 85 percent of our children, through either private care or public care, receive adequate immunization against diphtheria, whooping cough, and tetanus. So, if we maintain adequate health services today, we can be relieved of concern about this one problem that was of major concern during the last World War.

Today's diseases that will be aggravated by crowding are those that are primarily spread from man to man by the respiratory route, such as measles, mumps, influenza, the common cold. Measles could be a serious problem, but it won't be. At the present time the medical community of this country is spearheading a program to eradicate measles from this country. It is going to be successful. Next year measles should not be a problem to anyone. Mumps is a mild, benign disease. There will be a vaccine available for it by the first of the year. I don't believe this would really cause problems in a recovery ecology. Perhaps, many of the men here would think that mumps is not a benign disease, but actually, in terms of disabling the population, it is benign.

Mumps, measles, diphtheria are preventable before any disaster and they should be prevented in our modern society. We have the technology, we have the resources. It is just a matter of motivating ourselves and our people to accept the services that are available. There are other diseases, such as streptococcal infections and pneumococcus pneumonias, spread from man to man by the respiratory route and treatable, that will take some planning. In crowded conditions, streptococcal infections such as scarlet fever could be a problem. This is a disabling disease, not often fatal, but it would be a source of irritation to an already irritated population.

Both streptococcal and pneumococcal infections are easily treated with small doses of antibiotics, and I think this points up one of the main problems that could be faced in a postattack-recovery era. If we assume that production facilities are disrupted, a shortage of antibiotics will develop no matter how many we have in our stockpile. This will be particularly true if the medical profession uses them in a disaster period the way they use them in a normal period. Antibiotics are grossly overused in this country. It is a major source of medical-care expense that could be avoided, and we must educate our physicians to the fact that they do not need to treat every common cold with antibiotics, particularly if they are in short supply.

Another respiratory disease that many people say will be a major problem is tuberculosis. I would disagree with them. At the present time, about 25 million people in this country are infected with tuberculosis. This does not mean that they have the disease and that they are, at this point in time, capable of transmitting it to others. This is a relatively small part of our population. There are about 50,000 new active cases of tuberculosis a year, but this is steadily declining with modern technology. With adequate programs for the treatment of tuberculosis today and with adequate programs to give hemoprophylaxis drugs to people who are infected, we can eliminate the danger of tuberculosis in any recovery stage that may come about. Tuberculosis is an easily treated disease today. Preventing its spread will depend upon being able to recognize and treat those few people who are transmitting the disease.

Disease problems which may come about because of displacement would result from moving populations out of their urban environment into a rural one. This would bring man into contact with nature and with animals that he is not normally in contact with. What are some of the diseases that exist in nature? This depends upon the part of the country. The eastern seaboard could be faced with the potential problem of rabies. At the present time, rabies is epidemic in the foxes of the Appalachian area and populations wouldn't have to move too far from the District of Columbia to get into rabid-fox country. And if dog populations are not restrained, rabies can become a tremendous fear problem, if not a major health problem. There is nothing as frightening as seeing one case of rabies, or seeing one rabid dog coming down the street.

An important problem during a recovery stage, whether from a natural or man-made disaster, is control of the canine population -- the dog -- to those who live anywhere near a natural reservoir of rabies. Moving westward across the continent, you get into problems of skunk rabies. People don't realize how vicious a skunk can be, but a rabid skunk can easily bite six children in five minutes. The only solution during a recovery stage would be to have a public understanding that this could be a problem and to educate the public to be willing to sacrifice Fido, the household pet and the immediate source of danger.

Moving into the high-plains area, a displaced person would be put into contact with another disease, plague. Plague is endemic in this country. It exists in the ground squirrels and the very small mammals of the high plains roughly from Kansas to the West Coast. This disease is transmitted to humans by fleas. Fleas may leave an infected animal or dying animal and look for a blood meal. If a person walks by, the fleas will hop on them and bite them and in that way transmit plague. Each year we have maybe six or seven cases of plague in this country -- not a large number, but something about the word causes great concern. The chance that plague will become epidemic even under completely disrupted circumstances, however, is minor; and again, its prevention depends on maintaining sufficient knowledge about the disease among the medical profession -- an awareness that it does exist and is easily treatable.

Another problem will exist as man moves into new surroundings. He will have to try to adapt himself to a primitive way of life; he is going to pick up tools and things he is not used to handling and he is going to cut himself and drive bits of dirt into his skin. Among the diseases of nature transmissible to man is tetanus. The spores of tetanus are universally present in our soil. Any penetrating wound is a focus for a potential tetanus infection. Tetanus is a disease that has a high case-fatality rate. Even under the best medical management, only about 50 percent of the cases -- the patients -- will recover once the disease has established itself. And this is under normal conditions when complicated medical-care procedures involving respirators, anticonvulsion drugs, intravenous fluid are obtainable. Even now they are using decompression chambers to treat tetanus. In the postattack-recovery phase I doubt that we will have many decompression chambers available. This makes before-the-fact immunization imperative. The efficacy of tetanus toxoid as an immunizing agent is well-known. A recent article said that tetanus toxoid vies with yellow-fever vaccine in effectiveness as an immunizing agent; reactions of any consequence are extremely rare.

The unimmunized person with a penetrating wound presents a very difficult problem under primitive conditions. The antitoxin which is used as a passive immunizing substance is derived from horse serum. Inherent dangers lurk in using tetanus antitoxin without skin-testing the individual for hyper-sensitivity before deciding upon the type of antitoxin to use.

This type of procedure is time-consuming under normal conditions. It is so gratuitously difficult in the case of a disaster that we should prevent its necessity by actively immunizing people prior to the fact. In the matter of our economics, we could look at this a little further. The tetanus antitoxin, once prepared, has a shelf life of no more than four years. The so-called shelf life of circulating antibodies in the human body is a minimum of 15 years. By this, I mean that a person who has once been immunized will have a recall of antibodies for at least 15 years after his initial immunization. Why should we stockpile tetanus antitoxin on shelves and then throw it away in four years when by putting the toxoids to use we can maintain antibodies circulating in the bloodstream for 15 years? This is the type of preventive medicine, I believe, that we can practice today to prevent the problems of the future.

There are other disease conditions that will accompany primitive life -- primarily those that are spread from man to man by the enteric organisms through food and water that are not properly sanitized. One of these diseases -- polio -- would have been of major concern about 15 years ago. However, this disease, and the virus that causes it, have, for all intents and purposes, been eliminated from this country, so we really don't need to worry about it if we maintain adequate levels of immunity in our newborn population.

The biggest problem that we would face -- I dislike saying that we will face -- because I don't really think we are going to face it -- would be brought about by the diarrheal diseases. Fifty years ago we would have expected typhoid fever to be a major problem. Today, there are very few new cases of typhoid fever in our population; we have brought this about not by any drastic change in medical care, not by any vaccine, but by changing our environment by the additional miles of sewerage that have been laid in this country. But we will have problems with the other enteric bacterial diseases, such as Salmonella and Shigella. We will have problems with viral hepatitis -- infectious hepatitis -- which is spread through food and water.

Here again I think how we motivate society is going to be the important thing. We know what to do. We know that water has to be boiled under disaster conditions. We know that food has to be well-cooked. We know that refrigeration is important, but it may not be available. How are we going to keep people from fighting over what fuel or water that will be available? These are the problems we are going to have to face.

I have not mentioned the great epidemic diseases that most people think of in terms of disasters, such things as cholera, smallpox, typhus, yellow fever. I have not mentioned them because they do not exist in the United States, and yet, I have here a publication -- a survey of the infectious disease problem which relates to the postattack environment. We have four pages on cholera, a disease that does not exist, and we have one paragraph on food- and water-borne diseases. No mention of hepatitis. I wonder how much per page that book costs.

Regarding these diseases that don't exist in this country, prevention could be two-fold. One way would be to resort to quarantine to keep them out. This is almost impossible in today's society with modern transportation. You cannot expect to maintain 100 percent quarantine. However, I would imagine that international travel of unimmunized populations in time of disaster isn't going to amount to much, so this really isn't the concern.

I think the best way to keep these diseases from becoming a problem in this country is by attacking them where they do exist. An example of this, I think, is the joint AID*-Public Health Service activity in Africa. There are three areas in the world where smallpox is still a major problem and a threat to the United States. One is West Africa, the other is Pakistan, India, and the third is Brazil.

A year ago a joint program of AID and the Communicable Disease Center was started in 19 West Africa countries to immunize their population so adequately that we can break the transmission of smallpox and eliminate the virus from one big reservoir. This was done both from the standpoint of self-protection and as an example to the rest of the world of how something like this could be undertaken. Beginning in November 1967, we put 40 people in the field, 20 physicians and 20 operations officers. The Surgeon General of the U.S. Public Health Service was invited to go to Africa in January 1968 to give the 25-millionth vaccination. In less than one year we have been able to mount a program that has been eminently successful and is showing the people of Africa how they can begin to develop better local health services.

It is interesting to note that one of the countries in which we were operative was Mauritania. Although Mauritania broke diplomatic relations with us at the time of the Arab-Israeli conflict, the program was so successful that some of it is being continued in spite of the absence of American personnel. In Eastern Nigeria our smallpox technicians were the last people to leave as a result of the internal conflict. Let me repeat, the smallpox program has been eminently successful -- two federal agencies working together with countries of West Africa and accomplishing eradication. I think it is through imaginative and successful programs such as this that we will prevent the introduction of disease into this country, and hopefully develop an immunization against international misunderstanding, and make this seminar unnecessary.

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* Agency for International Development.

PUBLIC HEALTH SERVICE VIEWS ON

POSTATTACK MEDICAL PROBLEMS

Henry C. Huntley
Public Health Service

Even after the UNCLX attack that was described yesterday, there would be more people left in the United States, postattack, than lived there when I was born. We would still have a nation -- a nation which over these past 50 years has proven to be a pretty potent instrument in world affairs.

Having made those remarks, I want to say that the paper that Mr. Hallan presented is, in my opinion, really a masterpiece. It talks about the potential that the computer has today for predicting the outcomes of the various possible approaches to the solution to the postattack health problem. Now, we can consider three things as being important in the postattack situation, in terms of resources. The first, of course, is health manpower; it includes not only the physician, but the allied professions. We consider the expendable resources such as pharmaceuticals and other medical and surgical supplies as a second resource. Finally, we consider facilities because we have to have a place to treat the patient. If we are going to do real triage, the patients that we treat are going to need nursing care, presumably they will need a little supporting service in terms of laboratory, X-ray, etc. So these are the three components of health resources for minimizing the problems of the surviving casualties.

I believe all of us recognize from what we heard yesterday that there are going to be more surviving casualties than we can care for with any system that may be realistically devised. Theoretically, we can stockpile all the medical supplies -- drugs and other expendable materials -- that may be needed postattack. Theoretically, we can stockpile hospital beds, either in the form of our present packaged disaster hospital, or in whatever other form that may be indicated. But as yet, we have no practicable method of stockpiling medical manpower, and this is the limiting factor. Using the assumptions that we are working under we would have enough medical manpower to staff hospitals totalling two-million beds, postattack. These are more beds than we now have in the nation, but remember that this medical manpower would be utilized full-time in a hospital setting. As of today, the average physician in the United States spends about two-and-a-half hours a day in a hospital. Postattack, we think he would spend 12 hours a day in a hospital. Thus, we would have surviving medical manpower to staff and provide defensive medical services to two-million bed patients. We do not have that many hospital beds as yet. We can see in sight about one-and-a-half-million beds, if the packaged disaster hospitals that we now have are used to supplement the regular beds. So we are still about a half-million beds short; in terms of the 200-bed packaged disaster hospital, this means that we are still about 2500 units short of making the most effective utilization of surviving medical manpower. So this is where we are today, and these are some of the things that we are talking about.

Computer systems, such as the one described, are unquestionably of demonstrated value whether for estimating the potentials of emergency-hospital systems or for evaluating on-going medical-care systems. There really is no great difference among them except, perhaps, in the complexity of a computer system devised to determine the best methods of approach for emergency medical care, and one that could be devised for determining the best method of delivering day-to-day health services for the nation. We already have one for emergency health services. It was devised, I believe, by Lockheed, and it has been used in Texas by the Texas Hospital Association. It is programmed somewhat differently and had a different purpose than the one described.

This system has already been of demonstrated value in Texas. For example, the Texas Medical Society had programmed collecting stations into their medical system. We had had some reservations about this, and in the computer run it was demonstrated that the pile-up at collecting stations was beyond the limits of acceptability, and also that the individuals would tend to bypass the collecting stations and go on for immediate and direct hospital care, if it were available. Of course, if it were not available, the collecting stations would not serve any useful purpose either.

There is no question that these computer programs demonstrate many of the things that we need to know, and provide much needed information as far as research is concerned. Now, what concerns us is what is put into the system in terms of programming, and I think this is where we do have some reservations, not only about what Mr. Hallan has presented but also in some of the other areas.

First, I think Dr. Pettee's recommendation that we take another look at the Van Sandt formula for estimating survivors is a good one. It is very possible, even probable, that we will have a far greater number and percentage of burn and radiation injuries than we now are estimating, and far fewer contusions, broken bones, and other mechanical injuries, such as were experienced in Hiroshima. Of course this change would be caused by the much greater heat radiation and fallout effects of the hydrogen weapon compared to the Hiroshima weapon.

Take this change into consideration, and think about a medical-care situation such as existed in the United States before we had antibiotics or a good method for delivering intravenous fluids, or any very good thinking about what we needed to put into the veins. Think about the tetanus danger that accompanies burns -- and, despite all Dr. Sencer's good work, there are an awful lot of people in the United States who are not protected against tetanus. Then we will begin to think that medical supplies will make a difference in survival, particularly to survivors who have 15 to 20 percent of the total body surface burned, and those who need fluids, blood, etc., postattack, as a result of radiation exposure.

These are some of the things that we are thinking about when we consider how a computer study might be programmed and what might come out of it. Of course, I recognize that I am not looking at this objectively because, as a physician, I like to think that I and my kind would be able to make a difference in life and death because of our presence and our knowledge, and because we have the tools to work with and the necessary pharmaceuticals available.

As I said, we will never have enough medical manpower. We will have all the supplies, we hope, that the physicians can use; we hope eventually to have all the hospital beds that the physician can effectively utilize. But still this will provide only two-million hospital beds; if we consider an average stay of 6 days, this would mean that we could treat in the first 30 days, or in the acute casualty period, some 10-million persons -- but only if everything was perfectly organized and if the patients came in at exactly the right time, which, of course, is nonsense.

In any event we have been considering that this system might make a difference of about three-and-a-half-million lives on a national basis. All of you are familiar with the monster called Planning, Programming, and Budgeting (PPB); if you have not been exposed to it yet, you do not know what you have missed, because this is really a very interesting tool to work with. Utilizing it on the basis of the funds that we know are necessary, of the funds that have already been spent in stockpiling in the nation, and of the cost of operation of the program for the next ten years, PPB shows that we will be able to save lives at a cost of about $115 or $120 per life, if our estimates are anywhere near accurate. That is pretty cheap insurance, we think. We hope that we will be able to convince Congress that we need more research through the type of instruments that have been devised by the Research Triangle Institute. We need more study to be certain that we are on the right track.

We know, as Mr. Hallan indicated, that the relation of numbers of survivors to the amounts of supplies and medical manpower, etc., follows a law of diminishing returns. There is no question about that. But we also know that there is no question but that we are still on the upward leg of the curve that was demonstrated here. Because, with the best facilities, etc., the most we could hope for would be to provide care for 10-million survivors. We know that there are going be be at least twice that many. So there will be 10-million-or-more people who will not receive definitive medical care. We hope we will be able to screen out those for whom there is no hope. Then we will be able to screen out those who will survive without medical care, and treat only those for whom medical care can make the difference between either life and death, or full health and permanent disability. We do have a program, of which some of you may have heard, called medical self-help, that is a partial -- and I want to emphasize the partial -- answer to the shortage of medical manpower.

Now, in conclusion, we might say that this simulation model does provide, as Mr. Hallan said, a flexible tool, and, with varying input, we will obtain very good estimates of the difference made by varying types of organizations and varying amounts of different resources, such as manpower, hospital beds and medical supplies.

COMMENTS ON HEALTH SESSION PAPERS

Robert Price
Public Health Service

I am going to look at Mr. Hallan's and Dr. Sencer's papers together and give you my comments on them. I think that both papers raised the question: "What would be the quality of survival?"

The number of people who do not die is, as Mr. Hallan indicated, a very crude measure. Dr. Huntley's $115 for saving a life is equally crude: that $115 may automatically protect dozens of human images -- and we can remain human instead of becoming inhuman all because we have the ability to provide treatment.

Mr. Hallan asked whether we should reserve supplies for the long term -- for the treatment of disease and the long-term followup. Dr. Sencer raised some questions as to whether this is necessary. I have serious doubt that there would be antibiotics to treat the pneumonia that would occur; I honestly believe that there would be some very serious problems in terms of supply and demand. For example, a physician who is practicing medicine "buries" himself in the patient whom he is treating right now. When he is faced with a mass of casualties who need whatever care he can provide, he is likely to give them the best that he can give without concern over what the situation is going to be three months or two weeks hence. At that point in time he is not sure there is going to be a two months from now or a three weeks from now for him or anybody else, so he is going to do his best for the immediate moment. The most we can hope for is that maybe there will be some immediate triage of casualties. I have some doubts about this, too.

I think it would be well here to mention something about surviving burn patients. Our computer would say that there would be patients with certain types of burns. I gather that the preponderance of injury in a thermonuclear attack would be burns and that a good many burn victims would survive. I don't think the computer studies have ground in some factors that have been brought out by other speakers here, and which I presume will be emphasized by later ones. Have any of you seen an untreated burn of the elbow? An untreated burn of the shoulder? An untreated burn behind the knee? When nature tries to heal any joint that will flex, if you don't graft it and if you don't take care of it, it will heal in a grotesque kind of way. Obviously, a good many burned people would survive because there would be someone there to treat them, and to carry them to the toilet, and to carry them back, and to clean them up, and to keep them from becoming infected. But some of these people are not going to have anybody to take care of them, and will die of starvation or infection, of the streptococci we talked about or the staphylococci that are going to be around, because these people would be extremely vulnerable. So there is going to be a problem of the quality of survival.

I think that there would be one hopeful thing which I don't quite know how to express without sounding terribly cold-blooded; that is that there might be a kind of automatic triage. I think some of the people would die who the charts show are going to live. I think that they would die of other things than those now considered. Some of them would commit suicide; some of them would beg to be relieved of their pain or disability or loss of their image.

If the attack follows the heavier pattern that Dr. Pettee gave us, our enemies will have exorcised one of our worst ghosts. I think if Dr. Sencer were asked where he would begin if he were going to get rid of tuberculosis, for example, he would look right to the crowded core city because that is where tuberculosis has retreated. We are gradually cutting it out by chemotherapy now; we are cutting it out by improved standards of living, but the city is where the infections now survive and it is what would be destroyed by the attack we discussed.

I think we have a very serious job to do. I think we have a job of finding a place around which to organize humanity: it may well be the packaged disaster hospital, or the surviving community hospital, that provides that kind of organization where people can focus on the fact that we are still human.

SPECIAL TOPICS OF LONG-RANGE BIOLOGICAL AND ECOLOGICAL EFFECTS

Charles L. Dunham, Chairman

Dr. Dunham was assisted in planning and organizing this session by Mr. Hal Hollister.

FORECASTING LONG-RANGE ECOLOGICAL RECOVERY FROM NUCLEAR ATTACK

William S. Osburn, Jr.
U. S. Atomic Energy Commission

INTRODUCTION

Ecological effects of nuclear attack have been considered in numerous lectures, committees, conferences, panels, seminars, study groups, and workshops. A deluge of books, manuals, pamphlets, reports, and newspaper articles, often referencing a minimum of scientific manuscripts, have resulted. As nuclear testing has been conducted in few and rather specialized ecosystems, and under rather specific sets of circumstances, little unequivocal data exist to forecast ecological damage and recovery. Consequently, ecological predictions of postattack effects, being extrapolated from these few nuclear testing sites, from laboratory experimentation, from irradiation of several specific ecosystems, and from analogies of catastrophic events in nature, result in controversy.

Indications of the amount of thinking and the range of viewpoints concerning ecological effects and recovery from nuclear attack can be quickly gleaned from publications produced by the Technical Analysis Branch (Division of Biology and Medicine), U. S. Atomic Energy Commission, Washington, D. C. 20545 (particularly compilations of R. Lord and L. Eberhardt); the Hudson Institute, Inc., Quaker Ridge Road, Harmon-on-Hudson, New York 10520; the Stanford Research Institute, Menlo Park, California; the National Academy of Sciences - National Research Council; books such as Stonier's Nuclear Disaster[1] and Anderson's Thermonuclear Warfare[2]; the Proceedings of the Symposium on Ecological Effects of Nuclear War[3]; and several congressional hearings[4,5,6]. Succinctly summarized, according to the current status of knowledge, huge fires would likely -- would likely not -- result[5,6,7]; fire produces highly unfavorable -- favorable -- effects[8,9,10,11]; climatic and weather patterns would -- would not -- be altered[1,12,13,14]; outbreaks of insects, rodents, disease are likely -- are not likely -- to occur[1,15,16,17,18]. Regardless of choice, one seemingly can find published support for an extremely pessimistic "nothing can survive" view to an optimistic one "predicting ecological damage would go almost unnoticed."

Nevertheless, despite controversy, emotion, continuous repeating of unsupported statements and lack of incontrovertible facts, some points of general agreement are emerging. Hopefully, we can begin to use somewhat smaller brush strokes in painting the picture of long-term ecological effects of nuclear war than those suggested by John Wolfe in the 1959 Congressional hearings, ".....only a general picture can be painted, and that in broad strokes."[6]

This manuscript proposes to discuss the following: What are indications from the data most nearly relevant to nuclear war consequences, i.e., ecological studies of nuclear-testing sites, of gamma-irradiated ecosystems and of a radioactive-lake bed? What is the consensus of opinions regarding factors or conditions associated with ecological recovery from nuclear war -- fire, floods, erosion, weather modification -- and would ecological recovery materially impede national recovery? What radioecological theories or principles have been or are being developed which may be helpful in predicting radionuclide fate, radiation effects, and ecosystem recovery? Areas of weakness in ability to predict, and how we can perhaps improve accuracy of predicting ecological consequences from nuclear warfare, are considered throughout the manuscript. In addition, and perhaps of greatest value, will be the literature referenced. Care has been taken to see that, in addition to citing authors who have put forth estimates of ecological recovery from nuclear attack,there are also incorporated basic research data concerning factors most often considered to be of greatest importance in contemplating ecological damage and recovery.

SUPPOSITIONS GAINED FROM STUDIES MOST NEARLY RELEVANT TO NUCLEAR WAR CONSEQUENCES

What have we learned from: (1) studying ecosystems directly damaged by testing of nuclear devices, e.g., the Pacific Atolls, the Nevada and New Mexico desert ecosystems, (2) studying ecosystems subjected to relatively large exposures of chronic and/or acute ionizing radiation (gamma sources) from controlled sources, in one case those ecosystems typical of northeastern and southeastern United States, and in the other a tropical rain-forest ecosystem, and (3) studying a radioactive lake bed formed by draining a lake used for nuclear-waste disposal?

In the case of Pacific Atolls, quotations taken from the summarizing chapter of Hine's 1963 publication, Proving Ground, An Account of the Radiobiological Studies in the Pacific 1946-1961, demonstrate a rather optimistic outlook. "...Populations of animals and plants observed under field conditions--the sea urchins of Bikini in 1947, the grasses and shrubs restoring the natural cover of Eniwetok shot islands, or the rats of Engebi--exhibit a capacity to maintain themselves even in environments that have been exposed to the full effects of nuclear blast and to levels of radioactivity that all laboratory experiences indicate were totally lethal;..." and the field crews "...developed a confidence during the years of the healing powers of the natural environment..."* "They had seen islands swept clean, water churned, and the damage created by heat, pressure, and radioactivity..., and nowhere that they had studied the long-term effects of radioactivity as a separate phenomenon was there evidence that normal regrowth was not occurring."[19]

Dunn, Spellman, and Hess, after following periodically (1947-1950 and 1963-1965) the revegetational history of the first atomic bomb test site in New Mexico, U. S. A., reported the following: "The extent of the disturbance of the 'climax' through denudation was such that essentially the full sequence of successional stages described by Clements has followed," and further, "within a few days after detonation seeds were washed into the center of the crater and plants have been growing there since."[20] While vegetation apparently has not recovered its original status in the 20 years since testing -- recovery from disturbance is known to be slow in desert regions -- succession appears to be normal.

Moreover, results from irradiated plant communities on Long Island in New York State,[15] in Georgia,[21] within a Puerto Rico tropical montane rain forest (H. T. Odum, personal communication), and communities of the Southeastern U. S. (McCormick, unpublished data) indicate recovery apparently follows natural successional sequences.

At Oak Ridge National Laboratory, an artificial lake -- White Oak Lake -- was used for disposal of tons of radioactive wastes. Upon draining, soil surface radioactivity was too high to be considered safe to work upon for a considerable amount of time, but plants and animals invaded and quickly became quite well established.[22]

The one very important result common to all the above studies is that ecological recovery follows normal predictable successional trends, i.e., successional patterns following damage from radiation are the same as those following fire, logging, or other natural catastrophic events. As there is no reason to expect that ecological-recovery sequences worked out for other major U. S. vegetation types would not follow a similar path, we find strong support for two suppositions. The first is support for John Wolfe's 1959 summation in which he anticipates that

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* The concept of ecosystem healing power or resiliency is one frequently propounded by researchers of irradiated systems.

biotic succession would lead to full ecological recovery of landscape patterns "...probably not unlike the primeval distributions of forest, woodland, desert and grassland on this continent."[5] The second supposition is that progress towards predicting ecological recovery from nuclear war is closely related -- possibly limited -- to our general ecological knowledge. On the one hand this situation can be heartening in that we can benefit from the past 50 or 60 years of ecological study, yet on the other hand, it can be dismaying in that we have developed so few guiding ecological principles.

CONSENSUS OF OPINIONS REGARDING FACTORS RELEVANT TO ECOLOGICAL RECOVERY

A number of speculative postattack ecological-recovery situations have been constructed -- some quite grim. In forecasting these hypothetical sequelae of a nuclear attack, and in lieu of experimental data, resulting models, riding upon unproven tenets, extrapolations, and arbitrary assumptions produce quite different expressions of consequences. However, a number of factors or conditions are universally discussed, for example, fire, floods, erosion, weather modifications, and whether ecological recovery would materially delay national recovery.

This section of the manuscript (1) gives predictions of authors who have reviewed questions of postattack consequences in terms of fires, erosion, weather modification, rate of ecological recovery and ecosystem imbalances, (2) comments upon flaws of prediction and how the reliability of predictions could be increased, and (3) concludes with statements regarding likelihood of ecological damage delaying national recovery.

Role of Fire in Postattack Considerations

Predictions of fire impact on various ecosystems range from "essentially no damage" up to "a holocaust of firestorms from which recovery would be delayed for decades or centuries." As with most things ecological, results hinge heavily upon the sequence of environmental events before, during, and after a nuclear attack. Conditions influencing fire effects have been reviewed by most authors cited in the introduction, and several have attempted to construct postattack prediction models. Given a particular set of environmental conditions, ecological effects of fire are reasonably predictable. As these conditions -- drought, winds, etc. -- which dictate the magnitude of fire effect are presently far beyond our prediction capability, estimation of fire effects from nuclear warfare will be correspondingly limited.

Quotations from several authors provide what seem to be a consensus of opinions concerning important aspects influencing the role of fire in attack and postattack considerations: initiation of fires (flammability of wildland fuels), spread of fire, influence of biota, and secondary fires.

Hurschke has recently prepared a memorandum in which probabilistic estimates have been calculated for the quantities of U. S. wildland fuels that would be simultaneously flammable at a given time of the year.[33] In preparing this report, Hurschke contrived a wildland-fuel distribution, a phenological basis for calculating growth-stage-dependent burning indices, and a method for simulating the fire-depressing effect of snow cover. Results graphically depict the annual cycles of simultaneously flammable area for eight different fuel-type combinations -- e.g., grass, brush, softwood trees, hardwood trees, etc. These eight fuel type areas actually represent conversions from the 116 plant community units mapped by Kuchler in Potential Natural Vegetation of the Conterminous United States, 1961."[24] Reading these graphs is quite easy but interpreting them requires caution. In fact, as the author points out, no direct quantitative extrapolation from these results to damage assessment is possible without considering a number of other variables such as time of day, distribution of ignition points, and physical limitations to fire spread. Though the compilation contains few surprises, the use of probability language seemingly provides us with something more meaningful than such terms as "often" or "frequently."

In congressional testimony, J. E. Hill made cogent arguments in considering catastrophic fires.[5] He argued that very special conditions are necessary to initiate great conflagrations: several preceding years of drought, plus several rainless weeks immediately before an attack; in turn the attack must be accompanied by strong, dry winds and a large fuel source. These conditions occur relatively infrequently and seldom, if ever, over the entire United States at any one time. Consequently, the incidence of catastrophic fires in the United States is approximately [illegible] years apart. Once started, these fires are seldom stopped by fire-fighting but by natural, topographic barriers or by a shift in weather conditions. He (Hill) concludes that "large free-running catastrophic forest fires would occur very infrequently as the result of the detonation of a nuclear weapon."

A. Broido, in discussing the effects of fire on major ecosystems, concludes "...the ecological consequences of the fires that may occur after a nuclear catastrophe are not expected to differ seriously from the consequences of holocausts of the past" and "though we have experienced large fires since prehistoric times, interpretation of their effects on major ecosystems, are still quite controversial -- whether one considers the effect on plant succession, on animal life, on plant diseases and pests, on the chemical composition of the soil, or on such physical factors as temperature and humidity."[6]

The above quotations present brief but reasonable summations concerning fire in nuclear-attack situations. However, I would like to suggest two other likely important considerations which have received scant attention, but could be researched readily: (1) Redistribution of fallout nuclides by fire, and (2) Subdividing the geographical region to be studied according to some standard division.

Data concerning the effect of fire on the redistribution pattern of nuclear fallout are essentially nonexistent; a small study involving a cheat-grass ecosystem near Hanford, Washington, appears to be the only exception.[25] Yet, a fire occurring during or subsequent to fallout deposition would almost certainly place fallout nuclides on the ground surface in a highly erodible situation. Thus wind and water redistribution could cause high concentration in sites frequented by man, such as fence rows or along water courses. Odum points out it might be desirable to burn badly contaminated vegetation as a recovery measure.[26] This is based upon the assumption that there would be reduced fallout entering food chains, since newly produced plants, growing either from regeneration of shoots that sprout from buried and little-contaminated rhizomes or seeds, would have much less foliar contamination. Regardless of whether fire could be used as a decontamination process, the matter of fire and fallout redistribution should be further researched. The radiation level of some long-lived fallout nuclides is still high enough within some natural ecosystems to locate sites of concentration. Extensive fires have occurred and will likely continue to occur within these several U. S. vegetation types. Consequently, well-designed research projects might enable a rather clear picture of fallout redistribution by fire and subsequent erosion to be obtained. In addition, studies of present day patterns of wind-drifted snow or soil, especially in prairie regions, could well be used to anticipate nuclide redistribution after a nuclear attack.

Many discuss fire effects, some with rule-of-thumb statements such as "critical fire-spread conditions correspond roughly to maximum visibility," while others insert complex physical heat laws and formulae.[27, 28, 29, 30] Often, crudely derived assumptions regarding factors which play major roles in forecasting fire effects are combined with quantitatively derived data on factors which may play an insignificant role but happen to be easy to measure precisely. Sometimes a discussion follows refining predictions to fractions of a percent. This sort of treatment tends to lead the user into a false sense of security with respect to the validity of his results.

Inherent with predictability in general, problems enter because regions into which inquiry is being made by various nuclear-damage-and-recovery prognosticators are not homogeneous in terms of weather patterns, fuel quality and quantity, soil moisture, or other pertinent conditions. It would seem that rather than each individual subdividing the U. S. into a number of little-researched units, poorly known ecologically, he would refer to some standard landscape division, such as Kuchler's division of 116 units.[24] Basic to these units is the idea of homogeneity -- e.g., of vegetation density, height, phenology, etc. -- factors which almost surely influence ignition of fire, extent of fire, heat, area burned, and completeness of the burn. If data were organized according to these units, one could better rely upon past and present ecological research to help answer questions.

Summary considerations in regard to the role of fire are that most forests are remote from expected nuclear targets; approximately half of the lumber in the United States is privately produced and many of these private companies farm -- i.e., use stocking-harvesting regimes, maintenance of firebreaks and lookouts -- according to methods which provide maximum fire protection to their forests; many important lumber-producing conifers exhibit a wide range of preadaptations to fire, such as having serotinous cones which require heat to open them, or needing mineral soil for good seed germination and survival, or being able to sprout when aboveground portions are killed, or having growing tip thickly protected by dense needle clusters, or being able to dissipate heat rapidly, thus protecting the important cambial layer. The U. S. Forest Service is continuing its research into providing better methods to provide natural fire control to their forested regions. Hence, forests would not be expected to be extensively damaged, and the outlook is reasonably optimistic that no lack of forest products would keep national recovery from proceeding without serious interruption.

Role of Water and Wind Erosion in Postattack Recovery

Since severity of erosion would be directly related to the extent of fire damage, and since the consensus of opinion is that fire damage would not materially delay ecological recovery, it follows that erosion problems also would not hamper recovery. However, it is well to consider the role of erosive forces following a nuclear attack, since the above supposition might prove incorrect and since fire damage on a local basis might be severe.

The possibility of increased damage from water and wind erosion is related not only to the extent of damaged and burned vegetation, and upon the weather regime during and following the attack, but also upon a host of characteristics of the burned landscape, i.e., how large and complete the burn, the time of year, topography, amount, location, and vitality of remaining organisms, especially their reproductive potential.

H. H. Mitchell summarizes a preliminary survey of postattack flooding: "The damage that could be caused by postattack floods appears, then, to be small in comparison with the devastation caused by primary effects of a thermonuclear attack: blast and thermal and nuclear radiation."[31] He points out there is a distinctive set of conditions which determines the characteristics of floods such as seasonal distribution of rainfall, snow-melting behavior, and porosity of soil. Consequently, devastating floods rarely occur, and when they do, it is regardless of vegetation-cover conditions. Hence, because of seasonal variation, postattack problems will depend upon the time of year in which a nuclear attack is assumed to occur.

Mitchell further notes that it would be advantageous to analyze data already collected for major drainage regions of the United States so that over-all probabilities of flood damage can be determined for various seasons.

The report paints a rather little-effect picture. True, the ground cover or the water-holding capacity does not significantly alter maximum floods. However, many serious floods can be moderated or prevented by soils with a large water-holding capacity. The number of references cited for this study are meager, and most of the citations are not from journals, but books 30-or-more-years old. When one considers the enormous amount of research that has been done on flood control and relationship of disease and flooding, this study may have litle validity.

Katz, in an excellent compilation concerning nuclear war and soil-erosion problems and prospects, discusses basic factors governing soil erosion and concludes that, despite complexities of the many factors, runoff conditions can be calculated at least approximately. He particularly stressed that better methods of calculating runoff conditions can be derived.[32] As these data are available to make reasonable postattack flood predictions, it is regrettable that it has not been done.

In addition to direct flood damage, water erosion could well be a powerful force in decreasing or increasing radiation hazard via redistribution of radioactive fallout. Though absolute levels can not be predicted, gross patterns of radiation, less intense on steep, unvegetated terrain and with concentration on flood plains proportionally greater, can and should be estimated.

As in the case of water erosion, wind has the potential to alter ecosystems by redistribution of radioactive nuclides or topsoil. Few data exist to make reasonable estimates, though reports by Alexander, et al, and Osburn indicate the magnitude of redistribution of fallout via wind may be relatively large.[33,34,35] In any case, studies could now be designed in which snow-and-top-soil-drifting patterns could be studied in order to indirectly assess potential soil and fallout redistribution.

The possibility of creating a great-plains dust bowl by plants being killed from radioactive fallout has been frequently discussed.

However, I would not expect this, at least in uncultivated regions, as several million years of fire evolution of grassland ecosystems has shaped the development of many plant species that are fire, and likely radiation, protected. First, the radiosensitivity of some of the major grassland component species appears to be rather low (Whicker, personal communication). As Woodwell points out, even though 50 percent of the species might be killed, dry-matter yield might not be diminished.[36] Secondly, even if all plant shoots were killed, many grasses would be regenerated from deep lying rhizomes protected from ground-surface-fall-out radiation and from fire, by several inches of soil. Finally, even if plants were killed and ground-surface radioactivity remained too great for young shoots to withstand, it would be several years before roots would decompose enough for their binding power to become insufficient to resist complete wind erosion of the soil.

Modification of Weather

Many have conjectured about how nuclear explosions could affect or influence weather.[13,14,37,38], and others. However, as bomb-produced phenomena are generally an order of magnitude below that of many naturally occurring events such as volcanoes, most scientists have concluded that there would be no measurable effect on the weather more than a few miles distant from a nuclear detonation. However, Batten concludes "...that our knowledge is yet insufficient to provide unambiguous answers."[39]

Rate of Ecological Recovery or Ecesis

The rate of ecological recovery typically receives relatively little attention other than to state it is influenced by a number of environmental and biological circumstances. One consideration which has failed to receive adequate ecological attention is the size of the area of damage. Reestablishment of an ecosystem depends upon a process called ecesis (plant and animal invasion and establishment[40]). A good deal of research has been accomplished in particular landscape regions of the United States and these data could be brought to bear if one were considering recovery for that particular type of landscape. However, when the U. S. is considered as one unit, extrapolated information regarding dynamics of species invasion and establishment is likely to be invalid. Inherent problems concern a number of ecological concepts such as minimal ecological areas, population dispersal, competition, and others.

Ecosystem Imbalance

One major area of agreement among those who have devoted time to considerations of ecological damage and recovery from nuclear attack concerns the creation of an imbalance within an ecosystem whereby outbreaks of insects, rodents, and disease might be anticipated.[41,42,43]

Literature abounds with examples wherein ecosystem balance was destroyed by introduction of an animal or plant; jackrabbits in Australia and New Zealand and cheat grass in western United States are familiar examples. Outbreaks of locusts, spruce-bud worms, field mice, etc., occasionally occur. At present it is difficult to anticipate if, what, and how regulatory factors might or might not compensate for particular imbalances after nuclear destruction. However, several considerations should be examined. Insects and rodents which have high reproductive potentials and can most readily take advantage of additional sources of food or lack of predation may undergo phenomenal population increases. However, as ecological research progresses, we become better able to read signs of impending population explosions or plague outbreaks long before they occur. And as situations favorable for outbreaks usually take a reasonable amount of time to ripen, one may eventually be able to develop a program of preventative control which would keep pest populations reduced so that their build-up after a nuclear attack would be proportionally delayed. Hence research is needed concerning species which exhibit great population irruptions, have high reproductive potential, and would be directly or indirectly injurious to man or his supply of resources. It would be especially beneficial if some sort of table could be developed which would provide an index of population level, circumstances, and likelihood of an explosive increase.

Flaws or Weakness Commonly Contained in Predictions of Ecological Recovery from Nuclear Catastrophy

Authors of articles dealing with nuclear-war damage or ecological recovery often present convincing arguments. However, when their conjectures concern areas in which one is quite familiar, one frequently finds serious flaws in their predictions.

A common flaw in predicting postattack ecological phenomena concerns extrapolation of an effect or process, valid for a particular region, to a situation far removed ecologically. An example is Stonier's description of a hypothetical postattack sequence of events which would lead to catastrophic flooding.[1] This hypothetical situation was based upon what appeared to be a reasonable translation of an occurrence in northern Europe to a situation in the Rocky Mountains of Colorado. Briefly, and in actuality, in 1963, a layer of dust, presumably from Utah, was deposited on high mountain snowfields in Colorado. Stonier theorized: in northern Europe, farmers cover snow with coal dust to increase heat absorption and thereby proportionally increase the rate of snow-melt. As nuclear-killed landscapes would undoubtedly generate extensive dust available for deposition on snowfields, one could reasonably expect a corresponding increase in spring-snow-melt rate and the level of streamflow increased to the point where huge floods would result.

Actually, what happened following dust deposition in the Colorado snowfields in 1963 was as follows: the early-season snow-melt rate was much more rapid than one could expect from air temperature, and streamflow did increase. However, the June peak runoff failed to rise to ordinarily expected levels, let alone exceed them. The reason for this failure follows: the initial deposit of dust, as measured in the Boulder city watershed, was approximately 20 grams per square meter, but rapid melting, removing water and leaving dust and incorporated debris, soon caused the surface of the snow to become coated by an insulating cover, materially reducing the melting rate. Hence, rather than generating a flood, the dust created a situation whereby streamflow was more moderate and extended over a longer period of time than usual.

Another example of how an ecological extrapolation, or perhaps oversimplification in this instance, may be misleading is in the following statement: "For example, we know that insects can destroy food crops, that insect populations are controlled by birds that eat them, that birds are much more radiosensitive to radiation than insects, and, therefore, that radiation from a nuclear explosion may cause a sudden incursion of insect damage to the food supply,"[44] Though birds are known to control insect populations in specific situations, it is a gross oversimplification to suggest that birds are the only, or even a major, control of insect outbreaks. The danger of unproven, poorly supported or partially true tenets, such as birds controlling insects or insect outbreaks occurring in radiation-damaged areas, is that they are so appealingly simple they have been often quoted and could become guiding rules simply by repetition.

Models, such as Ayre's scenario presentations,[45] while excellent means of portraying ecological damage and recovery, result in the presentation of ecologically incompatible, if not impossible, situations; this is caused partly by lack of pertinent ecological data and partly by failure to select pertinent and plausible happening .

Anticipated Ecological Damage and Recovery

As previously stated, the ecological aftermath of a nuclear attack is highly speculative. However, a consensus of opinion of most ecologists who have seriously considered the problem may be summed up by the following:

"...and that ecological disturbances would not be such as to prevent recovery";[6] "...ecological imbalances that would make normal life impossible are not to be expected";[46] "...direct radiation effects from nuclear war on vegetation are not likely to seriously limit man's reconstruction of his renewable resources."[31]

RADIOECOLOGICAL PRINCIPLES

As expressed above, most individuals considering ecological recovery from nuclear attack believe resulting ecological imbalances would not effectively delay national recovery. However, as many uncertainties exist, expecially concerning long-term consequences, continued research is urged. As research continues, prospects for improving capability for predicting both fate and effect of ionizing radiation steadily improve. Techniques or methods, henceforth referred to as hypotheses or principles, which have helped or offer promise to improve the validity of predicting postattack recovery, will be discussed. In actuality, most of these hypotheses should be considered as interim statements requiring further evaluation and testing before they become firmly established in radioecological considerations.

Principles may immediately be categorized into two groups: those principles which help predict effects of ionizing radiation, and those which help predict fate of fallout nuclides.

Hypotheses which Aid in Predicting Ecological Effects of Ionizing Radiation

Numerous studies show promise of increasing our ability to predict effects of ionizing radiation at various levels on individual organs, whole organisms, or plant and animal assemblages. Within this manuscript, only those studies which show greatest promise of developing an hypothesis most directly applicable to forecasting ecological recovery from ionizing-radiation damage will be discussed. Subjects to be discussed concern predictions of: (1) radiosensitivity of vascular plants, seeds, and mammals; (2) interactions of ionizing radiation and other environmental stresses; and (3) relation between evolutionary development (or life form) of plant communities and radiosensitivity.

(1) Radiosensitivity of plants, seeds and animals.

Perhaps the most promising find, one which may well be considered a principle, is that developed by Sparrow and colleagues wherein a correlation between the volume of cell and nuclei and radiosensitivity of plant meristem cells has been demonstrated.[47] This volume is reasonably constant within a species, and plants with larger chromosome volumes at interphase are proportionally more radiosensitive. Thus, it has been possible to establish plant-radiosensitivity-regression curves, relating interphase chromosome volume to radiation exposure, using various end points such as slight effect, severe growth inhibition, and lethality. These regressions can then be used to estimate the expected radiation tolerance of species for which directly determined data are unavailable. Using the above method and by actually irradiating test plants, Sparrow has compiled a highly useful table of radiosensitivity estimates of a large number of higher plants.

Sparrow and Woodwell tested the practicability of the above hypothesis to predict radiation effects in a natural oak-pine ecosystem located on Long Island.[48] Comparisons were made between predicted results with those which occurred after irradiating the ecosystem.[15] Discrepancies between anticipated and actual results indicated other influencing factors must have been operative, as the precision of estimates was less than expected. Sparrow, in discussing additional factors beside nuclear volume which influence plant response to radiation, emphasizes the need to specify the life-history stage being irradiated, i.e., pollen, embryo, seeds, seedlings, young, mature or senescent plants are differentially radiosensitive.[47] In addition, other environmental stresses, operating in conjunction with ionizing radiation and occurring before, during, and even postirradiation, have been shown to further alter plant response and are discussed later.

Though a great deal more research is needed to improve prediction reliability, particularly concerning the yields of seed-producing plants, and alterations in tolerance to disease, insects, or environmental stresses, this nuclear-volume/radiosensitivity hypothesis and the tables of data supplied by Sparrow are of enormous value in evaluating potential effects of radiation on individual plants and communities.

Modifications of the nuclear-volume/radiosensitivity concepts are being developed to predict response to radiation of plant seeds, and hopefully certain mammalian groups.[49] Also Golley, et al., in studies of radiosensitivity comparisons between laboratory and wild animals, notes that wildness per se does not confer radiation resistance, but rather that species vary in response to radiation on the basis of their physiological, ecological, and evolutionary background.[50]

Others (My er, Ohio State Univ., personal communication) operating on the premise that radiosensitivity of hemolymph of insects may be comparable to radiosensitivity of blood in mammalian blood systems are attempting to develop a method of predicting radiosensitivity of insects.

(2) Interactions of radiation and environmental stresses.

Effects from particular radiation doses can be predicted reasonably well in laboratory or optimum-environment experiments, but wide discrepancies between anticipated and actual results may occur in field situations. This is because combinations of environmental circumstances elicit plant responses which may mask, intensify, or possibly inhibit other responses predicted from nuclear volume characteristics.[15,21]

Researchers investigating interactions of ionizing radiation with other environmental stresses have shown that the intensity of simultaneously operative or post-irradiation environment factors may materially alter plant response to ionizing radiation.[34,35,51,52,53,54,55,56,57] Golley and others are also investigating radiation/environmental stress relations among animals.[50] Relative amounts of light, temperature and available moisture acting in conjunction with ionizing radiation seemingly can produce significantly different effects than one would expect. Thus, the universally accepted ecological principle: "whenever an organism is growing in a situation which is near the limit of its tolerance to one or more factors, its sensitivity to other factors is often increased," seems to have validity even when radiation effects are considered, and thus may well be called a radioecological principle. Though not often stated, this principle has some intrinsic considerations: (a) if an organism is growing in an optimum environment, it may withstand a greater than normal intensity of one deleterious factor before it shows an effect, and (b) if an organism is growing in an environment unfavorable for one or more factors, another factor (ordinarily deleterious) may compensate for the limiting factor -- for example, shade might compensate for soil drought.

The above principle is somewhat related to the so-called LaChateliers theorem, i.e., "an intensification of an environmental factor tends to increase an organism's resistance to further intensification of that factor." This principle seems to be true in relation to such environmental factors as drought and frost, but in regard to radiation the question would be whether or not the radiosensitivity of organisms chronically exposed to radioactivity will be increased or decreased when they are later exposed to higher levels of radiation. The existence of acquired resistance seems to be accepted in particular types of animal studies,[58] but experimental data in regard to plants are equivocal.[56,59]

(3) Life form and radiosensitivity.

Under conditions of chronic exposure to radiation, as Sparrow and Woodwell indicate, any environmental factor which slows plant development, and thus increases both irradiation time and accumulation, usually increases the radiation response.

In the case of acute exposures, no method other than Sparrow's radiosensitivity predictions of individual species, has been developed to predict radiation effects upon assemblages of plants (plant communities or ecosystems) living under natural-environmental stresses. However, Woodwell, Brayton and Woodwell have recently presented a supposition which may possibly allow gross predictions of community response to radiation to be made.[18,60] Briefly, the contention is that plants adapted to tolerate harsh environmental conditions are also more resistant to radiation damage. It would seem "...that characteristics that confer resistance to certain types of environmental extremes also confer resistance to damage by radiation." The strong parallelism between effects of fire and of radiation on a particular Long Island plant community -- huckleberry populations decline at the expense of increases of blueberries and sedges -- is offered as one example of supporting evidence.

Another example, offered by Woodwell, to substantiate the above contention is that continuous irradiation of a forest community produced a sorting by size or life form (trees, shrubs, tall herbs, prostrate plants) along the radiation gradient, smaller forms of life being generally more radiation resistant than larger ones. It was noted that this condition frequently exists in nature along gradients of increasing climatic severity, such as the transition from forest through a shrub zone to one of prostrate plants in high-altitude or high-latitude regions. This relationship between life form and radiosensitivity, and the parallels between radiation effects and effects of environmental gradients may simply be a fortuitous happenchance, if real. Nevertheless, as these relationships would help predict community response to radiation, and perhaps basic processes of life response to environment, such studies should be intensified.

Furthermore, as a number of investigators believe a strong relation exists between life form and toleration to temperature extremes during the growing season (Dahl, Agricultural College of Norway, personal communication) studies similar to those conducted by McCormick,[53] concerning temperature and ionizing radiation should be increased. In addition, studies relating radiation sensitivity of interaction with environmental- or biological-stress-producing conditions such as frost, light quality and quantity, low humidity, disease, and insect infestations, should be conducted since many research areas are essentially unexplored and may offer rich returns in being able to predict radiosensitivity of organisms under disturbed environmental conditions. Too, the idea of evolutionary history being related to radiosensitivity could be tested, i.e., comparisons of the degree of radiosensitivity (or nuclear volume) with the relative evolutionary development, or primitiveness, of vascular plant species could lead to a statistical test for a significant correlation.

HYPOTHESIS AIDING PREDICTION OF FALLOUT NUCLIDE FATES

In considering ecological damage and recovery from nuclear attack, problems regarding levels of radiation to which organisms within an ecosystem may be exposed are frequently by-passed, or only briefly contemplated. The tacit assumption is usually that all organisms will be exposed to similar levels -- i.e., radiation doses are projected upon an infinite plane. Hence, predictions of radiation damage from fallout are made largely on radiosensitivity of organisms with little or no regard to the likelihood of differential exposures to radiation. As an indication of how misleading this can be, Osburn reported the levels of gross beta radioactivity per square centimeter of ground surface in a Colorado mountain watershed varied in 1963 among plant communities within an eleven-square-mile Colorado mountain watershed from a few picocuries to well over two nanocuries, and in a limited number of exceptional situations the level of concentration approached the millicurie level.[34] In addition, due to differential fallout distribution, buds of relatively radioresistant Vaccinium plants forming the ground cover in the sub-alpine forest region were exposed to well over 1,000 times more fallout radioactivity than buds of the radiosensitive overstory spruce and fir trees. Thus the magnitude of radiation dose, superimposed upon the landscape and occupying biota by the pattern of fallout accumulation would in many instances certainly outweigh the influence of differential plant radiosensitivity. Hence, it is obvious that, until one can estimate the radiation doses that various organisms will receive, it is of little predictive value to know only radiosensitivity of organisms. Inability to predict possible dosages may well be our weakest link in forecasting the impact of a nuclear attack. Russell, in commenting upon the greater amount of research effort expended towards strontium-90 and cesium-137 uptake from the soil as contrasted to foliar deposition, emphasizes this weakness: "...we may regret that greater attention has not been given to those aspects of the direct contamination of plants which exert a dominant effect in many circumstances."[61]

Fallout Retention

Beginning with nuclear detonation and projected until decay reduces radioactivity to insignificance, extensive research has been conducted concerning alteration of fallout-nuclide composition. Several general models have been constructed to depict and predict these sequences.[62,63]

Research has substantiated the accuracy of some compartments of these models but many unproved sections exist. One section which is poorly known concerns relative amounts of fallout intercepted and retained by various types of natural vegetation.

In particular, mechanisms responsible for differential interception and/or retention efficiency have been studied in only a few geographical regions, under a limited number of weather sequences, and for a minimum number of vegetation types. Consequently, few guide lines for quantitatively predicting fallout concentration in natural ecosystems have been formulated. For example, the 1963 Project Harbor report arbitrarily assumed a one percent retention of fallout on plants, without considering specific lodgement sites on particular plants.[48] Romney, et al., and Martin worked in a cold desert region;[64,65,66] Rickard carried out studies in a prairie region;[67,68] Russell reported results from a region relatively high precipitation and of permanent pasture;[61] Menzel, et al. experimented with horticultural plants in a wet and in a dry region.[69] All agree that the major amount of fallout was associated with foliar deposition which, in turn, was related to total precipitation.

As Miller suggests, the contamination of foliage by fallout particles of a given diameter should depend on amount of foliage surface available for contamination, the collecting efficiency (I prefer interception-retention efficiency) of foliage surfaces for particles of different sizes and other factors, such as wind velocity during and after particle deposition.[62,70] Additional factors which should receive consideration are gross morphology of plants, phenology, length of growing season, and the amount, type and intensity of precipitation.

Osburn reporting on the fallout-interception-retention efficiency of three different alpine-tundra-plant communities in 1962 and again in 1963 noted the efficiency ranged from 30 percent to 77 percent in 1962 and in 1963 was reduced to a range of 8 percent to 21 percent.[34] Although this difference could have been related to change in fallout-particle size or changes in the productivity or morphology of the plants, the most plausible explanation concerned the difference in weather regimes between the two years (largely the amount and intensity of rainfall), and perhaps some predormancy translocation of cesium-137 in regard to the Carex vegetation.

Although such factors as stickiness or pubescence undoubtedly influences fallout entrapment on plant surfaces, perhaps the single most important factor (if fallout particles are not too large, say, less than 10 micron[64]) is the relative leaf surface per unit ground-surface area, i.e., interception is highly correlated with plant density. As plant density is a parameter frequently measured by most plant ecologists, data expressing average plant densities according to season of the year are available for many major U. S. ecosystems and should be incorporated into nuclear-attack-damage considerations.

Furthermore, great effort should be directed towards a number of heretofore rather poorly researched items. For instance, attention should be devoted towards whether meristematic regions and reproductive organs of plants tend to accumulate or dissipate fallout nuclides. It is entirely conceivable that due to position within a plant community and especially due to morphology, meristematic tissue of a relatively radio-resistant plant such as the dandelion could accumulate a level of radiation exposure proportionally greater to its resistance than a radio-sensitive plant such as a pine or spruce tree.

Although levels of atmospheric fallout are now generally too low to study efficiencies of fallout entrapment by various plants and plant parts under various weather and phenological regimes, other indirect methods of study, such as the imaginative study reported by Miller concerning foliar retention of volcanic ash,[71] could be investigated. Perhaps field plots, wind tunnel, or growth-chamber situations to test entrapment of simulated-fallout particles of known size, deposited under specific moisture or wind patterns, could be utilized. In lieu of direct experimentation, perhaps measurements of debris loads naturally accumulated by plants, and/or of the amounts of various forms and intensities of precipitation intercepted, could give, indirectly, an index of possible fallout-interception efficiency.

Nuclear Fallout and Wild Animals

Pathways of fallout contamination leading to man have been extensively examined and are reasonably well understood. Yet, concentration of fallout nuclides on or in wild animals -- exclusive of certain ungulates, such as caribou, reindeer, and mule deer -- has scarcely been considered,[72] and consequently no rules to predict contamination have been ventured. Brown, et al., indicate, however, that direct fallout deposition upon animals could be quite important.[73] Although the study of Osburn concerns high-mountain ecosystems,[34] results may well have much wider application, or at least suggest several avenues which should be examined in order to establish valid relations between wild animals and a nuclear-fallout-contaminated environment.

During the autumn months of 1962, 1963, and 1964, approximately 500 mammals and birds were collected in the Boulder, Colorado, high-mountain watershed. Most animals were sectioned into subsamples of fur or feathers, stomach, cheek, pouch, or crop contents, prefaeces, and eviscerated-skinned body. Each subsample was ashed and counted for gross beta radioactivity expressed as picocuries per unit fresh weight. A representative number of subsamples were composited and subjected to nuclide analysis.

In general, the amounts of radioactivity contained in the various body components reliably reflected the food source, behavior or habitat of the animals, regardless of their taxonomic positions. Specifically, the large differences noted in levels of radioactivity of the skin and feathers of various species of birds may be explained by the differences in behavior patterns, especially those exhibited in the search for food. For instance, the radioactivity (picocuries/gram) of the skin and feathers of the following list of birds (and one mammal) was graded according to the relative amounts of time each species tends to spend flying:

> bat, _Myotis_, sp. (846); magpie, _Pica pica_ (118); goshawk, _Astur atricapillus_ (66); pipit, _Anthus spinoletta_ (37); sparrow hawk, _Falco sparverius_ (31); and the great horned owl, _Bubo virginianus_ (21).

Birds which spend a larger amount of time searching among pine needles or plants on the ground tended to encounter and retain larger amounts of fallout radioactivity. Examples are:

> red crossbills, _Loxia curvirostra_ (250); chickadee, _Penthestes gambeli_ (110); Clark's nutcracker, _Nucifraga columbiana_ (92); Junco, _Junco canicaps_ (67); and the rosy finch, _Leucosticte australis_ (59).

When all vertebrate animals utilizing the Boulder city watershed were categorized by feeding habits, flesh of predators and scavengers contained relatively low levels of gross beta radioactivity, with seed-eating animals next higher, followed by grazers, and finally insectivorous animals. The extended range was well over a factor of 10.

It is of interest to note that in the case of two rodent species (pika and pocket gophers) juvenile individuals relegated to less optimum sites than were the adults contained much higher radiation burdens. Under nuclear-recovery situations, this could be a significant mechanism to retard population explosions and needs further research to determine whether this situation might apply to other species.

Research by French strongly suggests granivores ingest less radioactive material than herbivores living in the same contaminated environment because herbivore food has a much larger surface area per amount needed to sustain life.[74,75]

Though meager, the above data indicate that relative nuclide-accumulation patterns of animals vary considerably, but can be contemplated where their general ecology is known.

Food Chains and Radioecological Concentration

Efficiency of radionuclide transfer from soil to plants, plants to animals, within animals, up to and within man has deservedly received an immense amount of attention. It is quite true that examples of huge radionuclide concentrations have occurred and food-chain nuclide-concentration sequences, especially the lichen-to-caribou-to-man nuclide transfer sequence, are familiar to us all.[76] Since a volume of more than 1000 pages has recently been published,[77] and contains a number of tentative predictability rules and models of nuclide behavior, I'll pass over this category with only a mention of its importance when estimating potential ecological consequences of nuclear war. Too, excellent studies by members of the Ecology Section, Health Physics Division of the Oak Ridge National Laboratory convey hopeful portent that nuclide concentration within ecosystems will soon be predicted with reasonable accuracy.[78]

Before leaving the subject of radionuclide distribution, there should be a mention of the little-studied phenomena of radionuclide translocation within some plant species. It seems that once potassium or cesium-137 is taken into their systems various species of sedges and grasses tend to retain and increase these materials.[34,79] Towards the end of a growing season as shoots wither, both cesium and potassium are translocated to the overwintering buds. As a number of animals tend to feed upon buds, and as young, developing shoots might have relatively high cesium-137 concentrations the following spring, this area of research should be further investigated. Assuming cesium-137 would follow the same pathways within a plant as does potassium, it would be a relatively simple matter to design a research program which would enable us to anticipate the role of cesium-137 translocation in nuclide concentration predictions.

Specific Nuclide Concept

The most promising candidate for being considered as a radioecological rule is the "specific nuclide concept," (ratio of the amount of radioisotope to total isotope of the chemical element considered) as expressed by Lowman.[80] Briefly stated, the distribution patterns of artificially introduced radionuclides can be predicted by obtaining qualitative and quantitative information regarding the distribution of stable elements. While this concept is essentially untested in terrestrial ecosystems, it appears to have validity for marine situations. If this proves reliable it will give us an extremely valuable predicting tool.

Conclusion and Recommendations

Studies of ecosystems subjected to lethal levels of ionizing radiation -- from nuclear testing, or from multicurie gamma sources placed within natural areas -- indicate ecological recovery follows pathways of succession which are predictable and quite similar to those following recovery from other catastrophic events such as recovery from fire. In order to test the universality of this concept of recovery, additional ecosystems representative of major areas of the United States should be tested.

Since recovery from nuclear war would be expected to follow normal successional trends, accuracy of forecasting ecological recovery could be materially improved by incorporating what ecologists have thus far learned. In fact, nearly all individuals attempting to forecast specific ecological effects or recovery from nuclear warfare have stressed the availability of methods and materials to improve prediction reliability.

Perhaps the weakest link in our ability to anticipate ecological consequences of fallout radioactivity concerns differential exposure of various organisms to initial and subsequent fallout-nuclide distribution. Research has demonstrated, at least for particular landscape units, that environmental factors responsible for vegetational differentiation are operative (highly correlated) in determining the deposition and distribution of radioactive fallout.[33] As these units (plant communities) have been extensively studied and are relatively stable, they should be functional units to study for predicting ecological recovery. Though the selection of an optimum-sized unit to work out ecological consequences (e.g., likely patterns of fallout deposition, fire, erosion, plant and animal invasion, succession, etc.) will be somewhat arbitrary, the unit should have sufficient homogeneity so that data researched from one segment, particularly concerning radionuclide distribution or effects, will be valid throughout. Though many parameters which are quite important for radioecological considerations are routinely measured in ecological studies, estimating ecological recovery from nuclear war could be improved by including other parameters such as estimating surface area of plants so that an index of their efficiency to intercept and retain fallout materials could be calculated.

The United States has been variously divided into landscape regions, from five to well over a hundred units. Kuchler has prepared a detailed map of potential vegetation types of 116 units for the conterminous U. S.,[34] and it is recommended that these units be given a trial as the basic-sized unit to use for predicting ecological consequences. It may be that many of the units will not differ significantly from one another as far as influencing fallout distribution patterns, nor in influencing radiation damage and recovery and can later be composited, or perhaps in some cases further divided.

As the International Biological Program plans to analyze major U. S. biomes (grasslands, conifer forests, deciduous forests, tundra, deserts, and a tropical region) in some detail[6] it would benefit ecological-recovery prognosticators considerably if the parameters measured could be increased so that all presently known important parameters for making valid forecasts of recovery could be included. These additions might well be estimates of the size and composition of annual and cumulative plant-seed "rains," plant regenerative capability after fire or erosion, indexes of debris or fallout-particle interception and retention, terrain shielding, concentration of water in relation to the morphology of reproductive organs of various organisms. Also of importance is ecosystem heterogeneity (diversity of topography, soils, vegetation, fauna, etc.). These factors influence initial damage upon an ecosystem from fire, flood, wind, etc., and thus play a significant role in the rate of ecosystem recovery.

As far as I know, no landscape unit has received a study of sufficient detail that the investigators will confidently predict the degree of damage a nuclear catastrophe might effect--initially or upon a long-term basis. However, studies of the Cape Thompson region in Alaska, of ecosystems at the Oak Ridge and perhaps the Brookhaven National Laboratories, and of the Battelle-Northwest and Savannah River ecology groups, as well as my own mountain-watershed study, are reasonably complete and perhaps if a researcher wished, a "radio-ecological survey manual" could be prepared which would represent the most accurate forecasts (including error in estimating) we could presently make regarding long-term ecological recovery from nuclear war. This manual could then serve as a guide for similar compilations in other regions of the United States. Certainly it seems reasonable that a guide to expected damages and expected recovery would be a worthwhile advance preparation, since even local effects of a nuclear war would be catastrophic to those involved.

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POSTATTACK INSECT PROBLEMS

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One area of concern in postattack recovery is the insect problem. Insects are man's chief competitors for the earth's food resources; they are vectors of disease, and when present in unusually large numbers they can and do destroy entire crops. Insects are also beneficial and necessary. They play a major, although ill-defined, role in many if not all ecological processes. Predaceous and parasitic insect species serve to control harmful species. Lastly, insects are vital in plant reproduction because they serve directly or indirectly as pollinating mechanisms.

Adult insects have been shown to be relatively resistant to ionizing radiation. Doses of 20,000 rads or greater generally have been required to produce total lethality in adult insects under laboratory conditions. In some cases, doses as great as 100,000 rads have been necessary to produce significant mortality. In insect control using the sterile-male technique, exposures of approximately 5000 rads are usually the levels which are used.

Birds generally are more resistant to ionizing radiation than mammals but are less resistant than insects. Radiation doses greater than 1000 rads would be necessary to kill adult birds. These doses, though, are one-tenth-or-less than those required to produce total lethality in adult insects. Because birds are widely recognized as predators of insects, this difference in radiosensitivity focused response on a postattack ecological problem, namely the possibility of severe bird-insect population imbalances. It has been postulated that insect plagues would be one of the major consequences of a nuclear attack, because birds are a constraint on insect-population size, and their destruction would release insects from control.

Most ecologists would consider this a superficial analysis and could suggest alternative insect problems which might result from an attack. Nevertheless, the bird-insect interaction has been most useful because it has served to focus attention on the fundamental problem. This is the problem of the response of mixed insect populations to prompt ionizing radiation and the ecological consequences thereof.

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Our concern about the responses of insect species and populations to attack or postattack environmental conditions stems from their importance to agriculture, food storage and supply, and disease control as well as their importance in recovery of our ecological systems. All of these are related to uncertainties in predicting the pattern of biological or ecological response to an attack or postattack environment.

Postattack insect problems can be categorized, in terms of research needs and present knowledge, as radiological or ecological. Radiological problems include beta-dose response, life-cycle or radiation profile, and comparative radiosensitivity. Ecological problems include population response, habitat, and secondary effects. A special aspect of the ecological problem is the response of beneficial insects such as pollinators and certain groups of predators. Both of these general problems are interrelated and any research program concerned with postattack insect problems must encompass both aspects. For purposes of this paper, it will be useful to discuss some of these separately. This discussion will be essentially a summary of the problem.

THE BETA-DOSE PROBLEM

Evidence has recently accumulated that the beta-dose component of local fallout may be significantly greater to small organisms than the gamma-dose component. It has been suggested that the beta-dose component may be 50 to 90 times greater than the gamma-dose component for those organisms which are exposed to and receive fallout particles directly on their surfaces. Many insect species may be especially vulnerable to direct contact with beta particles; the young insects are soft bodied and thin skinned, offering possibilities for increased beta-particle penetration and absorption. Young insects of many species spend their time on ground surface or on plants, particularly in crevices where they receive some protection from natural enemies. These microhabitats, however, would receive much deposited fallout. Insect eggs, which are much more radiosensitive than adult forms, are laid in the soil or, for a number of species, in and on plants.

There are little or no data on the beta-dose sensitivity of insects. Investigations are needed on beta dosimetry in insects representing typical body types. Likewise, investigations are needed on the field response of insects subjected to acute or chronic beta exposures within their natural habitats.

THE RADIATION-PROFILE PROBLEM

Insects have complex life cycles Generally they pass through a series of larval or nymphal stages changing gradually into adult form or else going through a special quiescent -- pupal -- stage during which metamorphosis to adult form takes place. For insects it is especially important that the radiosensitivity and response be known for their whole life cycle because sensitivity to ionizing radiation may vary by a factor of 100 or more over the insect life cycle.

Recently in our laboratory we have started studies on the comparative radiation profiles of a number of insect species. Two of the most recently completed investigations were on the house cricket (Acheta domesticus), and the common yellow mealworm (Tenebrio molitor). They have contrasting types of metamorphosis which represent the two main types of metamorphosis found in terrestrial insects. Thus they possess quite different early life-history stages -- differing in morphology and physiology and in their ecological requirements.

These first experiments involved exposures to gamma radiation ranging from 1 kR to 100 percent increments -- i.e., 1 kR, 2 kR, 4 kR, 8 kR, etc.

The four life-history stages of Acheta selected for investigation revealed a general pattern of decreasing sensitivity to radiation during nymphal development, if survival time following irradiation is compared to life expectancy of controls. At exposures to 4 kR and above, however, the observed mean survival times were surprisingly similar for all stages. Also Acheta appears to be more sensitive to radiation-induced mortality than are the majority of insect species which have been tested. In studies investigating radiation-induced sterility as a populational-control method, exposures of the order of 5 kR are commonly cited as producing little or no mortality.[1] Such an exposure produced severe shortening of lifespan for nymphal and adult Acheta.

For Tenebrio, comparison of radiation sensitivity of life-history stages revealed a more complex picture. Survival times of larvae after exposures to 4 and 8 kR, for example, were much longer than those of pupae and adults exposed to those doses. Small larvae, medium larvae, and large larvae showed decreasing radiosensitivity in that order. Adults and pupae, however, appeared to be somewhat more radiosensitive than medium or large larvae. Both pupae and adults exhibited a survival plateau, showing little or no increase in mortality when exposures were increased from 4 to 32 kR. Thus, the comparative sensitivity of the developmental stages was in part dependent upon the exposure.

Aside from the generalization that the younger stages are more sensitive to radiation than the older ones, a direct comparison of Acheta and Tenebrio is difficult. If mean survival times at 4 kR or 8 kR are compared with those for controls, the small larvae (Tenebrio) and small nymphs (Acheta) appear to be considerably more radiosensitive than older stages.

COMPARATIVE-RADIOSENSITIVITY PROBLEM

These results emphasize the need not only for studies of the comparative radiosensitivity of typical insect species under controlled and field conditions, but also the need for some general index of radiosensitivity. An index such as the interphase nuclear volume of chromosomes which has been worked out for plants by Sparrow and his associates might be useful.[3] Many insects have large numbers of small chromosomes, but with the newer measurement techniques a similar index might be feasible for this group. This is another area where research is needed.

ECOLOGICAL PROBLEMS

The information which we now have on radiation-induced mortality in insects is based largely on laboratory experimentation. Extrapolation of the laboratory findings to the field environments must be done cautiously. Within their habitats, insects are subject to a variety of stresses and interactions. These include climate, food supply, predators, parasites, and competition, to name some of the more important. A major uncertainty in our knowledge is whether radiation damage may be intensified by interaction with other environmental stresses -- extremes of weather conditions or loss of food resources, for example. There are now some very good data from plant studies and some suggestive results from small-mammal studies that ionizing radiation interacts with other environmental stresses. Our initial experiments using the cricket Acheta suggest greater mortality for irradiated crickets living under field conditions than those kept under similar laboratory regimes. The causal factors in these experiments that accounted for the greater field mortality appeared to be biological, i.e., predation and possibly pathogens. However, these experiments were limited in scope and the insects used were a domesticated species. Longer-term field experiments involving complete life cycles of several insects under a variety of radiation exposures are needed.

Postattack food production is a primary problem which involves insects. Insect pollinators are an important factor in this production. Honeybees and certain wild solitary bees have been shown to be essential for the production of many agricultural crops of seeds, fruits, and vegetables by virtue of their pollinating activities. The Bee Culture Branch of the Entomological Research Division, U. S. Department of Agriculture, has estimated that $1 billion worth of agricultural crops depend upon the honeybee for their production and another $2 billion depend upon the honeybee for good yields. At least 50 agricultural crops are involved.

Few studies have been made on the radiosensitivity of the honeybee, and none have involved the effects of ionizing radiation on the behavior of the honeybee. For these reasons, recently we have started a combined laboratory and field investigation on the radiation response of honeybees.

Individual lots of honeybees were tested for sensitivity to beta, gamma, and neutron irradiation under laboratory conditions. The results of these tests suggested that a level of 5000 rads of gamma radiation would reduce the lifespan of worker bees by only 29 percent. On the basis of these results, five hives of hybrid bees had doses of 5000 rads of cobalt-60 gamma at about 65 rads per minute. Hives were then returned to the field. The irradiation of the entire social unit -- the colony -- had a catastropic effect. Pollen collection dropped by 50 percent within 9 days and ceased completely by 16 days. Within 8 days postirradiation, about 99 percent of the bees being reared had died. Most of them had been removed from their cells and cast out of the hives by the worker bees. Within 12 days, 95 to 100 percent of the pupae in the capped cells were dead. Eggs, larvae, nearly all pupae, and adults perished, and the colonies were eliminated as functional units within 21 days.

The results of recent radioecological research on insects have emphasized two striking features of the insect problem as it relates to postattack research needs. The first is the importance of the evaluation of radiation effects in a full field experiment rather than extrapolation from laboratory experiments. The second is that complex insect communities such as social insects -- bees, wasps, etc. -- may be exceedingly sensitive to ionizing radiation.

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SOIL-PLANT RELATIONSHIPS OF RADIOACTIVE NUCLIDES IN FALLOUT

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The main view which will be developed here in the brief time available is that detailed consideration of the uptake of radionuclides from soil by food crops in a long-term postattack period can be restricted to several nuclides. The understanding of fallout composition and behavior gained from nuclear-weapons tests is one of the bases of prediction of postattack soil and plant relationships. It is assumed that relating the internal-emitter hazards, including the contribution by soil, to the total attack-casualty assessment will be attempted by other speakers.

Fresh debris of exploded thermonuclear weapons contains a mixture of hundreds of different radioactive nuclides. These originate as radioactive components of the device, as fission products, and as neutron-activated products of device and ground materials.

The fallout which eventuates from the explosion is frequently classified into local, tropospheric, and stratospheric. With increasing distance and time from the explosion, the number of radionuclide species in fallout at the time of deposition becomes reduced. This occurs because the great majority of the radionuclide species produced in the explosion are short-lived, much fewer have lives of intermediate length, and only a relatively-small number are long-lived.

Fallout on agricultural land may be deposited directly on plants or on soil. Where food and forage crops are standing in close-in fallout areas, it is possible that some will suffer radiation damage from high-intensity gamma and beta radiation, especially that emitted by short-lived nuclides. With increasing distance from the point of detonation, the primary potential problem of fallout on cropland becomes that of food-chain contamination.

The nuclides of fallout deposited directly on aboveground parts of plants need not be metabolized into the plant to contribute to the internal-emitter hazard to man and animals. The fraction of a particular nuclide which reaches the soil, however, must be solubilized and transported to the active root zone before it can enter the plant and be distributed to food parts. For an annual crop, or approximately the first year of a perennial crop, the main pathway of plant contamination therefore usually is direct deposition on the plant. At this stage fission products of relatively highest importance in food chains include iodine-131, strontium-89, and barium-140 and its daughter lanthanum-140. Neutron-activated nuclides would not be expected to be of significance past the first year, because of short lives. It has been estimated that at one month after a ground burst, the highest radioactivities induced by neutron irradiation of soil material would be phosphorus-32, calcium-45, and iron-55 and -59[1]. All of these are isotopes of essential nutrient elements.

During the long-term postattack period, when the significance of uptake through roots relative to direct plant contamination would be increased and would become predominant with time, only several fission products would be sufficiently abundant and biologically available to warrant detailed consideration. The following discussion of this situation is closely based on a recent paper on soil contamination[2].

Strontium-90, which has a half-life of about 28 years, would be the second most abundant fission product and the one about which most concern is usually felt. Perhaps this is rightly so, since its similarity to calcium brings it into the food chains and deposits it along with calcium in the bones of man and animals, where some of it remains for years. Cesium-137 would be the most abundant fission product in the environment. It is produced in amounts of 1.6 times as much as strontium-90, has about the same half-life, thirty years, and is found in most soils in about the same ratio to strontium-90 as when produced. It is generally more tenaciously held by the soil than is strontium-90 and hence has a somewhat lower plant availability than strontium-90. Since cesium is similar in its chemical properties to potassium, it is metabolized in the bodies of grazing animals and enters man's diet both in milk and in meat.

Strontium-90 and its daughter yttrium-90, and cesium-137 and its daughter barium-137 would account for most of the biologically available man-made nuclides in the soil. The other fission products present in soils in the greatest abundance would include cerium-144 and its daughter praseodymium-144, ruthenium-106 and its daughter rhodium-106, promethium-147, and antimony-125; this group of nuclides are only very slightly available to plants and hence, even when present in soil, do not get into foods and feed in significant amounts. Thus, the detailed discussion of fission products which are metabolized from soil over a period of years or decades can be restricted to strontium-90 and cesium-137.

Strontium-90 in soluble form is subject to rapid adsorption on soil particles by the process of cation exchange. The adsorbing constituents are clay minerals and organic matter. While in this exchangeable state, radiostrontium has approximately the same mobility as that of exchangeable stable strontium and calcium.

The downward movement in soil of strontium-90 due to such factors as percolating rain water, diffusion, and animal burrowings, is relatively slow. Even in the recent sampling for strontium-90 content of undisturbed grass-covered soils, collection of samples to a depth of only eight inches has recovered virtually all of the strontium-90 in the profile[3]. The distribution in cultivated soil, however, will be quite different. Depending on the type and extent of usual tillage practices, cultivation will tend to distribute the strontium-90 uniformly through the cultivated layer, or to place in mainly at the bottom of the cultivated layer, where it is subject to further downward movement. The uptake by root systems of various types will be affected to some extent by the distribution pattern. The presence of salts in irrigation water[4] and the fertilization and amendment of soils[5] generally increase the rate of downward movement.

Soluble and exchangeable strontium-90 are readily available sources for plants. There is, however, evidence from chemical extractions and from agronomic field experiments [5] that, at least in some soils, a part of the strontium-90 content becomes fixed in a non-exchangeable form. This form has been shown to be unavailable to plants[6]. Fixation, when it is observed in the field, usually appears to involve less than 10 percent of the total strontium-90, and its persistence has not been established.

In order to make generalized comparisons of the relative availabilities of various radioactive elements to plants, Menzel[7] examined the results of a number of field and greenhouse experiments from which the relative concentration factor of an element in the plant and in the soil could be ascertained, that is, parts per million in dry plant material over parts per million in dry soil. On this basis, the elements were divided into five groups, namely (a) strongly concentrated, (b) slightly concentrated, (c) not concentrated, (d) slightly excluded, and (e) strongly excluded. Strontium is classified in the second group, slightly concentrated, together with the similar elements calcium and magnesium.

An increase in the available calcium supply of a soil often reduces the radiostrontium content, or the ratio of radiostrontium to calcium, of plants. Despite a general lack of discrimination between strontium and calcium with respect to total uptake by the aboveground portion of the plant, specific plant parts do exhibit differences in strontium content and in the ratio of strontium to calcium. Roots generally show higher values of the ratio than do leaves, but fruits and grains show lower values.

A single annual crop generally will remove from 0.1 to 1 percent of the soil content of strontium-90. The exact amount of uptake depends on a large number of factors, including the type and size of the crop, soil type, application of lime, fertilizers, or other amendment, and cultivation practices[8].

The cesium-137 content of foods and feeds, especially in north temperate zone areas, has been derived preponderantly from direct atmospheric deposition on vegetation, and uptake from root mats and the organic layers of permanent pastures[9]. Another reason for this is the intensive fixation of cesium-137 in mineral soil horizons in a non-exchangeable form by the clay mineral vermiculite and vermiculitic interlayers of interstratified micaceous minerals[10]. The absorption of radiocesium from soils which do not contain such minerals is relatively much greater[9,11].

This widespread fixation results in both low mobility in mineral soils and a low uptake from them by plants. On the other hand, the mobility of cesium within the plant is relatively high, in contrast to that of strontium, which moves primarily away from the base. When the available potassium level of soil is low, applications of potassium fertilizer may decrease the uptake of cesium-137[12]. It has been observed, however, that the uptake by lowland rice growing in paddy soil is increased by application of nitrogen in the ammonium form[13].

Menzel's classification of elements on the basis of relative concentration factors[7] places cesium-137 in the category of "slightly excluded". The uptake from mineral soil by a single annual crop is usually less than 0.1 percent of the soil's content.

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MOVEMENT OF CESIUM-137 BY RUNOFF, EROSION, AND INFILTRATION FROM A SOIL UNDER DIFFERENT COVER CONDITIONS

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When fallout particles are being deposited, interception by plants is a common occurrence. This deposition on the plant leaves is followed by foliar absorption or by washoff.[1] The extent of each depends on the properties of the vegetation, radionuclide, fallout particles, prevailing climatic conditions, and time. Nuclides which reach the ground surfaces are further subject to movement either into the soil by percolating water or off the ground by runoff and erosion. Transport of radionuclides which are strongly sorbed by soil particles is defined by the movement of particles; radionuclides which are not sorbed by soil particles follow the movement of water. Since most radionuclides are sorbed to some degree by soils, their actual behavior lies between the two extremes.

The factors affecting sorption of fission products by soils and intake of radionuclides by plants through foliar absorption, as well as by roots, have been reviewed by several investigators.[2,3,4] Movement of radionuclides into the ground, particularly radiostrontium, has been investigated both in the laboratory and in the field.[5,6] Radiocesium, on the other hand, is readily sorbed and fixed in soils, and attention, therefore, has been focused on the mechanism of fixation in soils.[7,8,9]

In contrast to the downward movement into the profile, radionuclides may be transported off the soil by runoff and erosion. In samples taken to determine the worldwide deposition of strontium-90, special care was taken to avoid areas which showed evidence of erosion or accumulation from adjacent areas;[6] hence information on the areal distribution of radionuclides is not gained from these studies, as pointed out by the investigators. Frere and Roberts reported that as much as two-thirds of the strontium-90 deposited by fallout on a small watershed in Ohio was lost by this mechanism. Menzel found that as much as 30 times more strontium-90 was in soil particles from runoff than in the original

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soil plot in Wisconsin. Graham reported that when the rainstorm was less than 0.2 in. per hour on a Putnum silt-loam soil from Missouri, no runoff was observed and, therefore, no movement of radionuclides by this mode occurred.[10]

The limited amount of quantitative information on the transport of radionuclides by runoff and erosion, with the consequence of possible buildup in lower areas of contaminated materials, prompted us to initiate a program to evaluate this phenomenon under field conditions. For this report, we have included only summary results from two years of operation of our field plots. A more detailed account of our findings will be published elsewhere.

EXPERIMENTAL SETUP

For our initial test, we chose to follow radiocesium since this element is known to be sorbed very strongly by most soils. This high sorption suggested that radiocesium would concentrate in the uppermost layer of the surface zone and, thereby, be more susceptible to movement by runoff and erosion. To enable comparison of the behavior of radiocesium under different vegetative-cover conditions, three plots, each 2.3 x 2.3 meters, were installed and their original meadow cover modified. The alluvial soil of the plots, a planosol in the Red and Yellow Podzolic region, belongs to the Captina series and has a silt-loam texture. In the first plot, plot 1 -- bare soil, vegetation was killed with 2-4-D and removed. In the second plot, plot 2 -- clipped meadow, the meadow was clipped prior to tagging and the litter was left on the ground. In the third plot, plot 3 -- good meadow, the meadow was fertilized at the rate of 300 kg/ha of nitrogen -- as ammonium nitrate -- and allowed to grow tall. The vegetative cover consisted of a mixture of crabgrass and meadow fescue with crabgrass predominating.

In Figure 1 a general view of the experimental area is shown. Each plot was enclosed by a metal strip sunk into the ground to prevent surface losses to the outside. The study was conducted on the first three plots (on the right side of Figure 1), and the fourth plot was kept in reserve for future use. At the lowest corner of each plot, a runoff-catchment sink was cemented in place and connected to the runoff-collection pans shown in the lower left of Figure 1. Each pan was equipped with calibrated drums and water-level recorders. A recording rain gauge was installed in the experimental area. The information from the recording rain gauge on duration, intensity, and amount of rainfall for each storm was used in computing the erosion index (EI) value. It was also correlated with the runoff rates, and the amounts and starting times obtained with the water-level recorders for each plot.

Figure 1. General View of Study Plots Located at the Oak Ridge AEC Reservation in Tennessee on Alluvial Captina Silt Loam.

Application of cesium-137 tag was carried out using a modified orchard sprayer at constant pressure of 50 psi. Five millicures of cesium-137 were diluted to four liters in a weak HCl solution (pH = 4). This quantity was sufficient for five complete spray passes. Alternate sprayings were made in the direction right angles to the previous application. Cesium-137 tag was applied under dry-soil conditions; the first rain was recorded six days after tagging.

After each storm the runoff collected was sampled and the concentration of cesium-137 on the solid and in the liquid determined. Detailed area, soil, and plot descriptions, as well as tagging and sampling procedures, have been reported previously.[11]

BASIC CONCEPTS OF EROSION

Following washoff from the vegetation, movement of radionuclides in a soil will depend on the interaction of primary causative agents, such as rain, with the radionuclides and with the physical and chemical characteristics of a given soil material. Although this study was concerned with the movement of cesium-137 on a Captina soil in East Tennessee, similar principles may well be applied to other radionuclides and in other areas.

The universal soil-loss-estimating equation of Wischmeier and Smith was used.[12,13] The soil-erodibility factor K in $(g/m^2)/(dyne/sec)$ is given by

$$K = (1.0/SLC)(dA/dEI), \tag{1}$$

where

A = soil loss (g/m^2),

EI = product of storm energy and its maximum 30-min intensity (dynes/sec),

and S. L, and C are dimensionless correction factors for the degree of slope, slope length, and vegetative cover, estimated by

$$S = (0.52 + 0.36\, s + 0.052 s^2)/8 \tag{2}$$

$$L = (\lambda/2212.85)^{0.5} \tag{3}$$

$$C = \frac{\sum_{T_0}^{T_1} A}{\sum_{T_0}^{T_1} EI} (1/KSL) \qquad (4)$$

where

s = average plot gradient (percent),

λ = average slope length (cm),

T = time (years); $T_0 = 0$, $T_1 = 2$.

The values of factor K are calculated for a unit plot, defined by Wischmeier and Smith as a plot 2212.85 cm (72.6 ft) long, having a uniform slope of 9 percent.[12]

The value of K for Captina soil, listed in Table I, was computed from Equation (1) and the least-squares fit of EI and soil loss on bare soil plot 1. The available data for 44 out of 50 storms, with EI as the independent variable, were used. Of the six storms omitted in computation of K, plugging of the exit drain was observed on three, no runoff on one, and unaccountably high soil loss and very high EI value on the remaining two, respectively. The value for K of 1.96 ± 0.19 dynes/sec obtained by us agrees closely with the estimated value of 1.98 dynes/sec.[14]

Under bare-soil conditions of plot 1, vegetative-cover correction factor C is unity. The values of factor C, computed using Equation (4) for meadow plots, are given in Table I. A low value of C for plot 3 reflects a heavy meadow stand during the 2-year-study period. A high value of C for plot 2 is indicative of a poorer stand and the unfavorable initial conditions.[11]

To compute annual EI values for an area, Wischmeier and Smith recommend using the data from storms larger than 1.27 cm.[13] On our small-plots studies, runoff was produced even by minor storms (<1.27 cm), particularly in the winter and spring months. The EI values used by us here represent, therefore, the EI for all the rains that have occurred during the 2-year-study period.

The values of average slope (s) and average length of slope (λ) listed in Table I are different from those reported previously.[11] The average predominant land-slope and slope-length criteria which are

TABLE I

AREA, SLOPE (s), SLOPE LENGTH (λ), SLOPE SLOPE-LENGTH CORRECTION FACTORS (SL), COVER CORRECTION FACTORS (C), AND SOIL ERODIBILITY FACTOR (K), ON THE THREE RADIONUCLIDE-MOVEMENT STUDY PLOTS ON ALLUVIAL CAPTINA SI. L. SOIL IN TENNESSEE[a]

Plot[b]	Area (m^2)	s (%)	λ (m)	SL	C	K $(g/m^2)/(dyne/sec)$[c]
1	5.5	3.2 ± 0.2	1.8 ± 0.2	0.08	1.000	1.96 ± 0.19
2	5.3	4.6 ± 0.3	1.9 ± 0.2	0.12	0.040	
3	5.4	7.8 ± 1.0	2.2 ± 0.2	0.26	0.006	

[a]Correction factors (SL) were computed from equations given on page 153 of Wischmeier and Smith,[13] our equations (2) and (3). Soil erodibility factor (K) was computed from equation (1) and least-squares fit of soil loss as g/m^2 versus EI in dyne/sec, using C value of 1.0. Cover factors for plots 2 and 3 were computed from equation (4), using observed soil loss values and observed EI values and K and LS values listed above. Values of K and C are based on 2 years of data.

[b]Plot 1, bare soil; plot 2, clipped meadow; plot 3, good meadow.

[c]Conversion factors are as follows: 224.2 g/m^2 = 2242 kg/ha = 1 ton/acre; 0.4728 dynes/sec = 0.4728 $(ergs/cm^2)/(cm/sec)$ = 1 (ft-ton/acre) (in./hr); 4.74 $(g/m^2)/(dyne/sec)$ = 1 (ton/acre)/(100 ft-tons/acre)(in./hr).

applicable to agricultural fields[12] were not considered suitable for small-plot studies. In the context of the small-plot study, doubts arose regarding selection of deposition areas and of easily definable drainage channels.[12] When cover factor C for good meadow turned out to be lower by 1/3 than the lowest value in use, the procedure described below was developed to obtain the average slopes and slope lengths of our small plots.

The procedure makes use of a set of points distributed uniformly per unit of plot area but in random directions with respect to exit sink. Uniform distribution is obtained by inscribing the plot in a circle with the origin at the exit sink and dividing it into a number of equal annular zones.[15]

A number of points proportional to the area of the zone occupied by each plot segment are assigned in random directions[16] and located on the imaginary subannular arcs within each zone segment. The points are connected with exit sink by surface streamlines which cross the equipotential one-inch contour lines at right angles. The slopes at each location are calculated from elevations with respect to the sink and the length of surface streamlines. The average, listed in Table I, is taken as plot slope (s), and the average length of streamlines is taken as the slope length (λ). The same set of points was used for each of the other plots (plots 2 and 3); the values of s and λ obtained are listed in Table I, along with the computed SL (slope, slope-length) correction factor.

RESULTS AND DISCUSSION

Cesium-137 Leaching from Vegetation

After cesium-137 was applied on the plots with vegetation (plots 2 and 3), it was found that practically all the cesium was on the plant and litter material. In Figure 2 the percentage concentration of cesium in the dead vegetation for selected sampling dates following application is shown as a function of rain. The results show that, during the first 153 days following application, about three-fourths of the cesium originally present on vegetation was leached off, and that after 585 days practically all of it was leached. Limited data in Figure 2 also indicate that the initial decline in concentration in the clipped-meadow plot is more rapid. The reason for the lower loss from the good meadow could be that the pathway for leached cesium is partly along the blade of grass for the tall meadow vegetation which would tend to slow the transfer of cesium to the soil.[1]

ORNL-DWG 66-9769R

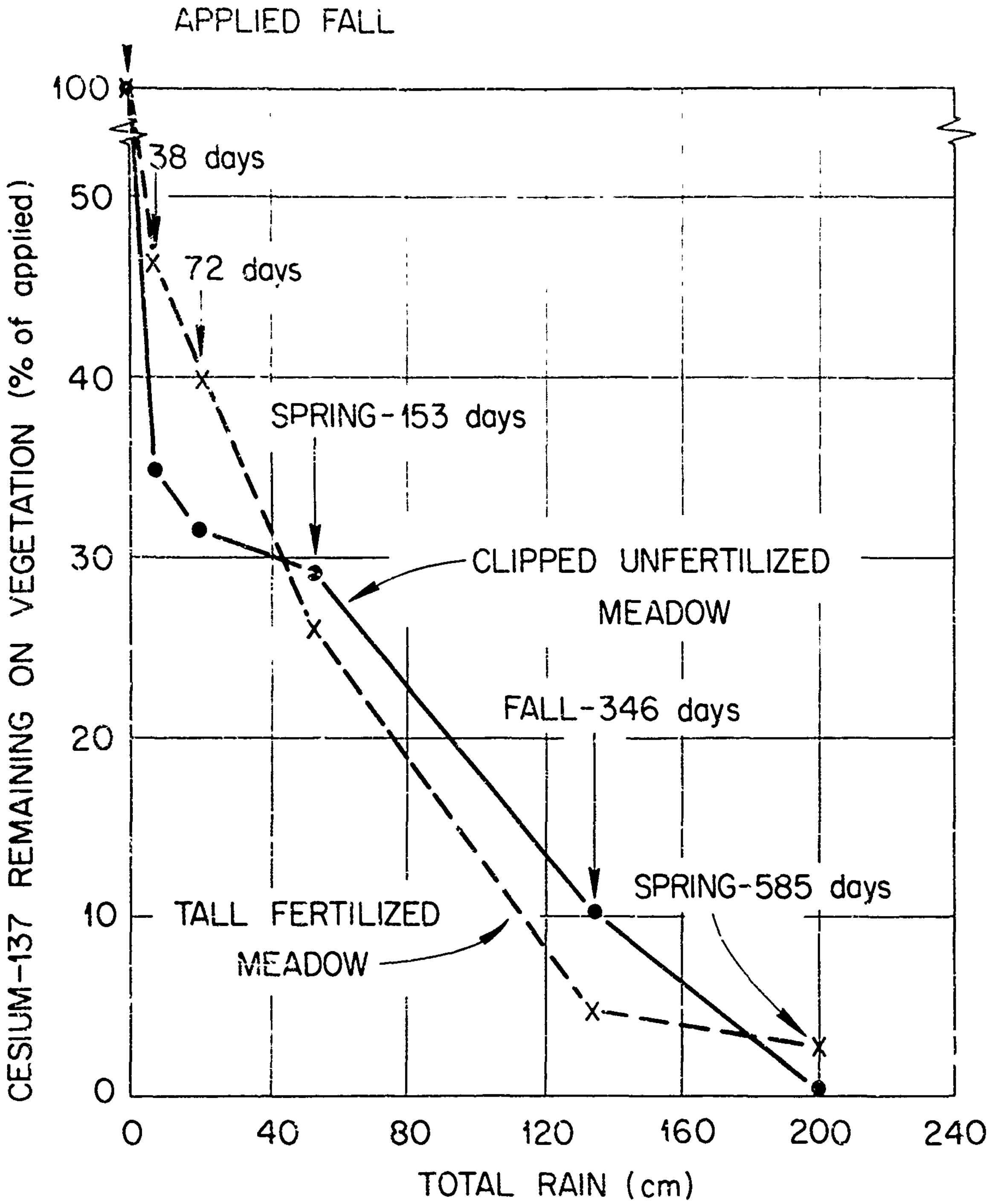


Figure 2. Percent of Cesium-137 Remaining on the Vegetation as a Function of Rain (cm).

Samples taken after 2 years (737 days) confirmed the total loss of cesium from vegetation: 0.3 and 0.1 percent were found in the vegetation of plots 2 and 3, respectively. These values and those reported for the 585-day samples were corrected for the additional vegetation due to new growth.

Cesium-Soil Loss Relationship

The relationship of cesium loss to soil loss was found to fit the logarithmic curve of the type,

$$Y = A(X/B)^n \qquad (5)$$

where

Y = the cumulative percent of cesium loss,

X = the cumulative soil loss (g/m^2),

B = a units constant = 1.0 g/m^2,

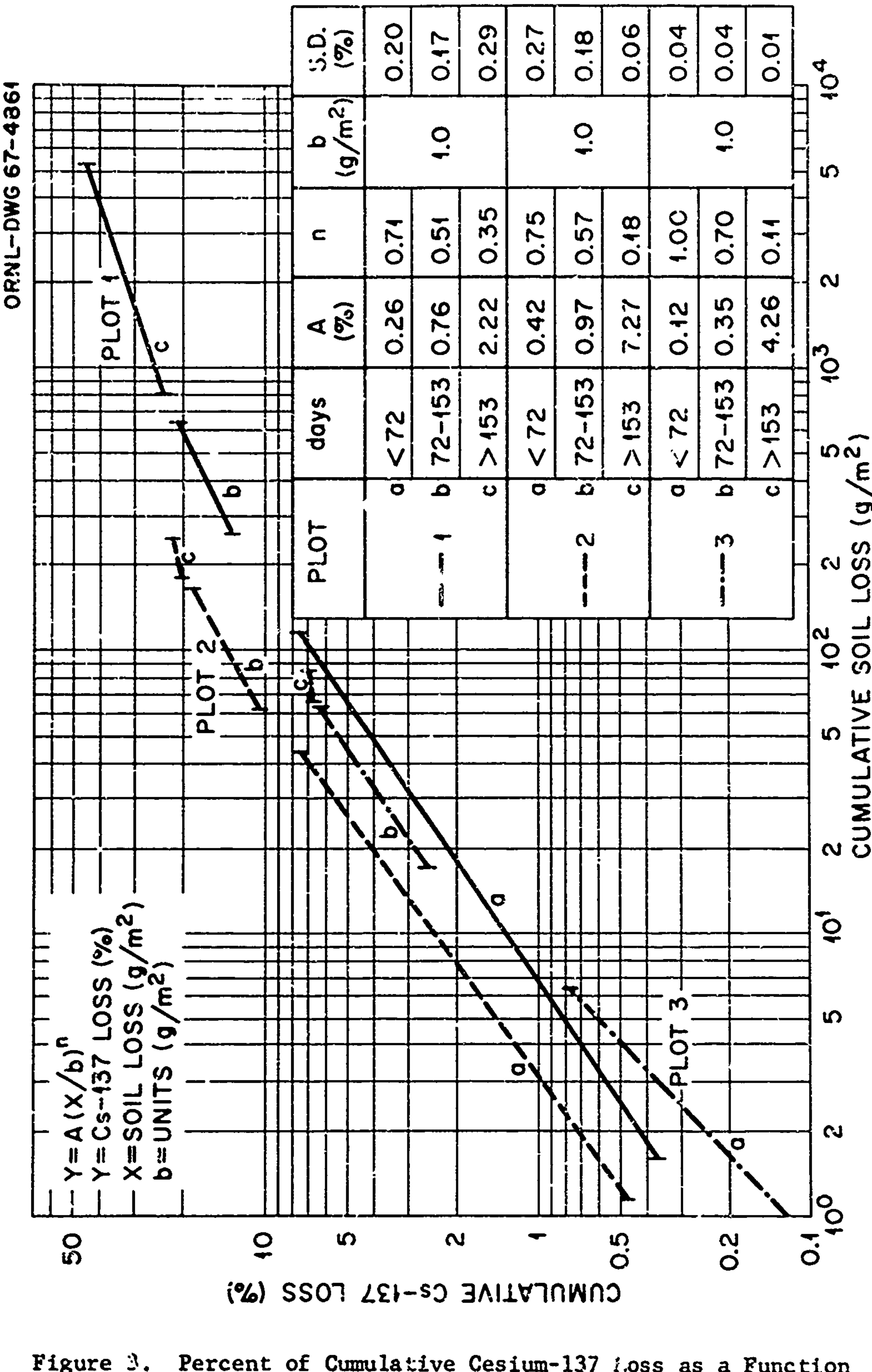
n = the cesium loss exponent ($0 \le n \le 1$),

A = the cesium loss value at unit soil loss (percent).

When the data obtained over a 2-year period were used, the best least-squares fits of Equation (5) were obtained when the data were split into three distinct time phases -- early, transition, and equilibrium -- and when each plot was treated separately. In Figure 3 the respective time-phase graphs for the bare soil (plot 1), clipped meadow (plot 2), and good meadow (plot 3) are shown in the logarithmic form. The time phases for this study refer to the number of days after the application of radiocesium. The time phases chosen by us here were based on information derived from empirical field data. The early phase, "a" in Figure 3, occurred during the first 72 days; transition phase "b" took place in the 72- to 153-day period; and the equilibrium phase "c" was considered to apply to the data in the 153- to 730-day period. The values of coefficient A, exponent n, and standard deviation of Y (SD) are shown in the insert of Figure 3.

When Equation (5) is plotted on the log-log scale (Figure 3), exponent n becomes the slope, and coefficient A is the Y-axis intercept at $X = 1.0\ g/m^2$:

$$\text{Log } Y = \text{Log } A + n \text{ Log } (X/B) \qquad (6)$$



PLOT		days	A (%)	n	b (g/m²)	S.D. (%)
—— 1	a	< 72	0.26	0.71		0.20
	b	72–153	0.76	0.51	1.0	0.47
	c	> 453	2.22	0.35		0.29
– – – 2	a	< 72	0.42	0.75		0.27
	b	72–153	0.97	0.57	1.0	0.18
	c	> 153	7.27	0.48		0.06
–·–·– 3	a	< 72	0.12	1.00		0.04
	b	72–153	0.35	0.70	1.0	0.04
	c	> 153	4.26	0.41		0.01

Figure 3. Percent of Cumulative Cesium-137 Loss as a Function of Soil Loss (g/m^2) for Plot 1 (bare soil), Plot 2 (clipped meadow), and Plot 3 (good meadow).

From Figure 3 and Equation (6) we see that the ratio of cesium loss to soil loss is linear on the logarithmic scale. The exponent n will be referred to as the "rate of loss" in the above sense in the following discussion. Since n is obtained from least-squares fit of Equation (6), it is not defined for $X = 1.0\ g/m^2$; the initial cesium loss per $1.0\ g/m^2$ of soil loss is then given by:

$$Y = A \tag{7}$$

The rate of cesium loss by runoff and erosion, as would be expected, decreased with time for all plots. This was due to the depletion of cesium on the surface due to runoff and erosion, as well as movement of cesium into the profile. During the first two phases, "a" and "b" in Figure 3, the rate increased with the amount of cover, higher rate being observed on the good-meadow plot 3 than on the clipped, poor-meadow plot 2, which had a slightly higher rate than bare-soil plot 1. This increase could be related to a washoff contribution from vegetation, the increase due to washoff per unit weight of eroded material being greater from standing meadow (plot 3) than from clipped litter lying on the ground surface (plot 2), although in both meadow plots cesium-137 was being added to runoff and eroded sediment through washoff at a rate greater than could be added by erosion of contaminated soil from bare-soil plot 1. After 153 days, the rate of cesium loss decreased with the amount of vegetation. By this time, on the average, only 27 percent of the originally applied cesium remained on the dead vegetation (Figure 2), and the new vegetation has taken over. The new vegetation cover was heavier on plot 3, which was fertilized the preceding fall, than on plot 2; the corresponding decrease in runoff and erosion rate of soil is, therefore, reflected by the decreased cesium loss rate.

The initial losses in phase "a" per $1.0\ g/m^2$ of soil in Equation (7) were highest on the clipped, poor-meadow plot 2, containing large amounts of loose dead-plant material in contact with the soil, followed by bare-soil plot 1 and good-meadow plot 3. Results in Table II indicated highest first year adsorption value -- columns 8 and 9 -- on plot 2, and the results of infiltration measurements showed that average infiltration rate was initially the lowest on the clipped-meadow plot 2. Resulting high concentration at the eroding surface could, therefore, explain the high initial loss value for plot 2. Higher loss per unit weight might be expected on the bare soil than on good meadow because of the higher soil surface concentration on plot 1, while cesium was still being leached off from the vegetation on plot 3.

Under the equilibrium conditions, "c" in Figure 3, inspection of the coefficients A_c suggests two conclusions. First, initial losses of cesium per unit weight of soil would have been relatively higher if cesium was in equilibrium phase, since little or no net movement into the soil would have taken place. Second, highest value of A_c on plot 2

TABLE II

ANNUAL AND TOTAL PRECIPITATION, RUNOFF, INFILTRATE, ENERGY-INTENSITY INDEX EI, SOIL AND CESIUM-137 LOSS ON THREE RADIONUCLIDE MOVEMENT STUDY PLOTS[a] ON ALLUVIAL CAPTINA SI. 1. SOIL IN TENNESSEE

Plot	Year	Rain[b] (cm)	Runoff (liters/m^2)	Infiltrate (liters/m^2)	EI[c] (x 10^3 dyne/sec)	Soil Loss[d] (g/m^2)	Cesium-137 Loss (%)	
							Soil	Solution
1			780	568		2023	30.33	0.39
2	1	135	523	825	15.7	206	18.35	0.54
3			251	1096		72	6.37	0.36
1			711	388		3235	12.14	0.18
2	2	110	260	839	14.6	44	0.52	0.05
3			152	948		13	0.07	0.04
1			1491	956		5258	42.29	0.57
2	Total	245	783	1664	30.3	250	18.82	0.59
3			403	2044		85	6.44	0.40

[a]Plot 1, bare soil; plot 2, poor meadow; plot 3, good meadow.

[b]Normal, 1931-1960 rain is 139 cm/year, U. S. Department of Commerce, 1966; Local Climatological Data, Annual Summary, Oak Ridge, Tennessee; 1 cm of rain = 10 l/m^2 of rain.

[c]Expected EI for the area is 9.9 x 10^3 dynes/sec/year, Soil Loss Estimation in Tennessee,[14] where 0.4728 dynes/sec = 1 EI (ft-tons/acre) (in./hr).

[d]Where 224.2 g/m^2 = 2242 kg/ha = 1 ton/acre.

could be indicative of highest potential concentration of cesium at the surface of the soil in the litter layer relatively more susceptible to losses by erosion than surface soil. This observation complements the adsorption data presented in Table II.

A summary of the yearly values of runoff, infiltrate, EI, and soil loss, in addition to cesium concentrations in the soil and liquid portions of runoff, is presented in Table II. Note that the higher soil loss of the bare plot in the second year did not result in an increase in cesium loss; this is likely due to mixing of contaminated sediment with uncontaminated sediment of the lower zone of soil. Movement of contaminated sediment down the profile is probably the mechanism of mixing, as the high adsorption for cesium exhibited by the soil precludes movement by desorption. Since the cesium in the runoff is on the solids, percolating water, like runoff, should also contain solids bearing cesium which moves downward until filtered by the mass of soil. In the second year, very little cesium was lost from the vegetation-covered plots; though the soil loss decreased by a factor of 5 from the first year, the cesium loss decreased by factors of 35 and 90 for plots 2 and 3, respectively. Hence, once the cesium reaches the soil, losses by runoff and erosion are greatly reduced through protection afforded by plant cover.

Distribution of Cesium in the Soil

In Table III cesium distribution on the study plots is given, both for the first year and the second year; in Figure 4 the respective locations of sampled cores are shown. To avoid disturbing the erosion characteristics of our small plots, only a limited number of cores could be taken. The results show that most of the radiocesium is in the 0- to 3-cm depth; however, considerable redistribution of applied cesium-137 within the plots becomes apparent from the results in Table III. Considering the 0- to 3-cm layer, this is true of cores E on plots 1 and 2. A glance at Figure 4 will show that these cores were taken from depressions close to the exit drain. Excessive accumulations, corresponding to core D on plot 2 and core C of plot 3 could have been caused by almost flat micro-topography and heavy cover in the immediate vicinity. Areas of excessive accumulation are further complicated by the nature of meadow growth and litter accumulations during the successive growing seasons.

In the 3- to 30-cm layer, in general, the amount of cesium was highest on the bare-soil plot, lowest on the good-meadow plot. During dry spells in the 2-year-study period, the soil surface on plot 1 (bare soil) and, to a lesser extent, on plot 2 would become extensively cracked. This cracking could have aided in subsequent mechanical washing of fine clay with adsorbed cesium into deeper portions of the

TABLE III

AVERAGE PERCENTAGE CONCENTRATIONS OF CESIUM-137 IN THE SOIL AFTER 2 YEARS AND CONCENTRATIONS AT SEVERAL LOCATIONS[a] AT TWO DEPTHS ON THE STUDY PLOTS[b] 1 YEAR AND 2 YEARS AFTER THE APPLICATION OF RADIONUCLIDES

Year (date)	Location	Plot 1		Plot 2		Plot 3	
		0 to 3 cm	3 to 30 cm	0 to 3 cm	3 to 30 cm	0 to 3 cm	3 to 30 cm
		Percent of applied radionuclides					
1	1	43.1	10.4	17.3	0.9	68.9	9.6
Oct. 8, 1965	2	93.5	11.1	49.4	3.9	32.5	1.9
	3	25.8	10.6	44.9	2.0	128.6	10.0
2	A	23.0	9.1	66.3	4.8	85.6	9.1
Oct. 15, 1966	B	24.1	12.1	12.4	2.4	43.8	2.7
	C	61.8	25.6	13.8	8.5	139.5	7.1
	D	32.6	4.2	121.2	11.3	59.0	4.1
	E	122.0	124.0	163.9	65.6	91.8	7.1
	F	22.7	5.9	56.4	5.9	73.9	1.7
Average		35.6	14.8	59.6	9.6	82.3	5.3

[a]Respective locations shown in Figure 4.

[b]Plot 1, bare soil; plot 2, clipped meadow; plot 3, good meadow.

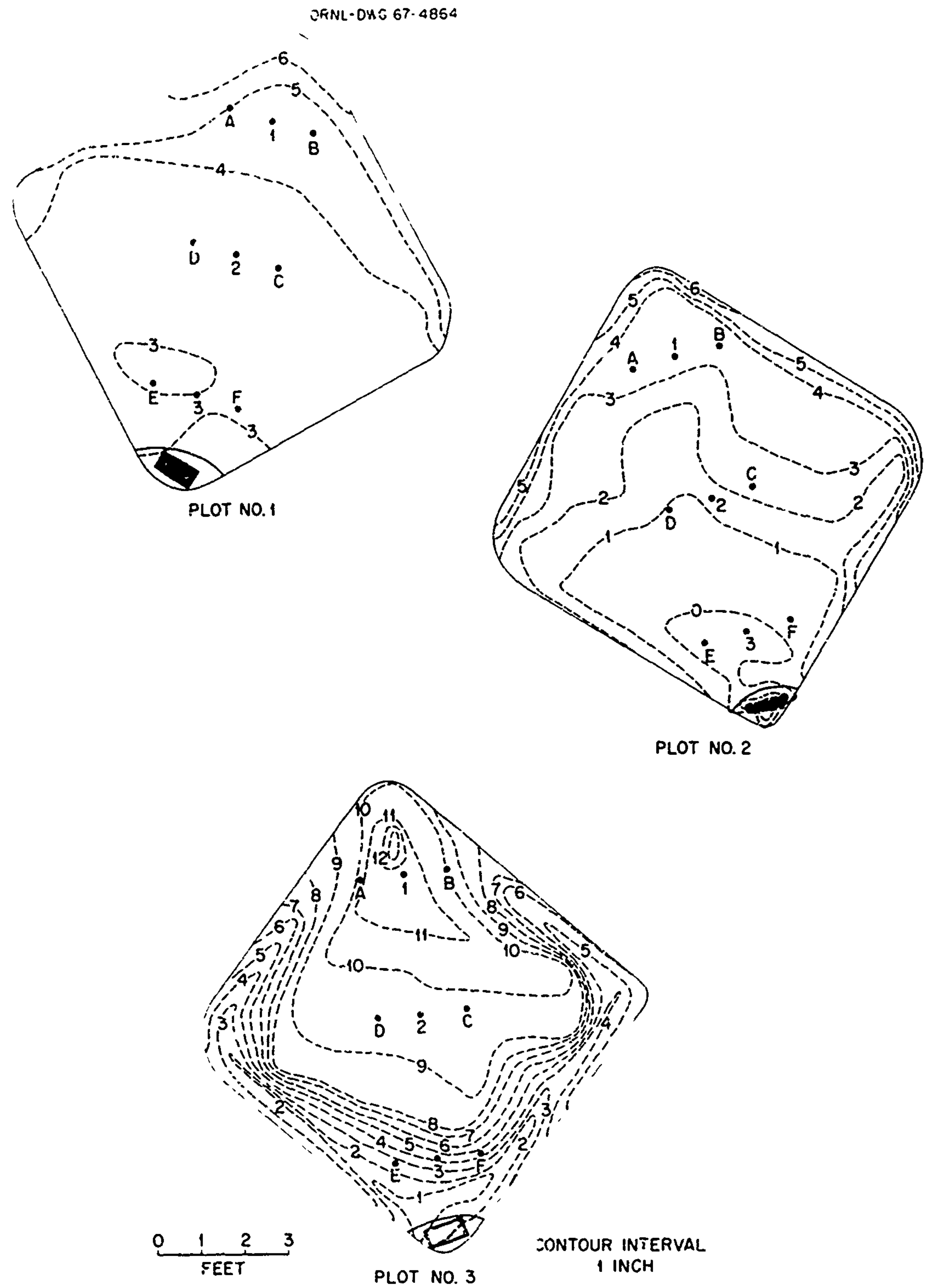


Figure 4. Location of Core Samples Taken After 1 Year and After 2 Years Following Application of Cesium-137 on Bare Soil (plot 1), Clipped Meadow (plot 2), and Good Meadow (plot 3).

profile. The influence of organic material, however, in the topmost layer of soil, which is proportional to the amount of cover and effectively absent on bare-soil plot 1, should also be taken into consideration.[17]

The average concentration of radiocesium in the soil was determined after 2 years of operation. The average percentages were adjusted for the area of depressions around E cores in plots 1 and 2 (see Figure 4). Values for plots 2 and 3 were not corrected for high values of cores D and C. The results are summarized in Table III. The highest concentration remaining in the soil is in plot 3 with 87.6 percent, followed by plot 2 with 69.2 percent and by plot 1 with 50.4 percent. To these values one might add the radiocesium found in runoff and erosion and on vegetation. Contribution by vegetation, including new vegetation, after 2 years was 0.4 percent for plot 2 and 0.5 percent for plot 3; contribution by runoff and erosion amounted to 43.4, 20.0, and 7.2 percent for plots 1, 2, and 3, respectively. The total radiocesium accounted for each plot is 93.8 percent for plot 1, 89.6 percent for plot 2, and 95.3 percent for plot 3; the difference from 100 percent is unaccounted for at this time.

Comparison of Findings with Others

We compare now the observed radionuclide losses with the findings of others. Direct comparisons are difficult, since experimental conditions differed but are informative. Comparing our initial results with those of Graham on his fallow plot,[10] for two rains of consequence with runoff similar to that of Graham's plots (about 19 and 41 percent versus 29 and 63 percent of Graham's), we found that cesium loss on our bare plot was 1.8 percent to Graham's strontium loss of 0.7 percent. It should be pointed out that Graham's fallow plot was kept clean by frequent cultivation and the soil remained loose and was free of weeds. On our bare-soil plot it was not necessary to cultivate and a surface seal was allowed to develop. These differences would result in lower losses for Graham's plot because cultivation promotes both infiltration and mixing.

Our highest single loss of radiocesium was 5.6 percent with 77-percent runoff on the bare plot; this value may be compared with over 25-percent loss of deposited radiostrontium from corn and oat plots in Wisconsin for samples taken on June 1957 by Menzel. In the results obtained by Menzel, each loss was based on the fallout occurring during a specified period. If we consider loss from our good-meadow plot (plot 3) for one rainstorm, the highest was observed on January 9, 1965, and amounted to 1.92 percent. The cesium-loss data obtained up to this date revealed that the cesium loss per gram of soil loss was 0.12 percent and was probably decreasing with increasing soil loss. Using this value for the specific loss, we obtain 1.27 percent as the value anticipated for 10.6 g of soil lost in this storm. The observed value is 1.92 percent. Sampling of the vegetation on March 22, 1965, showed that 13.3 percent of the radiocesium on vegetation was lost since December 31, 1964. During this period 34 cm of rain was recorded, of which 8.2 cm fell on January 9. Based on a semilogarithmic relationship of cesium loss from vegetation and rainfall, one calculates approximately 5 percent of the 13.3 percent was lost from vegetation in the one rain of January 9. If we assign the additional loss of 0.65 percent observed on that day (1.92 percent - 1.27 percent = 0.65 percent) to leaching loss from vegetation; we may consider that approximately 13 percent (0.65 ÷ 5 = 0.13) was lost through leaching in this rain. This value, though lower than the 25 percent observed by Menzel for corn and oat plots, is higher than the 1-percent loss he observed for the clover plot. Similar calculations for the clipped-meadow plot (plot 2) showed that 0.64 percent was unaccountable by the soil loss; but since only 2.3 percent (in contrast to 13.3 percent) was leached from the vegetation during this period, the possible contribution from vegetation leaching is approximately 80 percent for the rain on January 9, 1965.

Frere and Roberts report that one- to two-thirds of strontium-90 deposited by fallout up to 1960 was lost from cultivated watersheds in Ohio with an average slope of 13 percent. These values are higher than ours and possibly reflect the effect of cultivation, steeper slopes, and higher degree of washoff from vegetation. Interestingly, the watershed used as a reference was reported to have no recorded soil loss and the average strontium-90 content was slightly higher than surrounding areas; this observation implies that strontium losses are associated with soil losses (erosion) and not necessarily with runoff only, which confirms our finding with cesium.

SUMMARY

On the basis of the 2-year study, we conclude that cesium-137 loss by runoff and erosion can be considerable, particularly from the exposed bare-soil areas. With erosion loss on bare soil, plot 1, equivalent to 23 tons per acre, cesium loss amounted to 43 percent of that applied. Runoff and erosion losses of cesium from the vegetation-covered plots occurred primarily in the initial stages following the application and was due to the washoff from vegetation at a rate approximately ten times greater than what would be expected on the basis of soil loss alone. In the first year when radiocesium was initially on the vegetation, loss of one ton per acre of soil resulted in 20-percent loss of radiocesium.

Cesium loss is dependent on soil loss, and empirical logarithmic equations for the relationship are given. It was found that considerable redistribution within a plot can occur and that the uptake of cesium by new vegetation constituted only a small fraction of the total applied. Most of the applied cesium that has not been eroded was found in the 0- to 3-cm layer of the soil.

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THE RISE AND FALL OF IMPORTANT FISSION PRODUCTS
IN THE UNITED STATES FOOD SUPPLY

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This discussion will be limited to the fission products iodine-131, strontium-89, strontium-90, and cesium-137 as the ones that would be expected to cause the most trouble. Following a single detonation, iodine is of concern for about three months, strontium-89 for about 18 months, while strontium-90 and cesium-137 are of concern for many years.

The rise and fall of these fission products in food supplies is a direct function of the radioactive half-life of the nuclide and the fall-out rate when the food and/or animal feed is growing. By way of illustration, the time sequence following the 1961-62 atmospheric testing series was about as follows: (1) Iodine-131 reached a peak in 1962 and had virtually disappeared by April 1963, (2) the stratospheric fallout rate reached its maximum in 1963 as did the maximum concentration of the strontium nuclides and cesium in milk, (3) radioactive decay had removed strontium-89 by June 1964, but the maximum concentration of strontium-90 and cesium-137 in the total diet was reached at about the same time. In addition, the average milk concentration of these nuclides in 1964 was about the same as that of 1963, whereas we had expected it to be a little lower.

The explanation of this lag in the fall of the milk concentrations was that feed grown in the previous year, when the fallout rate was higher, had been stored and was used during 1964. The year's lag in the total diet reaching its maximum was identified as being related principally to wheat products made in part from wheat grown in 1963.

We expect the rate of fall from 1967-on to be very slow since the deposition rate in 1967 appears to be negligible as compared to that in 1963 through 1965. It is also worth noting that cesium-137 in milk is decreasing faster than strontium-90. This observation is consistent with the view that strontium may be more available for transmission to plants through soil and the root system than cesium.

DECONTAMINATION OF FOOD AND WATER

FOLLOWING NUCLEAR ATTACK

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Considerable attention has been given to the movement of specific radionuclides through the food chain to man. Most of the available data are from studies of environmental contamination contributed through fallout and from laboratory- and field-type tests in which tracer radionuclides were used. Data have been reported on the efficacy of water- and sewage-treatment processes for the removal of radioactive materials encountered in fallout, and for radioactive materials released into the environment under controlled conditions.

It is the purpose of this paper to review these data and to identify additional areas of research.

FOOD DECONTAMINATION

Food decontamination will be discussed from the point of view of procedures for reducing activity levels through farm practices in the vegetation-cow-milk-man pathway and through food-processing techniques in the food-man pathway.

Farm Practices

The relationships among soils, precipitation, and radioactive uptake or accumulation will not be discussed because these are considered by other members of the panel.

For a given fallout rate, Hansen et al. have reported that levels of strontium-90 and iodine-131 in milk could be reduced by optimal fertilization of the land.[1] Controlled experiments showed that milk from cows grazing on abundant, well-fertilized pastures contained 50 percent or less of these radionuclides than did milk from cows grazing on unfertilized pastures on the same farm. Dilution of the fission-product contaminants in the larger volume of faster growing fertilized forage accounted for the difference in radioactivity levels in the milk. This possible means of control is of value in areas where fertilization practices are marginal.

Intensity of grazing was also shown to influence radiostrontium levels. In studies reported by Burmann et al., two groups of cows were used -- one on a normal rotational grazing system followed by another, one plot behind.[2] Milk samples from the group following showed higher levels of strontium-89 and -90. One explanation, consistent with the results, is that cows forced to graze more closely to the ground also graze larger areas and consume more mat material than do the top-grazing cows. Another possible explanation for the observed difference is that the top grazers had the choice of more palatable portions of the plants, possibly containing less radiostrontium. Green chopping, however, which eliminates selection, resulted in lower milk radiostrontium concentrations than grazing the equivalent material, thus giving more credence to the first explanation.

Field studies with fallout contaminated pastures and food substances and laboratory- or field-type tracer studies provide data on the effect of modifying feed conditions on radioactivity levels. Cows on pastures contaminated with fallout iodine-131 showed very rapid uptake following consumption of exposed feed. When transferred to uncontaminated stored feed they showed a rapid falloff in milk iodine-131 levels.[3,4,5] Data reported by Straub and Fooks showed an initial half-life of 0.65 days over a period of 2 to 3 days followed by a half-life of 6.7 days for the next 20 days.[3] Sasser and Hawley reported half-lives ranging from 0.65 to 0.80 days for the first component and 2.5 days for the second component.[5] The differences could arise from the consumption of fallout iodine,[3] or the consumption of deposited iodine gas released into the atmosphere over the pasture.[5]

In another series of studies, Kahn et al. reported that the fall-off in strontium-89 and -90 levels in milk could be described as a sum of three exponential components, one component due to stored feed was assumed to be greater than 50 days and the other two components were found to be approximately the same for the two nuclides: 0.77 and 4.6 days for strontium-89 and 0.7 and 5 days for strontium-90.[6]

Further studies by Kahn et al showed that a change in food from pasture to stored feed reduced cesium-137 levels in milk in much the same way as iodine and strontium levels decreased.[7] A three-component exponential decay having half-lives of 0.8 ± 0.2, 4 ± 1, and ≥ 100 days was reported. These data show that the cesium-137 content of the milk was reduced to 50 percent of the initial value by the second day and to 20 percent after 5 days when less-contaminated stored feed was substituted for pasture feed. In the case of the strontium, the decreasing components would have reached approximately 10 percent of their initial value within five days and 3.6 percent after 10 days. Other studies with cesium-137 uptake from different types of forage and transfer to milk have been reported by Ward et al.[8,9,10] These show that the cesium-137 content of pasture and hay forage was 10 to 20 times higher than feed grains and several times higher than corn silage,[8] and that the crude-fiber content of the diet affected the transfer coefficient.[9]

Chemical Treatment

Several chemical substances have been used to aid the elimination of ingested fission products and minimize secretion in the milk supply. Materials tested include NaCl and KI, $KClO_4$, NaI, NaCl, L-thyroxine, D-thyroxine, or 2-4 dinitrophenol, and rockweed for the removal of iodine-131;[11,12,13] Verxite and rockweed, sodium alginate, and vermiculite for the removal of strontium; and vermiculite and Verxite for the removal of cesium.[13,14,15,16]

Although either NaCl or KI were effective in increasing urinary excretion, thus reducing milk secretion levels, the combination of both was even more effective.[11] Lengemann's studies showed that the addition of 10 g $KClO_4$ reduced the iodine-131 concentration from 1.7 to 0.4 percent of a daily dose per liter or a 4-fold decrease, 10 g of NaI caused a decrease from 1.2 to 0.4 percent or a 3-fold decrease, 60 g of NaCl reduced the level from 1.2 to 0.8 percent, 10 mg of L-thyroxine reduced the levels by a factor of 2, 10 mg of D-thyroxine increased the levels by a factor of 2, and 0.75 g of 2-4 Dinitrophenol had no effect.[12] Pulverized rockweek (Ascophyllum nodosum), a variety of seaweed, fed to cows along with iodine-131 at a concentration of 5 percent by weight of grain intake, reduced iodine-131 levels in milk by 21 to 42 percent.[13]

Studies by Gabay et al., with Verxite and rockweed for the removal of strontium-85 showed that feeding Verxite to cows after a contaminating event resulted in no effect on the excretion of strontium-85 in milk, whereas feeding Verxite before and during a contaminating event reduced strontium-85 levels in milk significantly.[13] However, calcium was also excreted because of the chelating effect of the Verxite. Rockweed had no anomalous effect on the excretion of strontium-85 into milk.[13] In one case there was an increase and in the other a decrease. Sodium alginate at a level of 20 percent of the diet, based on dry weight of alginate, reduced bone uptake of calcium-45 by 40 percent.[14] The authors conclude that there was still a very large amount of calcium available for absorption from the intestine in spite of the presence of the binding agent.[14] In the use of vermiculite, Hazzard reported no consistent differences between the treated and untreated animals which received strontium-85.[15]

A reduction of 33 percent in the milk levels of cesium-137 through the use of Verxite was reported.[13] In another study, no significant changes in the concentration of Na, K, Ca, or Mg were observed as a result of Verxite feeding.[16] However, marked differences in the cesium-134 levels were noted. An 88-percent reduction in the cesium-134 level of milk was noted at a Verxite-feed rate of 0.82 kg/day/cow. In another series of studies in which vermiculite was incorporated at a level of 10 percent into the grain ration, the percentage daily dosage of cesium-134 incorporated in milk was reduced from 2.6 to 0.4 percent.[15]

Processing Effects

Following a nuclear attack, the bulk of the radioactivity associated with most vegetables and fruits will be from foliar deposition. Depending on the nature of the food substances and the chemical form of the radioactive materials, washing, peeling, or other processing may reduce the radioactive levels of the food. This would assume that the water available for washing would not in itself be contaminated grossly with radioactivity. Root vegetables such as potatoes, carrots, beets, etc., would be less contaminated than would vegetables growing above the ground surface such as lettuce, cabbage, etc. In the case of the latter, perhaps only the outer leaves might be contaminated and removal of these would markedly reduce radioactivity levels. Data reported by Straub showed that washing would remove up to 60 percent of strontium-90 associated with lettuce, and that 87 percent of the strontium-90 in carrots could be removed by paring.[17] The high reduction in the latter case may have resulted from the removal of contaminated soil during the paring process.

A study by Reavey on levels of iodine-131 in milk and milk products showed that certain products had much lower iodine-131 when compared with the initial levels in the raw milk used to produce the equivalent amount of product.[18] Products having lowest levels were butter, cottage cheese, and nonfat dry milk. It was also shown that there was a direct loss of iodine-131 in the evaporation process. Under similar conditions, lowest levels of strontium-90 and cesium-137 were observed in heavy cream, cottage cheese, and butter. Where long-lived radioactivity is the source of contamination, the question of processing and substitution of particular food forms may not be as meaningful as in the case of short-lived radionuclides of iodine. In this case, the milk could be processed and stored for radioactive decay before consumption. Of course, if stocks of uncontaminated foods are on hand, these could be used for the more vulnerable elements of the population: infants and young children.

Removal of Radioactivity

Numerous authors have demonstrated the feasibility of removing certain constituents from milk. The most effective methods employed ion exchange. Cation-exchange treatment was used for the removal of radioactive strontium and cesium and an ion-exchange technique for the removal of radioactive iodine. With the cooperation of the Department of Agriculture and the Atomic Energy Commission, the Public Health Service carried out pilot-plant studies at Beltsville to determine the factors governing the processes. Following satisfactory demonstration on a pilot-plant scale, a full-scale evaluation of the method was undertaken with the cooperation of the Producers Creamery Company, Springfield, Missouri. These studies showed that better than 90 percent of the strontium could be removed from fluid whole milk in a plant processing 100,000 gallons of fluid whole milk per 8-hour day without detracting from the flavor, sanitary quality, or composition as a result of treatment.[19] Tricalcium phosphate was also investigated for the removal of strontium,[20,21] but did not prove any better than the ion-exchange method. Additional studies at the Producers Creamery Company evaluated a large-scale combined anion-cation fixed-bed system for the removal of iodine and strontium.[22] Results indicate a removal of 99 percent for iodine-131, 94.6 percent for strontium-85, and 90.0 percent for strontium-90. There was some decrease in flavor and a slight increase in psychrophilic counts during processing. Chemical and physical changes were similar to those found for the removal of strontium-90 alone. Bales and Hickey summarized experiences with the large-scale operation of a process for removing radionuclides from milk and presented some cost figures.[23] The cost of chemicals for regenerating the anion unit in the full-scale tests was approximately 1.5 cents per quart of milk. Cost of plant operation for strontium removal was 1.7 to 2.3 cents per quart, including approximately 0.6 cents per quart for chemicals. Since the addition of the anion column did not increase labor or other costs appreciably, the combined process adds approximately 3.2 to 3.8 cents per quart to the cost of the milk or an increase of about 16 percent to the consumer.

In discussions of the above and other papers on this subject, Glascock commented on some biological-test results. He discussed results of feeding trails with baby pigs fed from birth with milk passed through the plant and subjected to treatment with citric acid. The experiments lasted four weeks, during which four out of 15 control pigs died, while of the animals fed with treated milk thirteen of fifteen died. Glascock provisionally attributed the high mortality to the presence of citrate which prevents the clotting of milk and may have upset the digestive systems of the animals. In additional experiments with hydrochloric acid, still incomplete, the same pattern was emerging. Obviously, there is a need for more study of the final product produced by ion exchange before the material can be used in the fluid state.*

In summary, where stored feed of lower activity is available, its use is by far the most satisfactory method of reducing radionuclide levels in milk. Changes in farming practices by use of additional fertilizers, and chemical manipulation to increase urinary excretion to reduce milk levels are not as effective. There is a need, however, for studies in which a combination of procedures can be tried simultaneously to determine the over-all decontamination factor attainable. Chemical processing of the milk for the removal of radionuclides when fed in a fluid-unreconcentrated state still is open to question in terms of the biological consequences to the potential consumer.

WATER DECONTAMINATION

Extensive studies by Straub and his associates, as well as by others, on the removal of radioactive materials by water-treatment processes have been summarized.[24] Some newer information is available but it does not modify earlier results. In general, water-treatment processes are effective in removing those radionuclides which correspond to the normal chemical substances removed by such processes. The processes will be most efficient for the removal of radionuclides absorbed on particulate matter because normal coagulation, sedimentation, and filtration processes are effective in reducing

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* A note from Mr. R. E. Bales, National Center for Radiological Health, Public Health Service, U. S. Department of Health, Education, and Welfare, reports the following additional material from Dr. R. F. Glascock: "...I made a mistake in some of the information I gave you at Vienna. In particular, the nutritional experiments with baby pigs started between the 36th and 48th hour after birth and not immediately as I had mistakenly believed. We have now run another experiment with hydrochloric treated milk without any casualties at all and the harmful effect of this milk is therefore very much in doubt". U. S. experiments reported by Bales have shown no harmful effects to baby pigs. Bales also reported that Glascock stated use of the cheapest available grades of chemicals in their process tests as opposed to our (Bales) great effort to use food grade chemicals as well as to provide for and to maintain high sanitary as well as chemical quality may have a great bearing on any difference in results.

turbidity levels. Where lime and soda-ash softening is practiced, removals of strontium can be enhanced by the addition of increasing amounts of chemicals beyond those normally required. Some process modification is possible in the case of emergencies, such as the addition of clays and the use of a phosphate coagulation in place of conventional alum or iron coagulation. With such procedures decontamination factors up to 1000 are possible. Generally, however, with conventional processing, decontamination factors of 10 or less are possible.

Under emergency conditions and where small amounts of water are required for domestic use, primarily drinking, small quantities of water could be treated by passing the contaminated liquid through beds of leaves and clay. In passing spiked solutions twice through these improvised filters, removals of the order of 95.7 percent were reported (see reference 41 in reference 25). Another improvised filter, developed by Lacy,[26] consisted of several 5-cm layers of sand, gravel humus, coarse vegetation, and clay and removed 95.1 percent of the radioactivity. A more sophisticated unit was developed by Lauderdale and Emmons.[27] It included two columns with the first containing steel wool, burnt clay, and activated carbon, and the second containing mixed-bed ion-exchange media. Removals of 99.996 percent were reported.

In summary, emergency treatment methods are more effective for the removal of fission-product radionuclides than are conventional treatment processes. Some process changes can enhance removal efficiencies.

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LONG-RANGE BIOLOGICAL EFFECTS ON MAN OF A NUCLEAR ATTACK

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For purposes of this discussion, it is not necessary to distinguish between the two attack situations (CIVLOG and UNCLEX). Factors of two are relatively unimportant here, considering the uncertainties in the quantitative aspects of late effects of radiobiology, plus the fact that exposure estimates and body-burden estimates have to be chosen pretty arbitrarily. Who is to say which bombs will be duds, which groups of bombs will be faulty to some degree and which will fall wide of the target and may or may not produce double hits in some areas?

Our population is now nearly 200 million. The attack situations we have been asked to look at cover a wide range of populated areas, totally eliminate only a few major centers, and permit 95 million survivors in UNCLEX and 150 million in CIVLOG. It is interesting to speculate on whether recovery might be easier if the big cities and metropolitan areas of over one-million population were excised by multi-megaton weapons, leaving some 140-million persons to cope with fallout, internal and external radiation exposure, and other postattack residue. In any event, the ratio of facilities destroyed to the peacetime requirements for those facilities will be greater than one to one, and in certain areas may be as high as ten to one. On the other hand, peacetime requirements are more or less optimal and can be compromised to some extent at least in all but a few matters such as antibiotics, vaccines and antisera. The availability or absence of these will affect very directly the number surviving the immediate postattack-recovery period through the first full calendar year and beyond. Shortages of the above would lead to large-scale elimination of persons in the above 60- and especially above 70-age group from respiratory infections, terminating in pneumonia. Any impairment in our ability to cope with the contagious diseases would also cut a swath through those surviving the immediate postattack-recovery period, with many deaths falling in the above 60- and below 15-age groups.

I shall confine my remarks from this point on to the residual effects in the surviving population of the radiation exposures incurred as a result of the nuclear attack. My remarks will of necessity be general, and I leave it for the experts on the panel to fill in specific details and to demolish any unwarranted assumptions which I have made.

The effects as observed in experimental animals and in man at Hiroshima and Nagasaki, at Rongelap, in the Japanese fishermen on the Fukuryu Maru, and in accidental and therapeutic exposure situations include:

1. Cancer, including thyroid cancer
2. Leukemia
3. Thyroid adenomas and other benign tumors
4. Skin burns
5. Opacities on the posterior pole of the lens of the eye
6. Reduced immunological-response potential
7. Curtailment of average life expectancy
8. Chromosome aberrations in cultured peripheral and bone-marrow lymphocytes
9. Genetically determined effects in succeeding generations.

Other effects such as those on the cardiovascular renal complex and on endocrine functions are so intricately interwoven with the so-called aging effect as not to warrant separate considertion here.

A word as to exposures of the surviving population. I have generally discounted any contribution from worldwide fallout on the basis of considerations such as those Dr. Tompkins discussed earlier. Certainly it would contribute less than 1 rad average gonadal dose over a 30-year period, and less than 5-rad average bone, 2-rad bone-marrow and 1.5-rad whole-body exposure, except in the state of Alaska where there are some Indians in whom whole-body exposure might be as high as 100 rads if their habits of feeding remain as they are today. I base this statement on the UNCLEX over-all yield of approximately 3500 megatons of mostly surface detonations, as opposed to observed levels of fallout on the ground and in the food chain from 500 megatons of test detonations yielding approximately 200 megatons worth of fission, about 50 percent of which was released in 1961 and 1962 from air bursts. I have taken UNCLEX fission yield per megaton TNT to be 50 percent, or a total of 1750 megatons fission. I believe, therefore, that I have been conservative in assuming an average of no more than ten times the estimates of radiation doses in Table 13, Federal Radiation Council Report No. 4.[1] I have assumed no protective action taken against ingestion or incorporation into the food chain of worldwide-fallout fission products.

Finally, as to prompt-radiation exposure, I assume there will be very few survivors within the range of the prompt radiation who were not in shelters sufficiently substantial to reduce the prompt radiation to relatively small amounts. This means that in this study exercise, the vast majority of survivors, perhaps 95 percent or more, will have received principally fallout-radiation exposure, some 75 percent of which will have been incurred in the first 72 hours after the attack and which will have been received at dose rates of well below 1 rad per minute, 60 rads per hour and 1,440 rads per day.

Miscellaneous Tumors

Radiation has been observed to induce adenomas, carcinomas, sarcomas and lymphomas of one sort or another in a variety of tissues -- breast, ovary, pituitary, adrenal, lung, connective tissue and the like -- under a variety of circumstances. Whether any or all of these would appear in important amounts following exposures such as postulated in UNCLEX is uncertain. So far, the data from Japan is indecisive except for an increased incidence to date of thyroid cancer.

It may be that, as with Upton and Furth's "greenhouse mice",[2] the final story will be that the incidence of some cancers will be up and some down; the total, exclusive of leukemia, coming out about the same, and the average age of appearance of the cancers being earlier by an amount consistent with the life-shortening effect of the surviving population's radiation exposure.

Leukemia

The rule of thumb for high-dose-rate exposures is 100 cases per year per million population per 100 rads averaged over the ensuing 15 years. Thus we might estimate in a surviving population of approximately 100-million persons, who had an average dose of 100 rads at high dose rate, an average of 10,000 additional cases of leukemia per annum during the next 15 years. By high dose rate I mean a dose rate of at least one rad per minute, or better; one that would give 1440 rads in a day or 60 rads in an hour. I had to choose the 100 rad arbitrarily as I have no way of knowing what the dose break-down in the surviving population would be, beyond the information that 64,000,000 had less than 100 rad equivalent residual dose (ERD) and 29,000,000 from 100 to 300 rads ERD, etc. To work backwards from these is very difficult. Maybe the average dose at high dose rate for the entire surviving population is 200 rad. I doubt it. The figure would then become 20,000 plus some much smaller number for those with low-dose-rate exposures only, and minus perhaps some thousands among the high-dose-rate group with acute exposures of less than 50 rad. I will not belabor the point that Upton and Mole have long ago established: namely, that radiation leukemogenesis is very much dose-rate dependent even when exposure to neutrons is involved.

In any event, let us compare these rates of 10 per 100,000 population with some death rates in the year 1910 from other causes:

Tuberculosis. 100+ per 100,000 population
i.e. 100,000+ per year.

Typhoid and Paratyphoid Fever. 14/100,000
i.e. 14,000 deaths per year.

Dysentery, Diarrhea, Enteritis, etc. 100/100,000
i.e. 100,000 deaths per year.

Measles. 10,000 deaths per year.

Diphtheria. 12,000 deaths per year.

Scarlet Fever. 10,000 deaths per year.

Whooping Cough. 10,000 deaths per year.

One can quickly see where the emphasis should be placed: prevention of the old contagious and infectious diseases. I chose 1910 because then our population was approximately 92,000,000; not very different from the 94,000,000 estimated to be surviving the UNCLEX attack after 1 year. Today, under relatively optimal conditions, the annual death rate from all causes is a little less than one per hundred in the population, i.e., 1,000,000 deaths each year per 100,000,000 population, mostly cardiovascular disease and cancer. Under less optimal conditions which would pertain for many years following a nuclear attack, it would be reasonable to expect the death rate to be higher. Against this, the 5,000 to 20,000 added cases of leukemia for 15 years, plus perhaps some one- or two-thousand added cases of bone cancer each year that have been postulated by some beginning 10 or 15 years after the event, would hardly be noticed as a social, economic, or psychological burden.

Thyroid Adenomas

The Rongelap experience shows that 175-rad whole-body dose received over a 48-hour period plus 700- to 1400-rad thyroid dose from fission-product-radioiodine isotopes lead to thyroid tumors 10 to 12 years later in 60 percent of survivors who were under 5 years of age at the time of exposure. In spite of precautions such as avoidance of food and water contaminated with iodine-131, or ingestion of stable iodine during the immediate postattack period, I would estimate many thousands such cases scattered about the country in the high-fallout areas. These do not appear to be malignant tumors, but they might at least be a medical problem of considerable concern and psychological impact occurring as they do in teenagers and turning up a decade after the war just as society was getting back on an even keel and settling in for the long haul. The Rongelap data suggest, but do not prove, that lesser exposures, specifically total-body doses of 75 rad or less plus several-hundred rads to the thyroid from radioiodine deposited in the gland, are not likely to produce these tumors.

An effort to simulate the human experience in controlled studies in animals is, I believe, planned at Battelle Northwest Laboratory. This should give us a better fix on what to expect following reactor accidents with high releases of iodine-131 and in nuclear war.

Effects on Skin

It is difficult to predict how much of a problem, if any, skin burns would be. The Rongelap story indicates that fairly heavy contamination and ensuing skin burns did occur on exposed surfaces, especially about the neck creases, in the scalp, under the arm pits, about the anus, on the backs of the feet and between the toes in a barefoot population. Note that the areas listed are principally those where, once contamination has occurred, the material would tend to cling until positive measures to eliminate it were taken. Hats and full western clothes would protect all but the hands and neck-band areas. It is notable that hand burns, even on the backs of the hands and in the thin-skinned areas between the fingers, did not occur. That is, only areas with repeated contamination, the feet, and those where normal activity did not remove the contamination, were injured. The lesson I learn is that burns may occur, but need not. Burns of a severity which would lead to telangiectasia or late cancer are most unlikely except where barehanded persons handled filters in the air intakes of relatively close-in fallout shelters.

Radiation Cataracts

Neutron-induced-radiation cataracts, as seen at Hiroshima, would be essentially nonexistent among survivors of a war in which only megaton bursts were employed. The boundary of the area of essentially total destruction by megaton weapons extends well beyond the neutron flux. On the other hand, survivors of 1000 rads, or greater, whole-body gamma-ray exposures would be liable to not just academically interesting posterior-capsular plagues, as was true with more than 95 percent of the cataract cases in Hiroshima, but to full-blown vision-impairing, clinically important cataracts. In fact, if there were many tens of thousands of such persons among the survivors, beginning three years postattack those interested in perfecting their cataract-extraction technique in relatively young persons would no longer need to go to India for experience.

Effects on Ability to Form Antibodies

I bring this up because of late there has been some interest in whether the reduction in the number of immunologically competent cells during natural senescence also occurs in radiation-induced aging.

Albright and Makinodan at ORNL have gone so far as to suggest that the loss of progenitor cells observed immediately after an acute radiation exposure may be critical later in the animal's life.[3] Unfortunately, all that can be said today is that the crucial experiment has yet to be done. It is premature to speculate on the late immunological effects of radiation in the absence of data. I know of no data which suggest radiation-aged animals are more or less prone to die of or with infection than are the normally aged, though with low-level chronic exposure, middle-life deaths from infection have regularly been observed to be reduced.

Effects on Average Life Span

Radiation effects on average life expectancy would for many years be so mixed up with other nonradiation factors as to be lost. The experience in Japan which deals only with high-dose rate, and hence more effective exposures, would support this statement. Now, 20 years later, the data coming in are still not clear. Another decade or two will perhaps show a real pattern.

Cytogenetic Effects

Recently there has been demonstrated in cultures of peripheral blood and marrow lymphocytes chromosome aberrations which may be reasonably attributed to whole-body radiation exposure. Indeed, shortly after a dose of 50 to 200 rads at high dose rates, aberrations are present in numbers roughly proportional to exposure in rads. In Japan, 34 percent of a group of survivors of at least 100 rads of bomb radiation show complex chromosomal rearrangements 20 years later in 1 to 4 percent of examined peripheral leukocyte metaphases. Chromosome abnormalities were found in 0.6 percent of the cells of the exposed and 0.01 percent of cells of the controls. What all this may mean in terms of the other late manifestations of radiation exposure is quite unknown at the present time. It is currently under study in Japan and elsewhere.

Genetic Effects

As to the long-range genetic effects of a nuclear war of either the CIVLOG or the UNCLEX magnitude, there are a few points of reference that are worth noting. Geneticists have estimated that 1 to 7 percent of new random mutations would be likely to cause a genetic death in the first-generation offspring, and of these the majority of deaths would occur before the end of foetal life. Let us take 6 percent as a realistic number. In that case, in a surviving population having 1 to 2 x 10^6 births per annum and an average gonadal dose of 100 rads, which is definitely high for CIVLOG and perhaps for UNCLEX, no effect would be identifiable by any study comparable to the classic Neel and Shull study in Japan.[4] One can postulate a grand total of some 190,000 deaths from fully expressed lethal mutations over a number of succeeding generations (500 to 1000 years) if average gonadal dose was 100 rad and received chronically, i.e., at a dose rate of less than 1 rad per minute. If the exposures received were all in the high-dose-rate class, which of course the majority of them were not, the figure would be 760,000. These calculations are based on material developed by Norman Arnheim.[5] They are not assuming the same effect as that observed in mice, in which resting ova were found to be remarkably resistant, or to have remarkable repair processes following exposure to ionizing radiation. William Russell noted that offspring conceived several weeks after exposure of the mother to neutron or gamma radiation showed essentially no increased point mutations. Thus the numbers postulated even for the high-dose-rate case could be a great deal smaller. For the above numbers exercise, I have assumed the average gonadal dose to the survivors to be 100 rad and mostly received at less than 1 rad per minute. It could be 300 rad. The numbers would then be 3 times the above. Unfortunately, the information available to me on UNCLEX was all in terms of Effective Residual Dose (ERD). There is no clue as to how the dose was acquired nor as to what was the average total dose of the 66 percent of the population surviving who had less than 100 rads ERD. I suspect a 100-rad average is close to the truth, but I don't know.

I must rest on the statement that the effect -- i.e., the increase in the number of individuals born each year with tangible mutations -- would be lost in all the other background noise. Incidentally, I cannot pretend to evaluate the burden to succeeding generations of the introduction into the population of a much larger number of semi-lethals and less deleterious genes.

In short, the sum total in the surviving population of the long-range effects of the radiation exposures received during and after a nuclear attack, such as UNCLEX, will be a minor perturbation coming after a truly catastrophic event and during a long time period when disease-incidence rates and mortality rates from other causes will be higher than they are today. Long-range-radiation effects will generally be lost in the background noise with one possible exception. If there were an apprecia ble number of children and young adults surviving 1000 rads and more of gamma-ray exposure, a most unusual and conspicuous incidence of clinically important cataracts would appear in the middle-age-and-younger population group some 2-to-5-years postattack.

Those who follow may argue otherwise, but I submit the proposition to you that, as far as the long-range biological effects on humans of a nuclear attack is concerned, there is no important new research to be undertaken over and above that already underway here and in Japan; research which will add really important quantitative data for those concerned with technical estimates of what to expect by way of long-range effects, or for those who might be concerned with the situation of long-range recovery from a nuclear war. Certainly it would be nice to know precisely the number of cases of this or that to expect year by year as a result of different patterns of exposure, but in my opinion such information, though extremely valuable for those concerned with establishing peacetime standards of radiation control and for the theoretical radiobiologist, is not needed for an intelligent approach to the nuclear-attack problem. This is not to say that the sort of information Lushbaugh, et al, at Oak Ridge Institute of Nuclear Studies and Langham at Los Alamos Scientific Laboratory, are obtaining on early effects of a variety of exposure patterns are not extremely important to the OCD as well as to the National Aeronautics and Space Administration and the Air Force.

Which leads me to speak of Dr.Langham's most recent observations in Rhesus monkeys and which have a direct bearing on survival patterns.

Langham's Monkeys

Langham continuously exposed healthy, highly trained Rhesus monkeys to 50 to 75 and 100 rads per day, at 35 to 70 mrads per minute, of cobalt-60 gamma irradiation for 10 days. The LD/50-30 days* for high-dose-rate exposure for these animals is 650 rads. The results are important and were as follows:

> Four monkeys received 500-rad total dose. The low point of the white blood count averaged 3600. There were no symptoms.
>
> Four monkeys received 750 rad. 2 of 4 died with yellow marrow -- the averaged white-blood-count low point of the surviving animals was 600.
>
> Four monkeys received 1000 rad. 1 died with yellow marrow. The survivors' averaged white-blood-count low point was 400.

In short, close to 50 percent of these monkeys with an LD/50-30 days for acute exposure of about 650 rads were unable to survive more than a dose of radiation equal to 1½ times the LD/50 when spread evenly over a ten-day period. The results suggest that even for the Rhesus, 75 to 100 rads a day for 10 days is close to an LD/50 exposure. On the basis of this pilot-type experiment, it would be unreasonable to expect many humans to survive more than 750 rad accumulated over a ten-day period in any exposure pattern you may devise. The other extreme would

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* Lethal Dose in 30 days to 50 percent of those exposed.

be the person who was able to limit his exposure to not more than 15 to 20 rad on any one day, thus coming out with a 5 to 10 rad per day average at the end of the year. Rat and mice data suggest that he could survive up to 2- or 3000-rads cumulative exposure without symptoms. On the basis of the information provided me in advance of this meeting, I would estimate that no more than a few tens of thousands of persons in exercise UNCLEX could so neatly regulate their exposures.

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LONG-RANGE EFFECTS OF RADIATION

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The first flood of patients with mixed injuries and the radiation syndrome caused by exposure during the first few days and weeks post-attack will be followed by a steady but declining number of casualties whose exposure has been protracted over weeks and months.

Implicit in the concept of Equivalent Residual Dose (ERD) is the idea that the illness resulting from protracted exposure to radiation such that the ERD is substantially larger than 200 R will be a condition that resembles radiation sickness caused by a brief exposure to more than 200 R. It is also reasonable to suppose that such amounts of radiation will exacerbate and complicate the usual run of sickness and injury. Among a group of people with ERD in excess of 200 R the following conditions may be encountered upon clinical examination:

1. No symptoms, <u>but</u> signs such as leukopenia, anemia, or thrombocytopenia found on screening
2. Non-specific symptoms, e.g., malaise, fever, fatigue, <u>and</u> signs
3. Specific symptoms, e.g., purpura or bleeding, sore throat and/or sore gums, and epilation, <u>and</u> signs
4. Other illness, e.g., appendicitis, <u>and</u> signs
5. Other illness plus specific symptoms <u>and</u> signs
6. Trauma <u>and</u> signs
7. Trauma plus specific symptoms <u>and</u> signs.

The common feature of this array of clinical possibilities is the occurrence of signs of radiation injury (leukopenia, etc.) in everyone whose brief exposure dose or ERD was 100 R or more. Regardless of how medical services are organized postattack, the capability to screen large numbers of people is mandatory. The screening procedure need be no more than inspection of the person, a total leukocyte count, and an hematocrit. To conserve medical manpower, I believe that ambulatory care facilities should be urged to concentrate on screening as the principal means to identify radiation injury until daily case loads permit more extensive laboratory and clinical studies. Inspection and screening should not require a physician, and the doctors' time should be devoted entirely to the injured, the febrile, the obviously ill, and those identified as radiation casualties by the screen.

On the basis of analogy with general patterns of medical care (and other considerations noted below), I question the estimate that 80 to 90 percent of those seeking or requiring medical care between D+30 and D+90 will need hospitalization. In our prepaid group-practice program, for example, we supply about 5 times as many ambulatory services as in-hospital services. I would expect the severity of all illness postattack to be distributed in a fashion with respect to severity that is not greatly different than that observed in peacetime. Thus during any week I would expect that the number of people with minimal to moderate radiation sickness plus asymptomatic cases would be several times greater than those with a condition severe enough to require hospital care. Furthermore, fallout in any area will surely have a distribution of density of contamination ranging from high to low. As a first approximation, I would expect that about 2/3 of the occupants of any large, fallout area will live more than halfway beyond the midpoint of the highest and lowest.

Regardless of how well or poorly the medical services of the nation are organized, the real situation will surely be the establishment of a large number of trading areas each serving several thousand survivors. These small areas will be linked in various fashions with hospitals and with safe areas for the evacuation of those who should not -- if possible -- receive further exposure. I would expect there to be many more people in the convalescent or protective category than in the category where hospital care is mandatory.

Since there is no specific treatment for radiation injury, hospitalization should be restricted to those who can benefit from it. The less severely afflicted will do equally well at home and in rest areas; special terminal-care facilities will need to be developed for those who are fatally afflicted.

I think the most serious problem is not the volume of patients, but the development and enforcement of guidelines that conserve medical manpower and medical supplies. The primary goal of the medical service postattack must be to preserve the effectiveness of the work-force needed to maintain essential services and to carry on reconstruction.

RECENT PROGRESS IN ASSESSMENT OF HUMAN RESISTANCE TO TOTAL-BODY IRRADIATION

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Postattack recovery will depend largely upon man's ability to perform in high-radiation fields. His radiosensitivity will limit these operations because an amount of exposure must not be allowed that will lead to a high incidence of radiation sickness, or subsequent death from hematopoietic damage. Our knowledge of man's radioresistance is still quite meager. It is based on observations of accidental radiation exposures of normal men in situations where dose is a matter of retrospective conjecture; on observations of human effects after two atomic attacks where thousands of individual exposures and total-body doses are still being computed after 20 years of study (the Atomic Bomb Casualty Commission and Ichiban Programs); and on therapeutic and clinical observations of total-body irradiation of patients whose exposures were measured precisely, but whose high probability of becoming ill and dying had singled them out for radiation therapy. From such studies in the past, the lethal dose for man has been estimated as lying between 300 and 450 R. Confidence in this range is high, but any assumption of precision here is unwarranted. A recently completed retrospective study of more than 500 total-body-irradiated patients of different ages, sexes, and diseases, has attempted, by use of modern statistical techniques, to obtain more precise estimates of human dose/response relations. Probit regression analyses of these data pretending* that the necessary assumptions for this kind of data treatment were valid, have yielded estimates of the effective single doses required to cause various incidences of the untoward responses of acute radiation sickness and the hematopoietic damage. Conceptually such an approach avoids the clinically ambiguous impressions that 200 R will cause a man to vomit while 450 R will kill, and allows estimates of the probability of radiation-induced response while defining the limits of certainty.

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* We <u>pretend</u> because we know the assumptions basic to the model can not be met.

The data in Table I show such estimates for loss of appetite, nausea, vomiting, and diarrhea in man. These data are not directly applicable to a population of normal healthy men, but since civil-defense-planners must not base their projections on the most resistant healthy status of man, they can use estimates such as these from sick patients that overstate the radiosensitivity of normal man.

All these data were derived from situations where the exposures were prompt, i.e., given in less than 2 hours. Dose protraction, however, promises to reduce the incidence of these effects in man, according to observations made in animals and in the accidentally exposed Marshallese natives where instead of the expected 60 percent incidence of vomiting, only 10 percent became sick.

Clinical evidence is abundant that dose fractionation diminishes the incidence of various responses to radiation exposure, but no estimate based on clinical data exists on the extent of this modification. It is assumed that, as with skin erythema or moist desquamation, the percent probability (P) of vomiting or death is related to the product of total dose and a fractional power function (x) of the number (N_f) of individual exposures: $\underline{P} = \text{Dose} \cdot N_f^{(x)}$ We are now studying this problem retrospectively using about 1000 therapeutic case histories of fractionated total-body irradiation. In addition, we are making observations on whether dose protraction also diminishes clinical signs of radiation damage. The latter study involves the therapeutic trial of a newly constructed facility for total-body irradiation of patients with chronic blood dyscrasias. This facility has 10 cobalt-60 gamma-ray sources arranged in such a way that an isotropic-flux volume of 16 x 16 x 8 ft is produced and has an exposure rate of 1.5 R/hr. The patient is allowed to move at will about this room in which he lives for 3 to 5 days, or as long as may be needed to expose him to the dose his therapy requires. Three of the five patients studied to date in this facility previously received the same dose (70 rads) in another total-body irradiation facility where the dose rate is 60 times as rapid (1.5 R/min). All experienced severe acute gastrointestinal reactions with the more rapidly delivered dose, but were symptom free in the new facility (Table II). Depression of blood elements after exposure in the two facilities was compared; effects were less pronounced and less persistent after exposure at the low-exposure rate. These limited observations imply that the concept of equivalent residual dose is correctly applicable to man and that clinical data can be obtained that may allow tailoring of the appropriate constants to fit the concept directly to man's radioresistance.

Table III contains estimates of the population incidence of various symptoms of radiation sickness that might be expected if an infinitely large number of people were simultaneously exposed to a single dose of 10 rads of total-body irradiation. The estimated incidences are all below 4 percent, a level that could easily be tolerated under austere conditions, and suggest that in extreme emergency situations man can work in much higher radiation fields much longer times than previously imagined. If total dose and exposure times of personnel are controlled, a balance can be achieved between the needs of the population to be rescued and a tolerable incidence of acute radiation sickness in the rescuers. Exposures of more than 30 R obtained at low rates over an entire day for several days up to a week will probably not cause even these low incidences of acute gastrointestinal symptoms. Since such exposures will, however, cause depressions in blood levels of important cells that can lead subsequently to infections and other diseases, the 30R/day/week exposure must be restricted to as small a number of heroic civil-defense volunteers as conditions permit.

TABLE I.

RECENT ESTIMATES OF EFFECTIVE DOSES (RADS)

FOR SOME HUMAN PRODROMAL RESPONSES *

Responses	ED_{10}	ED_{50}#
Anorexia	39^{+17}_{-20}	97^{+31}_{-26}
Nausea	51^{+17}_{-20}	139^{+72}_{-33}
Emesis	62^{+20}_{-20}	183^{+178}_{-53}
Diarrhea	87^{+46}_{-61}	238^{+122}_{-55}

* Space Radiation Study Panel Report (NAS/NRC).

\# ED_{50} = the "Effective Dose" that will probably cause 50% of the subjects under study to show a specific response that is defined with some temporal relation to the insult (here, total-body exposure to deeply penetrating gamma radiation for less than two hours).

TABLE II.

INITIAL EXPERIENCE WITH LOW-EXPOSURE-RATE

TOTAL-BODY IRRADIATION FACILITY (1.5 R/HR)

No.	Patient Dx.*	Patient Sex/Age	Total Residence Hr / Day	Total Exposure R/Hr	Average Fraction/Day %	Prodromal Symptoms
1	IT	M/61	116.0 (4.8)	150/100.0	86.2	0
2	CLL	M/75	73.1 (3.0)	100/66.7	91.2	0
3	CML	M/12	74.4 (3.1)	100/66.7	89.6	0
4	CML	F/45	78.7 (3.3)	100/66.7	84.6	#
5	LS	M/79	76.2 (3.2)	100/66.7	87.5	0

* IT = Ideopathic thrombocytopenia.
CLL = Chronic lymphatic leukemia.
CML = Chronic myeloid leukemia.
LS = Lymphosarcoma.

Nausea relieved by eating.

TABLE III.

INCIDENCE OF RADIATION SICKNESS

Per thousand persons exposed to 10 rad whole-body radiation.

For	DATA* FROM ORAU	DATA* FROM Others
Anorexia	5	40
Nausea	4	15
Vomiting	3	11
Diarrhea	12	2

* Obtained from therapeutic studies on patients at the Medical Division, Oak Ridge Associated Universities (ORAU), and 50 other U. S. hospitals (Others).

RADIATION CARCINOGENESIS IN SURVIVORS OF NUCLEAR ATTACK

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INTRODUCTION

This projection of the possible carcinogenic effect of radiation exposure in survivors of nuclear attack is presented in terms of absolute-risk estimates, i.e., in terms of the number of additional cases of cancer per million persons exposed to a unit dose (rad). These risk estimates are based chiefly on data from survivors of the atomic bombing of Hiroshima and Nagasaki. Some additional supporting or qualifying estimates based on data from people exposed to medical radiation are also given.

Data and risk estimates for radiation carcinogenesis in man have been extensively reviewed in a publication[1] by the United Nations Scientific Committee on Effects of Atomic Radiation in 1964, and in reports[2,3] of the International Commission on Radiological Protection in 1966, which are essentially in agreement with the United Nations document.

Owing to the insufficiency of human dose-effect data for low doses (below 100 rad) or for low-dose rates, the estimates of risk at these low levels can be made only indirectly by extrapolation from available data at higher dose and dose-rate levels, when such data provide reasonably valid dose-effect relationships. When the available data are reasonably compatible with a linear dose-effect relationship, which implies a constant ratio of effect to unit dose independent of dose size and rate, the assumption of this relationship is most practical in that it permits a single estimate of risk per unit dose over the dose range for which the relationship is valid, and it provides a convenient linear extrapolation to lower dose levels. Furthermore, on the basis of the reasonable assumption that the effect per unit dose at low dose levels will be no greater, and probably less, than that at higher dose levels, this extrapolation of the linear relationship to low-dose levels tends to give either an upper limit or an overestimate of the risk at low doses or dose rates. This is so particularly if the dose-effect relationship is derived from data in the dose range in which the frequency of the effect is increasing most rapidly with increasing dose.

In view of these and other uncertainties and of biological and dosimetric variables which are not taken into account, including the probable differences in effect of radiations with different characteristics, the risk estimates given below are at best tentative and gross approximations which are better regarded as orders of risk rather than as accurate estimates.

RISK ESTIMATES

Leukemia

The leukemia incidence data on Japanese A-bomb survivors for the dose range of 100 to 900 rads are compatible with a linear dose-effect relationship and permit a risk estimate of:

1 to 2 cases/10^6/year/rad

averaged over the first 14 years (to end of 1958). Since 1958 the excess cases have been reduced but have not disappeared. The duration of risk and the total risk estimate must await complete ascertainment. However, an upper limit for the total for 20 years may be estimated as:

20 to 40 cases/10^6/rad, in 20 years.

Supporting this risk estimate is a risk estimate of about 0.5 cases/10^6/year/per rad (averaged over an average of 7 years at risk) in spondylitics receiving therapeutic spinal irradiation. Assuming the spinal marrow to constitute 40 percent of the total active marrow, the theoretical risk estimate for whole-body irradiation would be about 1.3 cases/10^6/year/rad or similar to the risk in the A-bomb survivors.

Some justification for assuming that leukemia or other cancers can be caused by very low doses is provided by the evidence that doses of the order of 1 to 5 rads of diagnostic irradiation to the fetus in utero may have caused an increased incidence of leukemia and of other cancers to develop in children. Estimates of the risk per rad based on these data are greater than those for irradiation of mixed populations of children and adults by a factor between 2 and 10, however.

Cancers Other Than Leukemia (Combined)

Available data are not sufficient to permit independent risk estimates for every other specific type of cancer individually. However, in circumstances involving irradiation of the whole body (or a large part of it), it may be sufficient for present purposes to consider the possible risk for all cancers combined.

Although human data are also insufficient to establish reliable dose-effect relationships for all cancers combined, the recent data on the Japanese A-bomb survivors, together with the data on the irradiated spondylitics, and on the children irradiated diagnostically in utero not only indicate an increased incidence of nonleukemic cancers combined, but seem to suggest that the total increase in cancer mortality within a period of 20 years after irradiation is about twice the increase in mortality due to leukemia alone. On the basis of these estimates, and on the basis of the assumption, as a working hypothesis, that the dose-effect relationship for adults is linear over a range from one to several hundred rads, it has been tentatively presumed that the risk of death from cancer (other than leukemia) may be about the same as that for leukemia, that is:

<u>1 to 2 cases/10^6/year/rad</u>.

As in the case of leukemia, the risk estimate for the fetal irradiation would be several times higher than for the adult.

The modal induction times for many cancers other than leukemia may be considerably longer than that for leukemia, and therefore the ascertainment of the incidence of radiation-induced cancers other than leukemia may presently be much less complete than that for leukemia. If this is so, then the present risk estimate for cancers other than leukemia may be too low, owing to failure to take into account a possible future rise in excess incidence. On the other hand, the present estimate may be too high if the dose-response relationship is not linear. However, the total risk for 20 years may be estimated as:

<u>20 to 40 cases/10^6/rad, in 20 years</u>.

<u>Thyroid Cancer</u>

Combined data from various surveys on the incidence of thyroid cancer developing after therapeutic irradiation of the neck region of children for benign conditions have permitted a rough estimate of risk. Without accurate estimates of the radiation dose to the thyroid, and without careful establishment of the inclusion or lack of inclusion of the thyroid in the main radiation field among these children, the incidence of thyroid cancer has been shown to be approximately proportional to dose in the dose range between 100 and 300 rad. This relationship has given rise to a risk estimate of about:

<u>1 case/10^6/year/rad</u>

averaged over a period of about 16 years. The period of risk may be longer, however.

More recent and refined analysis[4] of a major group of such subjects in one of the surveys, based on estimated thyroid dose (150 to more than 1,000 rad) among those children whose thyroids were likely to have been included in the main radiation field, gives a risk estimate of:

$$\underline{5.5/10^6/\text{year/rad}}.$$

Data on adults are insufficient to permit reliable risk estimates. The meager data which exist suggest that adults are less susceptible than children. On the other hand, the induction period may be longer for irradiated adults than for irradiated children, and there is a possibility of less complete ascertainment for adults which could make the presently seeming difference in susceptibility at least partly more apparent than real.

It should be pointed out that, in contrast to leukemia and many other cancers, thyroid cancer of the type induced by irradiation of infants can commonly be treated successfully, so that the associated mortality would be considerably less than the incidence.

Notes on Risks From Internally Deposited Radioactive Isotopes

In addition to the risk involved in irradiation from external sources is the risk imposed by the radiation of the body from internally deposited radioactive isotopes associated with fallout. In the case of those isotopes which are disseminated widely throughout the body, the risk may be considered in the same light as is the risk of leukemia and of other cancers combined after whole-body irradiation. However, in the case of those radioactive isotopes which become localized preferentially in specific organs, such as iodine-131 in thyroid and strontium-90 in bone, there is an additional specific organ risk which is not reflected in the whole-body radiation risk estimates.

Data from animal experiments have suggested that the carcinogenic effect of iodine-131 on thyroid may be considerably less per unit dose than that of radiation from external sources. However, the comparison here involves two sources of radiation at widely different dose levels and dose rates, and in some cases the doses from iodine-131 may have exceeded the optimal dose for tumor production per unit dose. Human data are inadequate to resolve this question.

In considering bone sarcomas which may result from strontium-90, there are no available human data. In regard to risk associated with fallout from weapons tests, it has been suggested[3] that the ratio of the dose commitment for endosteal tissues to that for bone marrow is about 1:2, and that taking account of the relative susceptibility of these tissues to radiation carcinogenesis, it follows that the risk of induction of leukemia is likely to be greater than that of bone cancer, even if strontium-90 is considered alone.

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PROSPECTS FOR ECONOMIC RECOVERY

Joseph D. Coker, Chairman

NATIONAL ENTITY SURVIVAL
FOLLOWING NUCLEAR ATTACK

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INTRODUCTION

Although policy studies of nuclear war have emphasized population survival, national survival and recovery implies considerably more. National survival and recovery implies the restoration of all important elements of national power and well-being. In a general economic sense, this means the population; the physical resources required to sustain the population and the institutions required by the population to make use of its resources.

While it is necessary to measure total national survivors, such a measurement is not sufficient. To study the longer-term problems, it is necessary to consider the population in terms of their roles in the postattack period. Such population groups cannot easily interchange roles. The geographical location of population groups would affect their postattack utility since large-scale shifts of population groups in the postattack period could result in delay in recovery and increased burdens on the rest of the economy. The postattack environmental conditions could also have a significant influence on survivors' capabilities. Residual radiation, damage to housing, loss of family members, and other conditions would all affect the performance of survivors.

Industrial survival must be sufficient to support survival needs of the remaining population and at a later time to provide for a reasonable rate of reconstruction. Finer subdivisions of resources must be examined in order to pinpoint potential problem areas. Loss of critical and unique resources, such as petroleum for example, could unduly hamper recovery, unless detailed advanced planning and preparation has been undertaken.

Institutions play vital roles in the national enterprise, but their contributions are often difficult to measure in economic terms. However, continued existence of political, social, and economic institutions must be guaranteed if a recognizable national entity is to emerge after attack.

It has been recognized for more than a decade that postattack operations would change their character with the passage of time because of the changes in the damage conditions and the objectives of the passive-defense organization. As a consequence, the transattack and the post-attack period were divided into operational phases. Four phases are now generally recognized: (1) attack and shelter, (2) initial recovery, (3) reconstruction, and (4) final recovery.

The attack and shelter phase begins with tactical warning and ends with the emergence of the population from shelter. The principal objective during this phase is the immediate survival of the population. The initial recovery phase is the interim period after emergence from shelter until the basic necessities for continued survival are assured. The objective is the protection and subsistence of survivors and interim restoration of vital functions. The reconstruction phase begins after this interim condition and continues until essentially normal social, economic, and political conditions are restored. The final recovery phase in an indefinite period, during which efforts would be directed primarily at eliminating the long-term nuclear-damage effects on biological systems.

CONCENTRATION OF VALUES

When target values are accumulated for an ordered list of localities, the concentration of the values can be determined. Figure 1 shows the percent of national value (in terms of various indicators) as a function of the number of cities ranked by population. Population concentration is expected to continue so that in 1975 approximately 35 percent of the people would be in the first 25 cities and over 45 percent in the first 50 cities. Concentration of manufacturing within the first 50 cities is expected to be somewhat greater by 1975.

The concentration of economic and political institutions appears to be much higher than that of population or industrial resources. Results shown for public administration (federal) indicates that over half of the personnel are located in the first 25 cities. The concentration of public administrators would be substantially higher if consideration were limited to personnel with central planning and policy roles.

Managers in the primary-metal industries are also more concentrated than population. However, the manager distribution is highly correlated with the Manufacturing Value Added (MVA) of the primary-metal industry. The other distributions shown are related to the central management functions of principal financial and business operations. These functions are substantially more concentrated than population, industry, or managers in general.

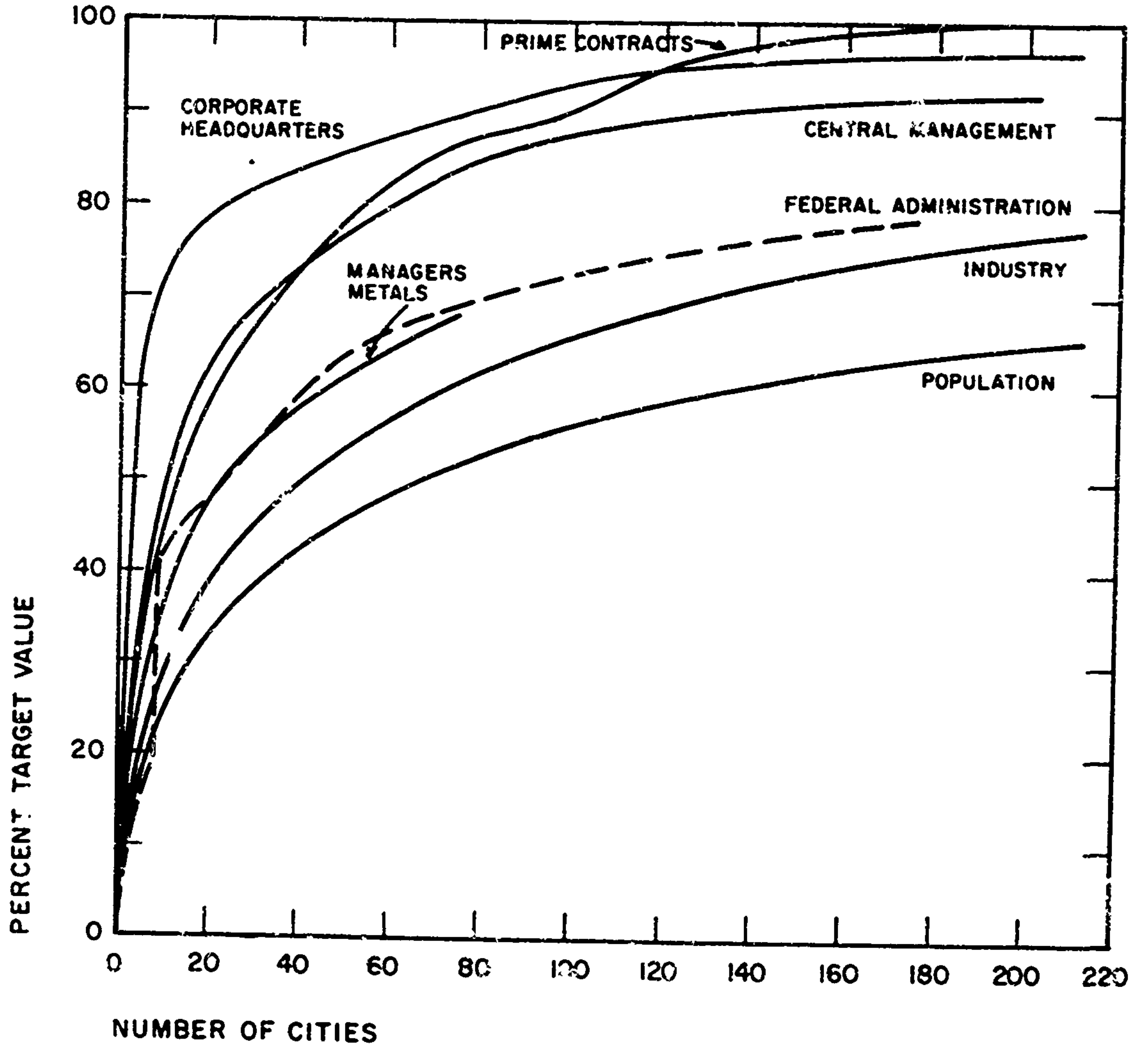

Figure 1. Distribution of Values in Metropolitan Areas.

Distribution of technical management supporting the government programs can be illustrated by the concentration of prime contractors. The curve represents the dollar value of classified and unclassified contracts for the year 1962. While a substantial portion of such contracts is conducted at locations other than in the city containing the headquarters of the prime contractor, most of the planning, scheduling, and final assembly is done by the prime contractor.

Both the central administration and prime contractor distributions indicate concentrations of approximately two-thirds of the value within the first 25 cities and over three-fourths in the first 50 cities.

Top management is even more concentrated than central administration or prime contractors. Distribution of corporate headquarters of the top 500 business organizations is weighted by total sales. The distribution tends to overestimate the concentration of top management since many of the larger corporations have decentralized management among divisions. On the other hand, most of the successful companies do provide essential long-term planning and financial guidance to the various divisions. In addition, if selections were made of personnel to handle the intricate job of reconstructing a damaged economy, most of them would be from the top-management group.

A number of other indicators have been considered. The distributions of employees of financial institutions and legal-service organizations are quite similar to the distribution shown for managers (primary metals). Managers of all manufacturing industries are only slightly less concentrated. Examples of groups that are not more concentrated than population or total industry include the total class of managers, officials and proprietors, and medical and other health services.

All of these distributions have a degree of relevance to the problem of resource and institutional concentration. When taken as a group, they allow some consensus judgments. The concentration of the economic and political institutions is substantially greater than the concentration of either the population or the physical resources of the country, and these institutions tend to be concentrated in the principal cities of the United States.

IMBALANCES INTRODUCED BY NUCLEAR ATTACKS

Widespread nuclear attacks would not only reduce the over-all level of survival but also would introduce imbalances among the national elements required for survival and recovery. The amount of imbalance varies widely with attack design. Up to the present time, postattack recovery problems have been considered for only a restricted range of attacks; also our knowledge of many physical and economic processes as well as the data needed for their measurement are clearly inadequate. For present purposes, the general characteristics of some postattack problems will be illustrated with results from a single attack.

The kind of imbalances that might appear among various national elements is indicated in Figure 2. For a mixed attack on military and civilian targets (3,000 megatons surface burst) slightly more than 60 percent of the population survived. Some other important elements exhibited greater reductions. Central management, public administration, and industrial capacity all show a tendency to be reduced to a greater extent than population. Imbalances of this kind have been a fairly general result of attacks involving the larger cities, as might be expected due to the higher concentration of these elements in the top metropolitan areas.

Another kind of imbalance observed following such attacks relates to classification of survivors by organizational role. Survivors will include many injured, sick, and other groups that would be generally ineffective. The success of the postattack recovery effort will be determined by effective survivors who are able to fill the necessary roles in a given postattack period. In the 3,000-MT attack, the survivors were separated into injured; sick; dose limited; homeless; aged, disabled, children, non-working mothers; and effective survivors. Of the approximately 140-million survivors in the nation only about 38 million might be considered as effectives during the 5 months after attack. The imbalance was particularly noticeable in the damaged metropolitan areas where effective survivors were reduced to about 9 million out of 60-million survivors.

INDUSTRY SURVIVAL

In attacks against population, industry as a whole often exhibits reductions somewhat greater than does population. A more detailed examination of industrial sectors indicates substantial variations in survival levels, as illustrated in Figure 3. Undamaged capacity measured in terms of MVA was approximately 40 percent. Certain sectors were more severely affected. These include food processing, transportation, and instruments. Such irregularities in surviving level might under some conditions introduce constraints on the use of the capacity in other sectors due to interindustry dependence during the reconstruction phase. In this particular attack, an input-output study did not indicate any major constraints on utilizing surviving capacity. The remaining capacity appears to be sufficient to meet consumer final demand with

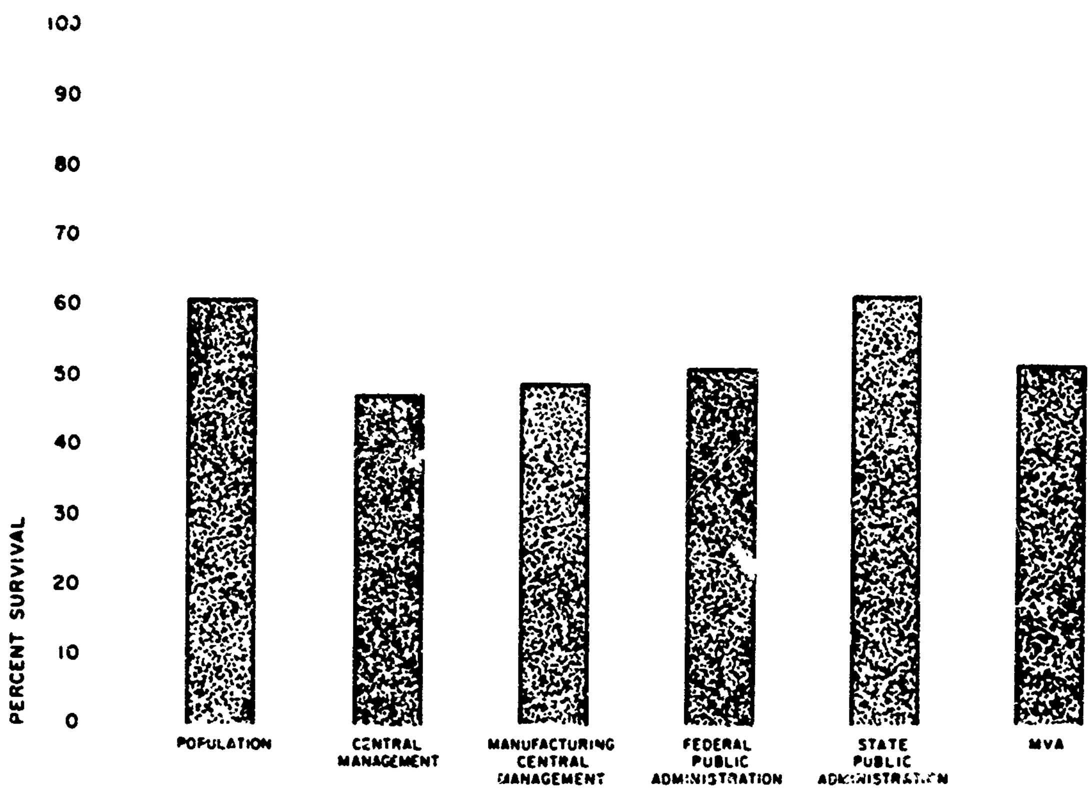

Figure 2. Survival of Elements of the National Entity.

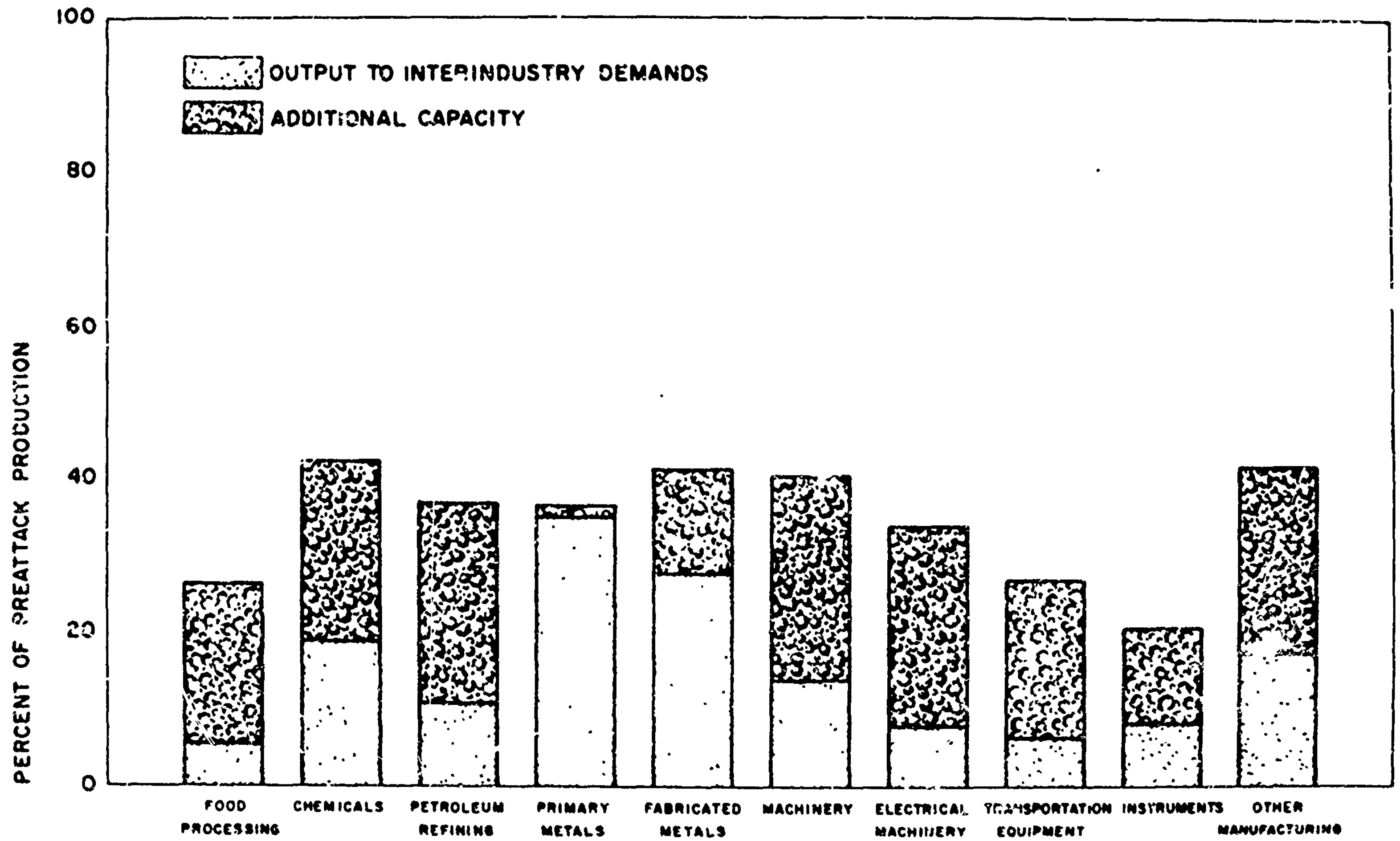

Figure 3. Industrial Output Requirements for Full Operation of Undamaged Industrial Capacity.

an excess that might be used to aid reconstruction. Heavier attacks might change this outlook, especially if larger fractions of the population survive or the attacker makes a special effort to introduce imbalances. Also, it should be recognized that the available interindustry data for input-output studies are suspect when used to model interindustry dependencies in a postattack environment.

EFFECTS OF DOSE BURDEN ON SURVIVORS

The problems of recovery following attack would be made more difficult by the radiation dose burdens accumulated by survivors during the attack and shelter phase. With the currently approved OCD shelter program, an appreciable percentage of blast survivors could be subjected to lethal-radiation doses. Sublethal doses causing sickness could further reduce effective survivors. In view of uncertainties as to actual doses received, operational limits might be imposed for persons with estimated doses above 100 R. This consideration could more than double the percentage of population unavailable for early recovery effort during the initial recovery phase. Many of these people will be available later to join the labor force.

A possibly greater source of delay in resuming production could result from a loss of production workers from surviving industrial plants. In Figure 4 delays due to dose restriction and loss of workers are indicated. For this attack, 36 percent of the MVA survived; however, early production was held below capacity by dose limitations and loss of workers. In the case where workers in the same city could transfer freely from one industrial plant area to another in the same metropolitan area, production appeared to be limited to the 26-30 percent range by loss of workers or dose restrictions. Where workers were limited to the same plants, capacity in the initial recovery period might be held below 10-13 percent. Extension of work hours would alleviate part of the problem -- retraining and movement of workers might eventually permit nearly full utilization of capacity. However, it appears from this and other evidence that full use of capacity is unlikely in the first 6-months-to-a-year after attack.

FOOD AND AGRICULTURE

A sizable portion of the recovery effort in the first year after attack would be directed toward provision of the necessary food and water and the continuation of agricultural production. A widespread attack would cause a loss of part of food stockpiles and growing crops as well as many agricultural workers. Local supplies of food appear to be sufficient to support the surviving population in the first weeks

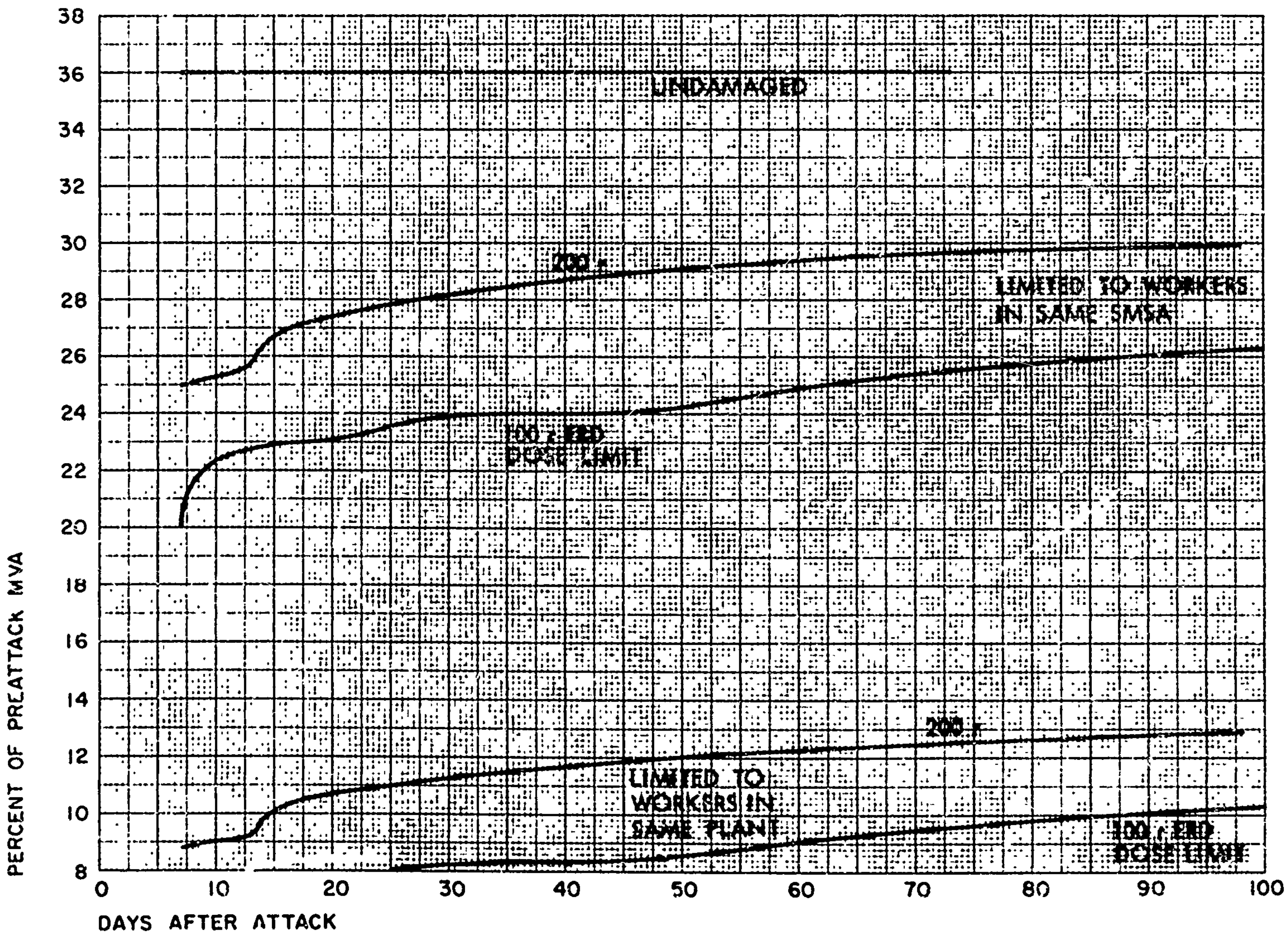

Figure 4. Availability of Industry.

with proper management. During the first year, the national stockpiles of food and feed would be very helpful in supporting the population and farm animals. However, production of important crops and animal products in the first year would also be required to meet minimal needs. In attacks examined to date, feasible production of food products appears sufficient to meet the need in the first year with proper management. The loss of important farm inputs such as petroleum and other energy sources might alter the situation by reducing the first year's harvest and limiting crop planting for the subsequent year.

Contaminated food and water would also provide a lesser but still significant threat to the population. Additional doses from contaminated water have been calculated for the thyroid, large intestine, bone, and total body. An examination of the problem for the referenced attack indicated that the serious problem was limited to just a few cities. In these cities, thyroid doses in excess of 4,000 rads appeared possible. Doses to the intestine and bone were below sickness levels; however, these doses might be significant when added to external radiation doses received by these same people. Since the thyroid dose to children could be many times higher than that to adults, serious thyroid damage to children could occur in some of these communities. Dose due to the ingestion of contaminated food appeared to be relatively low compared to doses from other sources.

SUMMARY

The complex system we call the national entity cannot be clearly defined even in its present state; as a consequence, there can be no single measure of value that can be used to measure the condition of the nation following an attack. A series of indirect indicators can be given to reflect the condition of essential elements: population, resources, and institutions. The aggregate information thereby provided should provide useful policy guidance for solving postattack-recovery problems.

Examinations of postattack-recovery capabilities have been made in the past few years for a small number of attack conditions. For these attack conditions, it appears that national survival and recovery could be achieved providing efficient use is made of remaining resources. However, heavier attacks or attacks designed to induce imbalances in national elements might reduce our confidence in achieving survival and recovery. Regardless of the attack scale or design, requirement for planning and the implementation of postattack procedures is clearly essential.

A SURVIVAL MODEL
OF POSTATTACK PHYSICAL CAPACITIES

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PURPOSE AND SCOPE

The general purpose of this paper is to describe a post-nuclear attack survival model prepared at the Research Analysis Corporation (RAC) to meet the analytical needs of a contract with the Office of Civil Defense. The description will cover technical characteristics of the model in terms that show the place of this model in the family of economic models that exist for similar purposes. It will also cover the present uses of the model and some contemplated improvements that are expected to make the model more useful.

A DIGRESSION OF INPUT-OUTPUT MODELS IN GENERAL

The rationale of the RAC model may be a little easier to follow if it is preceded by a short digression on relevant characteristics of input-output models in general, the class to which the RAC model belongs.

Basic Characteristics and History

The distinguishing feature of an input-output model is its use of a separate production function for each of a substantial number of producing sectors into which the economy is divided. Such models have been responses to needs for identification of the sectors of the economy that would be stimulated by particular kinds of exogenous increases in final demand. During the depression of the 1930's, it was considered important to know the industrial distribution of new employment generated both directly and indirectly by different kinds of government public works and relief programs. During World War II, it became important to trace the pressures on plant and equipment capacities that would be generated directly or indirectly by increases in military programs. Needs such as these generated informal calculations consistent with the basic principle of input-output analysis; but, after the war, stimulated by the theoretical and empirical work of Leontief and the Harvard Economic Research Project, the U.S. Government, foreign governments, and other research groups at various times made formal input-output models of countries and regions. Such models have been considered by their authors to be useful in tracing the impacts of all sorts of exogenous changes in final demand; and, in recent years, an added use has been found in analysis of the economic difficulties created by unbalanced destruction of production capacities. Heavy destruction of some kinds of capacity can idle other capacity that has suffered no direct damage.

As in the cases of other models, input-output models may be either static or dynamic. A static model describes equilibrium rates of flow under circumstances in which technology and stocks of capital do not change. A dynamic model permits the events in early time periods to affect events in later ones.

Some of the input-output analysis of national economies has been enriched by use of linear-programming mathematics. When used in input-output models, linear-programming mathematics determines the selection of activity levels of the various sectors that maximize some linear function of the final demands.

A Dilemma on Aggregation

Usually the level of disaggregation of production for an input-output model is determined by the kind of data and computation equipment that are available. But authors of input-output models are likely also to worry about how much disaggregation is desirable in principle. If the economy is divided into a very small number of sectors, the benefits of input-output models are realized only to a slight extent. However, if the economy is divided into a great many sectors, the substitution possibilities of the real world are not easy to reflect in the production functions of the model. For example, one may have reasonable confidence in a model according to which a particular class of equipment requires a given number of dollars of aggregate raw material industry outputs per unit of equipment output. Doubt appears, however, when an attempt is made to determine a necessary distribution of input cost between metals and plastics or, within metals, among the different kinds even if a base-year distribution is known. In the real world, proportions among inputs are subject to change with changes in final demands and with changes in the mix of resources available for producing inputs.

With good luck one may stumble on a level of model aggregation that correctly forecasts whether a particular set of final demands is or is not feasible with available capacities. But there is no objective way of determining what that level of aggregation is; and, even if that level of aggregation is the one used, it is likely to be incorrect in identification of the sectors that are limiting. Areas of overaggregation may conceal capacity shortages; and areas of underaggregation will surely generate shortages that are capable of being relieved by substitutions of alternative production processes.

GENERAL POSITION OF THE RAC MODEL AMONG POSTATTACK MODELS

Major characteristics of the RAC survival model may be described in terms of treatment of imports, treatment of time, types and aggregation levels of data, and use of linear programming.

As is true for most postattack models, it is assumed in the RAC model that noncompetitive imports continue to be supplied by one means or another to the extent that they are needed for domestic production. An example is chromium, which is used customarily in great quantity for alloying with steel, for plating, and as a paint pigment, and which has virtually no domestic production usable for those purposes. It is also assumed, however, as in the case of most other models, that shortages of the kinds of items for which the United States is ordinarily self-sufficient (e.g., fertilizer) cannot be made good by imports.

The model is static. It refers to rates of production during a period of indefinite length following decontamination and repair of light damage. This is a lesser capability to handle changes in production circumstances over time than the capabilities of models in the Postattack Resources Management (PARM) system developed at National Planning Association under the leadership of Marshall Wood, and less than the capability of the Industrial Readiness Army Mobilization (IRAM) model, developed some time ago at RAC by Fassberg, Moder, and Igo in connection with an Army study of postattack mobilization capability.[1]

For nonagricultural sectors the RAC model uses, with small modifications, the classification and input-output ratios of the 1958 interindustry study of the U. S. Department of Commerce.[2] Some of these modifications are similar to those of the Recovery Model of the PARM System.[3] The agricultural parts of the RAC model use some data from Department of Agriculture work in support of the 1958 interindustry plus a considerable amount of other Agriculture research completed for other purposes. The result is a model with what is probably the most detailed breakdown of agricultural production for any comprehensive model of total production in the United States. The detail in agriculture is in line with the primary use of the RAC model for survival studies and with the key importance of agriculture in survival.

The dilemma with respect to level of detail in specification of input requirements for production is handled for the agriculture and food processing parts of the model by linear programming mathematics that choose from among a given set of alternative processes the ways of maximizing the number of survivors with the mix of capacities remaining after nuclear attack. The Peskin[4] and Fassberg models have used linear programming mathematics to select a mix of final demands that, with no process alternatives, maximizes some objective function of many final demands; and the PARM system models provide for some process alternatives but without use of rigorous optimization mathematics for the selection.[5] Outside of the agriculture- and food-processing sectors, the key sectors of the RAC model, there are no process alternatives; but the need for alternatives is less because of the rather high level of aggregation.

SOME PRINCIPAL DETAILS OF THE RAC MODEL

Figure 1 is a diagram of the model structure. It represents 81 rows and 129 columns. Each column belonging to a column class describes the inputs and outputs associated with one unit of the column activity. In general, pluses indicate inputs per unit of the activity; minuses, outputs. Each row describes an equation for balancing inputs and outputs. Each constant to the right of the equality or inequality symbol is an amount of the item that must be not less or not greater than the cumulative product of the column variables and their unit inputs (positive), and outputs (negative).

Classification of Activities and Constraints

It is convenient to examine the model structure both as a collection of columns and as a collection of rows.

The first class of columns has only one member, the column of inputs associated with support of one-million people. The human nutrient rows have minimum requirements for calories, proteins, fats, iron, and calcium plus maximum intakes of calories, fats, and total weight of food. There is no specification of foods by which the nutrients are to be supplied, so there is no attempt to include indirect requirements. The remaining nonempty rows have direct and indirect requirements for various kinds of capacity to supply specific nonfood commodities and service requirements of each million people. These can and do have indirect as well as direct inputs to nonfood requirements because the model permits no flexibility in ways of meeting nonfood requirements.

The crop and livestock-product columns have inputs and outputs per unit of each kind of crop and each kind of livestock product. Food crops have outputs (negative entries) of food and sometimes of feed by-products, and inputs (positive) of industrial products used directly to produce crops plus industrial products used directly and indirectly to process the crops and distribute them to consumers. All crops have alternative processes that use normal preattack inputs of pesticides, fertilizers, and petroleum products and normal inputs minus one or both of pesticides and fertilizers. Absence of one or both of fertilizers

Activities / Types of balance	Persons Supported	Production: Crops	Production: Livestock products	Production: Industrial inputs to agriculture	Government operations		Constant terms
Human nutrients							
Lower limits	+	-	-			≤	0
Upper limits	+	-	-			≥	0
Livestock nutrients							
Lower limits		-	+			≤	0
Upper limits		-	+			≥	0
Land classes							
Upper limits		+				≤	Postattack availability[a]
Stipulations		+				≥	Postattack availability[a]
Industrial inputs to agriculture		+		-		≤	0
Special constraints							
Soybean-grain mix		+ -				≤	0
Level of government					+	=	Stipulated level of government activity.
Industrial capacities	+	+	+	+	+	≤	Postattack availability[b]
Byproducts	+	+ -	+ -	+	+	≤	0
Livestock capacities			+			≤	Postattack availability[b]
Labor	+	+	+	+	+	≤	Postattack availability[b]

[a] Same as preattack

[b] Output of damage assessment

Figure 1. General Form of the Model.

or pesticides increases the amounts of other inputs needed per unit of crop activity measured by outputs. Livestock-product activities produce human nutrients directly plus, in the case of beef, an industrial by-product, hides and skins. They consume livestock nutrients that are outputs of crops grown for feed (including grass) and the byproduct outputs of crops grown primarily for human food.

The columns for industrial inputs to agriculture have outputs (negative entries) of fertilizer, pesticides, and petroleum products used directly in agriculture plus, in lower rows, the direct and indirect capacity inputs to production of the outputs.

The final class of vectors has only one member: the direct and indirect capacity inputs to a unit of activity of federal, state, and local government plus, in the level of government row, an appropriately scaled number to count the number of units in the solution.

The rows for lower limits on human nutrients state that minimum inputs of each nutrient to population support, minus the outputs of the crop and livestock activities, must be less than or equal to zero. The rows for upper limits state that maximum inputs minus outputs must be greater than or equal to zero.

Similar rules apply to minimum inputs of Department of Agriculture feed units, proteins, and to maximum weight of ration, the three categories used for animal nutrition. A feed unit is the amount of any feed that is about equivalent to a weight unit of corn in marginal feeding value to a class of livestock having an otherwise balanced diet. If the diet is not balanced, or if the analysis is of total diet rather than marginal changes, it is desirable to consider less aggregated nutritional elements; and the model considers one -- protein.

In the cases of both human and animal nutrition, the world has many more kinds of important nutrients than there are rows. It was considered, however, that diets of natural foods and feeds that are adequate with respect to the nutrients accounted for are likely to be close to adequate with respect to other nutrients. In any event, it is comparatively easy to modify the model by adding rows for additional nutrients.

Agricultural and pasture lands are classified by types of agricultural activity they can support. The entry in each column of a row is an amount of land of some class required per unit of the agricultural activity. The constant on the right side of the inequality sign is the amount of the class of land available. A class of land is defined in narrowest terms by the kind of crop that can be grown on it with the productivities specified by the matrix elements. Substitutability of land among crops is achieved in a rough way by excess of the sum of acreages in narrowest crop classes over the amount of land in classes defined as aggregates of those classes. For example, the amount of land suitable for each of wheat, corn, oats,and other grains exceeds the aggregate amount of land stated in the model as suited for grains; and the sum of acreages in all land classes exceeds the total amount of land available. Each crop has an input requirement of land at each applicable level of land aggregation, to make sure that none of the restrictions on land use are exceeded.

In the cases of wheat, fruit, and vegetables, there are not only maximum uses of land, but also minimum uses. In the case of wheat, this is because of the belief that some of the wheat land would have little productivity in other uses. In the cases of fruits and vegetables, this is because the amounts of land involved are too little to affect possible outputs of foods of greater energy value and the reservation of land for these purposes would serve as an indirect way of insuring availability in the diet of some nutrients not accounted for directly. Vitamin C is an outstanding case.

The rows for industrial inputs to agriculture refer to the same items as produced by the column activities with the same names; but, in the cases of fertilizers and pesticides, the row units are physical quantities while the column units are 1958 values of the Office of Business Economics (OBE) interindustry study. The row restrictions are that total inputs to crops minus outputs of the industrial items must be less than or equal to zero. The entries in the columns for industrial inputs to agriculture are ratios between the units of measurement used in the rows and the units used in the columns.

The first special-constraint row limits the amount of soybean meal that can be used as human food to 20 percent of bread grains plus 4 percent of meat. This is a palatability restriction that may, perhaps, be relaxed in future use of the model. The government row stipulates the scale of government with the mix of direct and indirect inputs provided by the column of government operations.

The industrial-capacity rows provide direct- and indirect-capacity requirements for crop and livestock activities. The entries in the crop and livestock columns cover only the direct- and indirect-capacity inputs to the processing of foods produced by agriculture. The direct inputs to agricultural production are provided in the rows for industrial inputs to agriculture; direct-and indirect-capacity requirements of those inputs appear in the columns for industrial inputs to agriculture. In all cases total inputs of any particular kind of capacity must be less than or equal to the postattack availability of that kind of capacity.

The byproduct rows refer to inputs and outputs of cotton and of hides and skins. In both cases requirements for the items, minus outputs, must be less than or equal to zero.

The livestock-capacity restrictions are maximum outputs of livestock products as limited by the size of livestock herds.

The labor row was inserted for use in a problem involving an attack in 1975 and therefore reflects estimated peacetime productivities of labor in 1975. It is likely to underestimate labor requirements in a postattack situation because of productivity declines resulting from conservation of scarce industrial materials, use of makeshift facilities, transfer of labor to unfamiliar duties, domestic problems of workers, and novelty of the problems facing industrial management. The row should be redundant, though, in any problem involving high ratios of population survival to plant and equipment survival.

The Final Demands

As noted, the model has two kinds of final demands on the economy: government operations and support of population.

In keeping with the idea that the model is for survival analysis, the government operations are of types that exclude new construction and military expenditure. This does not mean that there would be no such government operations, but it does imply a high priority for bare survival of governments and population.

The requirements per unit of population supported are more austere than are commonly stated in other studies, including econometric studies of peacetime-expenditure patterns. There are three principal reasons for the greater austerity here. The most important reason is rejection of peacetime poverty standards in favor of a standard of good physical health, which involves a much smaller drain on resources. Peacetime-poverty standards have nonhealth components (e.g., recreation, household appliances, and clothing) that are affected by advertising and the examples of people who are not classified as poor. In the postattack situation, if survival is at stake, these artificial components of minimum standards should disappear. A second reason for a lower survival standard here stems from a, perhaps, less than customary degree of inflation of standards with components that, while not absolutely necessary, are considered sufficiently easy to provide so that they might well be considered requirements. Cigarettes, for example, may be essential, but only if it is sufficiently easy to provide them. The third reason is a principle followed in the present model of excluding items that, no matter how necessary for small percentages of the population, are not generally required for survival. Examples are drugs needed to keep small percentages of the population alive special diagnostic equipment for early discovery of diseases affecting small percentages of the population (e.g., sigmoidoscopes, which are on official survival lists), and specialized surgical equipment.

Under these principles the model has a standard that is intended to provide a diet of quantity and quality sufficient to maintain the entire population in good health indefinitely plus whatever non-food items may be required to prevent large portions of the population from dying of exposure and epidemic disease. In addition there must be some small expenditure for communications and work clothing that are really indirect inputs to production even though they are accounted for as consumption expenditures. Even here, though, the approach is austere. Nobody in the model drives a car to work. If walking is impossible and there is no mass transportation, he moves closer to his work or does not work.

Use of OBE Data

The Department of Commerce has published interindustry flows, direct inputs per unit of output, and direct plus indirect inputs per unit of final demand for the 1958 economy, divided into 82 sectors.[6] It has also published transactions tables disaggregating the food processing (Industry 14), non-ferrous metal (Industry 38), and the public utility (Industry 65) sectors.[2] For the RAC model a new table of direct and indirect requirements per unit of final demand was calculated with the additional detail on transactions in 1958. There were a number of departures, however, from the OBE procedure for calculating the table.

The most interesting departure from a theoretical viewpoint, and also potentially of numerical significance for some survival problems, was the handling of byproducts. The OBE transactions table makes no distinction between byproducts and other outputs of an industry. It is all homogeneous dollars of output. The requirements tables do make a distinction. They suppress interindustry flows of byproducts while preserving the transactions-table definition of output of an industry as including byproducts by the fiction of treating any sales of a byproduct to other industries as an intraindustry rather than an interindustry sale. For example, the OBE coefficient tables say that the meat-packing industry itself consumes an amount of its own output (including hides and skins) proportional to the ratio of hides and skins to meat in production. The RAC model defines output of the meat-packing activity as including only the value of the meat and considers the hides and skins output as if it were a negative input, which is the standard RAC model procedure of defining any output. Feasibility of any set of postattack activities in the RAC model requires not only that food consumption be no greater than production of food, but also that consumption of hides and skins be no greater than production of hides and skins. Meat-packing and beef-production activities are generated in the RAC model by requirements for meat or hides and skins, whichever is the larger.

The separate handling of each of any set of joint products in the RAC model is applied not only to joint products in beef and cotton production, two areas where one of the joint products is not a principal product of some other industry as already defined by OBE, but also to cases where one of the joint products was a principal product of some other industry. An example of the latter could be gas fuel, which is a byproduct of coke production in the steel industry as well as a principal product of gas utilities. This way of handling byproducts is a natural extension of linear programming and related mathematical approaches to input-output analysis of an economy. It has been used before in input-output models by National Planning Association in its PARM system and as early as 1956 by CEIR, the latter in work not available for distribution.

The RAC model used a further modification of the OBE data in suppression of inputs to industry from agriculture and in reduction of the printing and publishing and packaging requirements of some of the food industries. The deletion was because the agricultural inputs were to be replaced by the RAC sub-model for agriculture. The reductions were in the interests of austerity. It is not necessary to have as many small packages and all of the printing that goes into the present packaging of food.

A third modification of the OBE approach has already been indicated. Although the food processing industries take inputs of agricultural products, the RAC model treats food processing as an input to the activity that includes the growing, processing, and distribution of food; and the name of the activity is the name of the crop that is processed. Bread production, for example, is an input to all of the bread-grain producing activities and to soybean production for the portion of the latter that may be used in bread production.

A fourth modification was to treat margins between producer and consumer values of food-processing-industry output as required inputs to the food-producing industries. The trade and transportation components of these margins come from unpublished OBE data.

Capacity Constraints

It is customary in input-output models having capacity constraints to put a capacity limitation on the activity of every sector of the economy that is used in the input-output analysis. But this can involve spurious constraints on the economy, particularly where there is a surplus of labor. Some capacities can be improvised from other kinds of idle capacity with negligible inputs to the conversion. Other capacities are for service or other types of input that increase labor productivity but are not necessary if there is a plentiful supply of labor. Still other capacity requirements are outright errors resulting from the convention in input-output models of freezing a base year proportion between the output of an industry's products produced within an industry and the outputs of that industry's products by any industry producing one of those products as secondary production in plants devoted primarily to other products. For example, if an automotive parts plant happens to make a part for one of the washing machine manufacturers in the base year, the OBE model generates an indirect requirement for automotive-part-industry capacity in production of household appliances.

The RAC model aggregates metalworking capacities to deal roughly with the convertibility of different kinds of metalworking capacity to production of repair and maintenance parts for machinery ordinarily produced in other industries (much the way many machinery and other metalworking plants converted during World War II to production of military and other essential metal products); and it suppresses other kinds of capacity requirements entirely. When it suppresses entirely a capacity requirement that saves only labor, there is no harm done for the case where there is a labor surplus; but, where substitution of another capacity is required, the model does underestimate requirements of the substitute capacity and will overstate the capabilities of the economy if the substitute capacity is not in surplus. But the danger of this kind of overstatement of capability of the economy appears slight compared to the danger of assuming absolute requirements for capacity that is not needed.* In general, the kinds of capacity requirements suppressed for the RAC model are capacities for nonessential consumer goods and capacities for personal services.

CURRENT AND POTENTIAL USES

Essentially the present model has been run on five problems. The first problem had as the only capacity restrictions classes of land, 1963 fertilizer capacity, and 1963 pesticides capacity. With unlimited food-processing capability and with livestock herds permitted to grow

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* The PARM system deals with the latter kind of danger by interrupting computations to permit human judgment to be applied to the question of whether capacity bottlenecks that have appeared should be ignored in further computations.

to optimal size, population of over a billion people could be supported. The next two problems were projections of a postattack situation in 1975. The projections covered 1975 capacities and labor productivities, but left other technology unchanged. It was found in these runs that the postattack capacities could support in each case almost twice as many people as were estimated to survive direct weapon effects. This was not unexpected, because both attacks had population losses from direct weapon effects in greater proportion than property losses. The fourth and fifth problems were for postattack situations with population losses made arbitrarily small in relation to property losses, the extent of which cannot be described in an open meeting.

In all postattack cases, the capacities were estimates of what would remain after decontamination, repair of light damage, and reopening of transportation bottlenecks to light traffic. A byproduct of the calculation of maximum number of people supportable was always a set of shadow prices of all capacities. The shadow prices of surplus capacities are, of course, zero since a shadow price is an amount of increase in objective achievement per unit of marginal increase in the availability of the capacity. The shadow prices of the constraining capacities are in effect measures of the payoffs in objective achievement from pre-attack protection of capacities. They also suggest where postattack investment might be profitable. They only suggest this because the total effect of an investment involves reduction in other productive activity because of diversion of inputs to the investment activities.

Work on the model during the current year will include modification to optimize a postattack investment program for survival. The changes will be the minimum necessary for this capability. That minimum includes the introduction of an investment period preceding the steady-state period and the inclusion in the investment period of investment and inventory-depletion activities. The problem will be to maximize the number of people surviving to and through the steady-state period by optimal selection of inventory depletion, investment, and other productive activities. The length of the investment period will be about a year. A year appears long enough for substantial investment projects to be completed without being so long as to permit major payoffs during the period from large investment projects that are started early. In addition a year is long enough for use of steady-state indirect requirements for production without substantial overstatement of those requirements.

With the model modified in this way it will be able to make a finer distinction than now between cases where the entire population can be supported and cases where it cannot. At present there is no provision for relief of critical bottlenecks, except by substitution or by assumption that stockpiles can be sufficient for an indefinite period. With the modification the model will be able to explore the possibility of relief through investment and through preattack stockpiling of particular volumes needed to tide the economy over until postattack investments can be completed.

In closing, I should like to emphasize that the model refers only to technological capacity. Monetary problems, difficulties of appraising and adjusting to new situations, and other interferences with efficiency in use of resources may reduce achievement well below what is technologically feasible.

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POSTATTACK VIABILITY OF THE UNITED STATES-1975

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INTRODUCTION

The Engineer Strategic Studies Group has undertaken for the Army Staff a series of studies examining the probable postattack conditions of the major nations of the world in the event of a general nuclear war, and in so doing we are addressing several specific questions. The first study in the series is Postattack Viability of the United States in 1975, and it addresses two specific questions. First, what will be the probability of survival of our nation in detail? Specifically, what will be the population survival by individual labor skill and by geographic location? Likewise for industry, how much of each sector will survive, where will it survive, and how much can the surviving industry produce? That is the first question. The second: what limiting effect will the residual labor force and economy have on military operations in the postattack period? Will postattack military operations even be feasible? As the study title implies, this information is desired for the 1975 time frame.

POPULATION DATA BASE

We began by developing detailed data bases of our labor force and industry and projecting them to 1975. Some selected summaries are shown in Figure 1.

The 1960 census determined that there were over 179 million people in the continental United States, Alaska, and Hawaii, including an active labor force of almost 70 million with some 64,600,000 persons employed in the civilian labor market. During the 15-year period between 1960 and 1975, the over-all population of the United States is expected to increase by 29 percent and the labor force is expected to increase by 36 percent. Most of the increase in the labor force will be from natural growth of the population; the remaining increase will be due to the continued rise in the percentage of women entering the labor force. These projections were obtained from the Bureau of Census and from the Bureau of Labor Statistics. Recent estimates for the third quarter of 1967 indicate that the population projection is a little high but the labor-force projection is very close.

CATEGORY	1960	1975	15 YEAR CHANGE
POPULATION	179,326,000	231,627,000	+29%
LABOR FORCE	64,639,000	87,983,000	+36%
SELECTED SKILLS			
ENGINEERS	860,900	1,742,900	+102%
DOCTORS, ALL TYPES	247,600	585,800	+137%
MANAGERS (SALARIED)	2,554,300	3,428,000	+34%
MACHINISTS	498,700	634,300	+27%
POLICEMEN	252,200	302,600	+20%
FARMERS	2,481,200	1,465,300	-41%

Figure 1. Population Data Base.

The Bureau of Census identifies 240 individual skills in the employed civilian labor force. There are additional breakdowns within many of the skills. The number of workers in each of these skills is reported in the 1960 census and is based on a 5 percent sampling.

The 240 individual skills were analyzed for importance in a postattack environment and the list was reduced to 116 by grouping together those occupations that could be performed with little or no training and by grouping those occupations not considered essential in a postattack environment. Within the 116 individual skills breakdown there are similar occupations with different degrees of skill. For example: in a postattack situation, apprentice carpenters would be expected to perform as journeymen carpenters, so both these skills were included. Our 116 skill groupings are postattack-oriented to provide a measure of critical occupations, including management.

We analyzed Bureau of Census, Department of Labor, and contract study-group publications for trends in labor-force changes and we found that since World War II, the number of professional and highly skilled workers is increasing at a much faster rate than is the labor force as a whole, while the increase in lesser-skilled workers is below the average. Employment in some occupations, notably farming, is decreasing. There is also a migration of the population, especially the working ages, to metropolitan areas and to the South and West. Between 1960 and 1975, urban areas will grow one-third faster than the nation as a whole, and the West will grow twice as fast as the national average.

The problem that faced us was in utilizing these trends to project the growth of each skill within each locality -- localities in our data base are counties or their equivalent.

We made our projections by developing a set of ratios based on the assumption that the rate of growth of the local skill is related to the rate of growth of the same skill nationally and to the rate of growth of the population both locally and nationally.

INDUSTRIAL DATA BASE

We developed a detailed data base of our economy very much as we did for the labor force and we were faced with the same sort of problems.

Our national economy, over-all, has been increasing at about 4 percent annually. The current fiscal policy of the federal government is to maintain an annual growth rate of 4 percent. After considering these and other factors, and after consulting with various economists, we selected an average annual growth rate of 4 percent for use in our study.

We also selected 1960 as the base year to match our population data base. In 1960 the Gross National Product (GNP) was $503 billion. Projecting to 1975, it will be $905 billion, in 1960 dollars.

However, before we could project the economy to 1975, we first had to identify it in detail for our base year of 1960 -- a task not so easy as we thought it would be. We used the Department of Commerce 86-sector industry breakout to describe the economy, and we located it geographically by county by developing sets of ratios using the assumption that the size of an industry in a locality is related to the size of that same industry nationally and to the number of workers in the industry, both locally and nationally.

For these assumptions to be valid, all workers in any one industry must have approximately the same productivity regardless of their geographic location. We believe that this is true because the open competition of the American business system makes this necessary.

Our detailed study of specific industrial sectors (see Figure 2 for examples) indicates that, as with population, growth will not be uniform either by industrial categories or by geographical location. The industrial base of the nation and the national labor force obviously are closely interrelated, and the movement of the labor force to the large urban areas and to the west will also be reflected by movement of industry. Industry attracts labor and vice versa. These trends are expected to continue.

Industrial growth in the United States is dependent upon the increase in output resulting from a growing labor force and from increased productivity of the workers.

To determine industrial growth resulting from labor force increase, we applied National Planning Association estimates which we were able to calculate at the state level. We then applied ratios tieing local labor by industry to the labor force in the same industry at the state level. Because increase in productivity was not taken into consideration at this stage, outputs were understated.

We determined productivity increase for each sector by calculating the difference between the National Planning Association's growth rates from labor increase and estimates of total industrial growth. This difference, which is the growth resulting from increased productivity, was applied to each sector in each locality.

The major deficiency in the data base is that it is static. That is, we had no way of projecting new industry entering a local area or old industry moving out.

CATEGORY	1960 *	1975 *	15 YEAR CHANGE
GROSS NATIONAL PRODUCT, ALL INDUSTRIES	503	905	+80%
SELECTED SECTORS			
AGRICULTURAL PRODUCTS	23	34	+47%
PRIMARY IRON AND STEEL MANUFACTURING	8	11	+39%
PLASTICS AND SYNTHETIC MATERIALS	2	7	+271%
MOTOR VEHICLES	7.4	23	+205%
ELECTRIC, GAS, WATER AND SANITARY SERVICES	11	38	+256%
WHOLESALE AND RETAIL TRADE	75	128	+70%

* BILLIONS OF 1960 DOLLARS

Figure 2. Industrial Data Base.

EFFECTS FROM NUCLEAR ATTACK

We programmed several different nuclear attacks against our data base. Primarily they were aimed at the over-all destruction of the United States. No particular segments of the economy were singled out for special attention. A recent study by Mr. Richard Laurino of Stanford Research Institute indicates that it may be more profitable to include emphasis on a particular sector while still maintaining an over-all-attack philosophy. We are inclined to agree with him and will begin testing this philosophy soon.

In our damage assessment we used several fallout-shelter postures and several active-defense postures to provide a spectrum of damage. Our procedures were standard practices used by all of the computerized assessment programs, with one major exception. Industry assessment is customarily based on physical plants being located by coordinates. Our data base is of the entire economy and it is not physically possible at this time to locate by coordinates every plant of every industry in the United States. Our solution to this problem was to collocate industry with people. Recently Mr. Jack Vaccara of the Office of Civil Defense, faced with the same problem in using our data base, collocated it with fallout shelters rather than with over-all population. I think his solution may be more accurate than ours. One of our systems analysts is examining each industrial sector vertically trying to identify the controlling subsector. If he can do this, then we can locate by coordinates these controlling subsectors and attack them. We will continue to examine various methods of damage assessment.

Shown in Figure 3 is an indication of the magnitude of the attacks we used. The black areas are counties that received direct weapons effects -- blast. The lined areas are those counties with lethal fallout only. The areas in white received no damage of any kind. We made separate analyses of each of the three areas. As an example, I will comment about only the undamaged areas, because in most vulnerability studies the undamaged portions of the nation are almost always ignored. But, as indicated in Figure 3, about one-half of the land area of our nation would be entirely free from blast damage, fire, or lethal fallout. Although this would be the outlying portions of the nation, these portions contain over 20 percent of the population and industry. This unscathed industry, with about $180 billion in terms of GNP and almost 50 million people with functioning local governments, would be a tremendous potential asset and would be the backbone of the nation for the first few weeks of the postattack period. It is from these areas that actions must proceed to weld the surviving resources into a viable national economy.

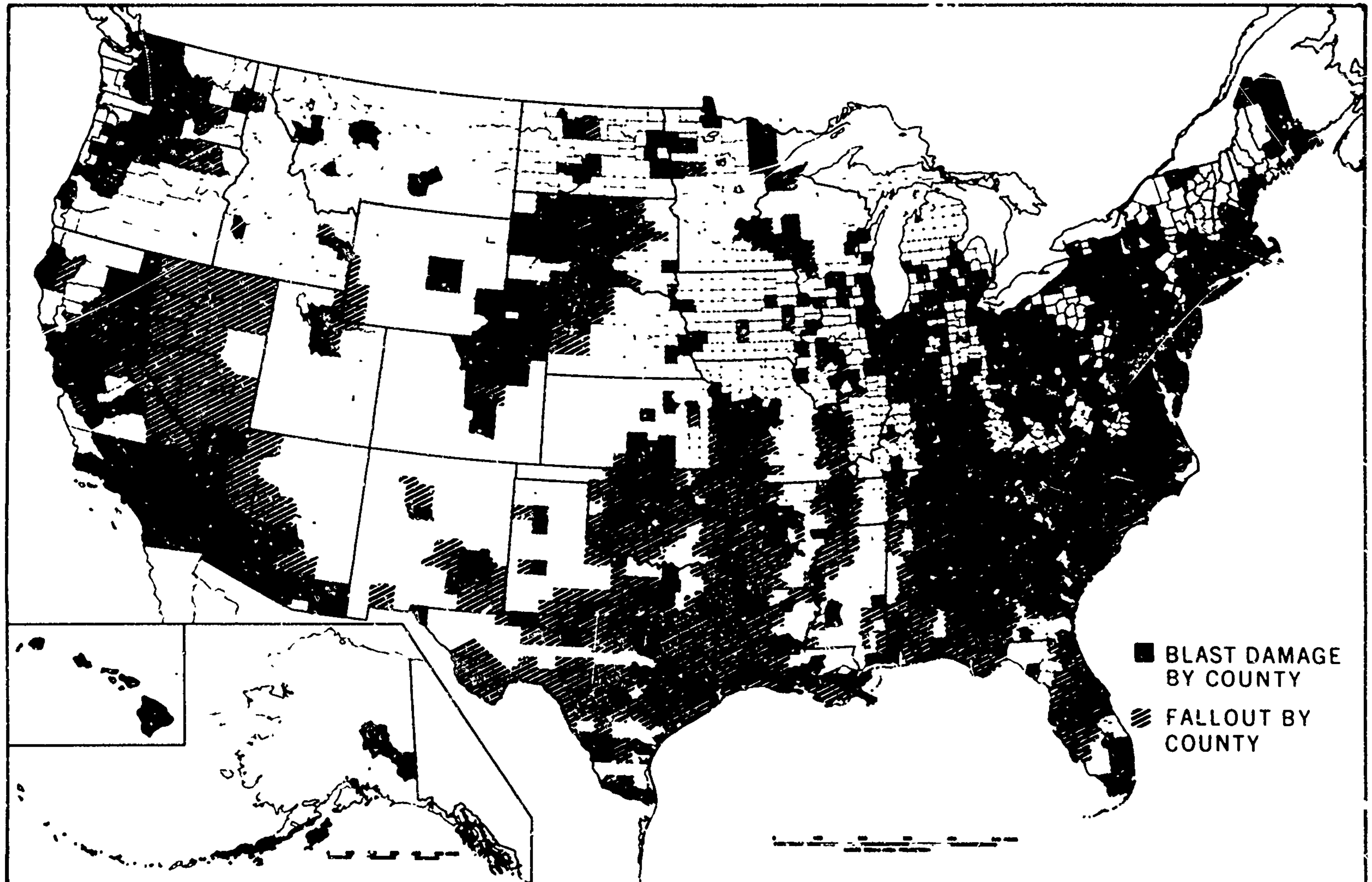

Figure 3. Damage to the United States.

POSTATTACK VIABILITY

In determining our postattack national viability, we considered a number of factors, both in independent study and as elements of larger problems. For example, in our analysis of the postattack economy it was fairly easy to determine the surviving physical-plant capacity. We simply added up what was left, but this is not sufficient to predict postattack production capability. Actual damage to our industrial physical plant was about 33 percent, i.e., from $900 billion to $600 billion. Our surviving economy would not be able to produce at that 600 billion-dollar level, however. Almost all 78 sectors in our economy require inputs from at least 25 other sectors, and 3/4 of them require inputs from more than 50 other sectors. Calculation of the production drawdown that would result from this industrial interdependency was one of our more difficult problems. We designed a computer model using the Department of Commerce input-output matrix of the economy and assessed the effect of this interdependency degradation at about $100 billion. This would reduce our postattack GNP potential to the order of $500 billion.

We encountered an imbalance between the industrial capacity and the surviving labor force in our study because of the shortage of labor. This is shown in Figure 4. But as with industry, simply adding up what is left of the labor force is not sufficient to predict postattack productive capability.

Our peacetime economy, which generated $900 billion GNP, preattack, was based on the employment of a labor force on an 8-hour day, 5-day week, 50-week year. In the postattack situation we would certainly not be limited to those utilization rates. We could bring more people into the active labor force or work longer hours, or, more realistically, effect some combination of these actions. During World War II, we greatly increased the number of women workers while extending the average work week to 48 hours. We also know that our World War II experience does not constitute a maximum utilization. Other industrial nations, notably the United Kingdom, Germany and the Soviet Union, were under much greater stress than we were. Using as a basis their experience, which included a 56-hour week, more women in the labor force, and greater utilization of 14-to-17-year-olds, we could attain about 90 percent of our preattack level of labor effort even after a very damaging attack. With this maximum utilization of labor we would have large numbers of workers in excess of those required to operate the residual industry. It is from this excess we could draw off military manpower requirements. After the heaviest attack studied, there could be about 11 million males, of ages 18 to 35, in excess of those required to operate the surviving industry. Using World War II rates of induction, some 4½ million men could be mobilized, in addition to the 3 million that are normally in the military forces. This would give us a considerable potential for subsequent military actions. Less-damaging attacks would permit the mobilizing of even larger military forces.

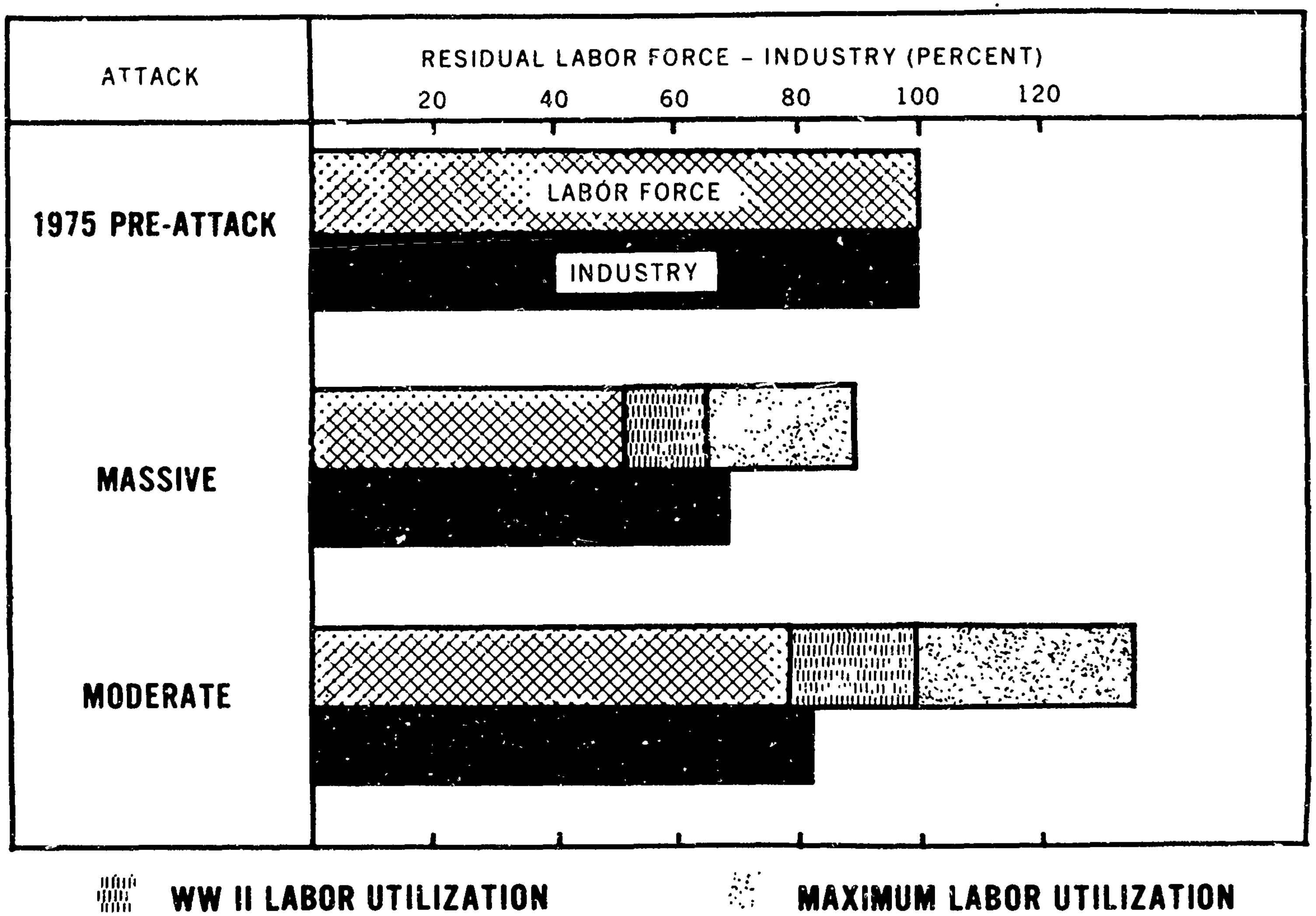

Figure 4. Postattack Viability.

COMPARISON OF PREATTACK AND POSTATTACK ECONOMIES

It is logical to raise the question: Will our postattack economy support the military operations necessary to maintain the United States as a world power? We examined this. The left-hand circle on Figure 5 illustrates the general nature of our peacetime preattack economy. Note that about 8 percent of our production is allocated to defense, while almost two-thirds of our economy is directed toward consumer requirements. In the aftermath of a nuclear attack, we would certainly be forced to make economic adjustments. If we adopted controls such as those used during World War II, consumer needs would require only about one-third of the surviving industrial capacity. Two factors account for this. First our standard of living during the 1940's was somewhat lower than today, and second, because of the fatalities, the.e would be about 100 million fewer people to support. By redirecting production from nonessential items to war materiel as we did during World War II, we can make available for war purchases about $300 billion. This is almost twice the amount we spent in 1944, the peak year of spending in World War II, and more than 4 times what we have spent during FY 67. With resources of this nature, the United States would still possess tremendous national power.

HISTORICAL COMPARISONS

To gain a better appreciation of what these postattack residuals mean, we can compare them to an equivalent year in our past. As indicated in Figure 6, the 130 million people that we estimate would survive a massive attack would be a population equivalent to that which we had in 1939. The surviving industry would have a potential of producing a GNP equivalent to that of 1961. In essence, we would have a capability considerably exceeding that with which we came out of World War II.

As an additional comparison, figures for Germany for 1939 are shown. With these relatively meager resources, Hitler prosecuted a pretty effective war for 4 or 5 years.

In summary, a massive nuclear attack on the United States would certainly constitute a catastrophe of the highest order. But although much would be lost, much would remain. Our studies indicate that we would have the capability and, given the will, we can emerge from such a holocaust to maintain a dominant position in the world and sustain the western values we cherish.

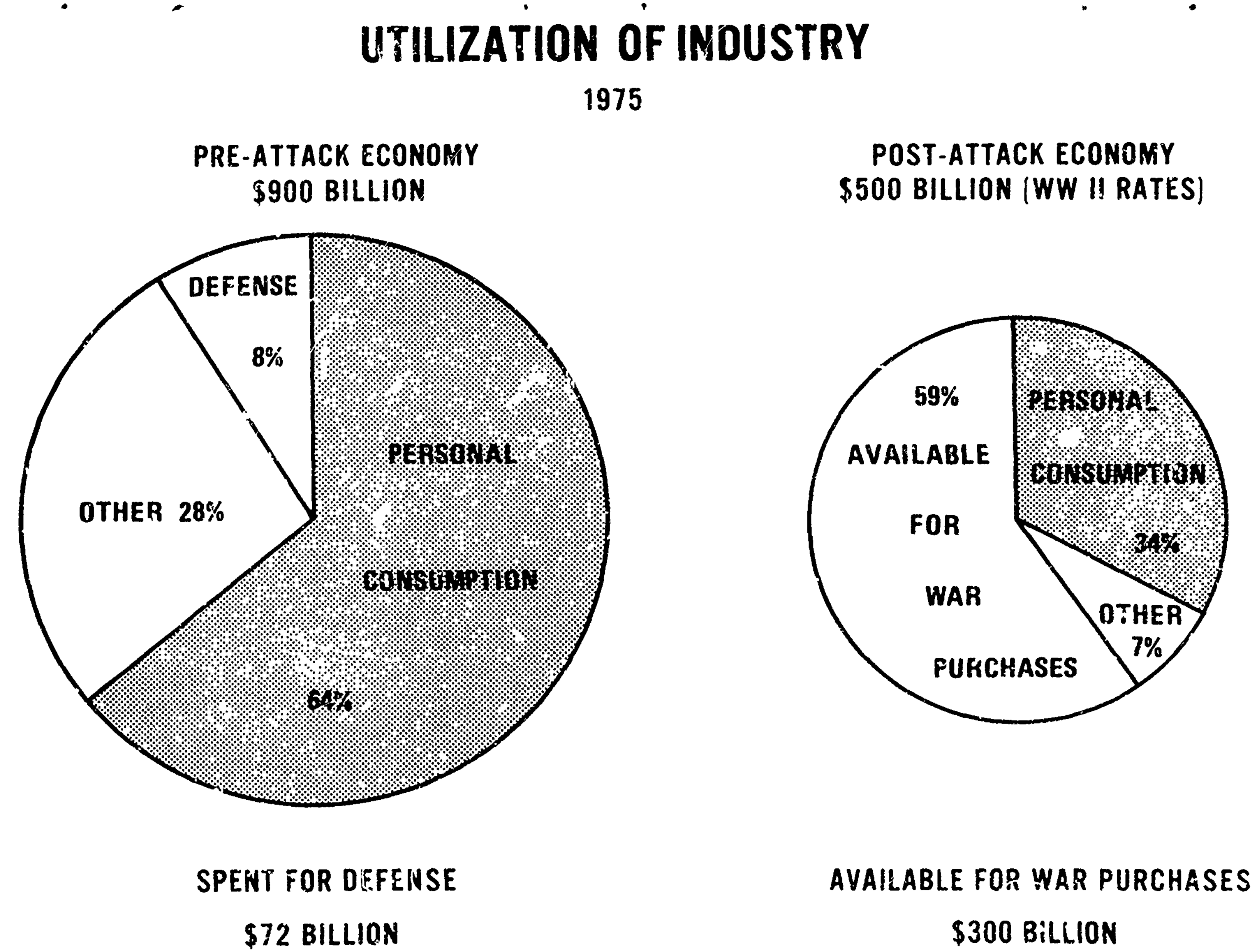

Figure 5. Utilization of Industry - 1975.

RESOURCES		EQUIVALENT YEAR IN HISTORY
UNITED STATES		
POPULATION SURVIVING –	130 MILLION	1939
INDUSTRY (GNP) SURVIVING –	$500 BILLION	1961
GERMANY		
POPULATION –	78 MILLION	1939
INDUSTRY (GNP) –	$58 BILLION	1939

Figure 6. Survival of the United States in 1975 - Historical Significance.

ECONOMICS

William A. Niskanen, Chairman

ESTIMATES OF THE POTENTIAL OF THE UNITED STATES ECONOMY FOLLOWING A NUCLEAR ATTACK IN 1975

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Institute for Defense Analyses

INTRODUCTION

This paper presents the methods and a summary of the data and results of a study of postattack economic potential undertaken by the Institute for Defense Analyses at the request of the Office of Civil Defense. The objective of the study was to obtain estimates of the performance of the economy following two separate attacks which were postulated to occur in June 1975.

At that time the nation's civil-defense posture is assumed to consist primarily of a fallout-shelter system. The first attack, designated A, is a counterforce attack. Effects on population and physical capital stocks are essentially collateral damage from weapon detonations on military targets. The second attack, designated B, differs from attack A in that part of the strike force has been retargeted in a deliberate attempt to destroy people. Consequently, both the nation's population and productive capacity suffer more severely.

Damage assessments for these attacks were performed by the National Resource Analysis Center and by the Office of Civil Defense. These assessments consisted of estimates at the national level of the number of survivors and percentage damage to industries.

Estimates of the potential of the United States economy following the two attacks were generated as solutions to a linear programming problem. Maximization of total value added within a set of upper and lower bounds on final deliveries was taken as the objective of the postattack economy. The constraints of the problem included a set of linear production relationships, a set of restrictions on emergency outputs, and a labor-force limitation.

In addition to the damage assessments, the model required data describing the peacetime state of the economy in 1975 and the minimum final deliveries needed following an attack. A number of alternative

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* In collaboration with Jane-Ring F. Crane, Institute for Defense Analyses.

projections and estimates were available or could be extrapolated from existing data. The model was solved with various combinations of the available input parameters. A range of solutions was obtained by varying the expected number of survivors and the proportion of the population in the labor force. Several hundred cases were actually run and examined to produce the results of our study.

The results of the study indicate that the survivors of the attacks may suffer only a minor reduction in their accustomed standard of living provided that the surviving resources can be organized to maximum advantage. In fact, living standards within the first year following either attack could compare favorably to those enjoyed in this country in the late nineteen fifties.

THE METHOD OF ANALYSIS

The problem of estimating the potential of the United States economy following a nuclear attack lends itself to a linear programming formulation. In fact, several such formulations have been attempted including one made several years ago at the Institute for Defense Analyses.[1] The model used in our current study is an extension of this previous work.

Assumptions

The linear structure of the model was dictated primarily by the nature of the available data and the requirement that it provide an operational description of a postattack economy. Conceptually, the model is based on a series of assumptions concerning economic objectives, preferences, production processes and the effects of an attack.

First we have assumed that maximization of value added within a set of upper and lower bounds on final deliveries of goods and services is an adequate approximation of the nation's postattack economic objective. Value added or Gross National Product is defined as the total value of all final deliveries of goods and services minus imports. A final delivery is the last stop in the economy for a good or service. Personal-consumption expenditures, expenditures by the federal government or state and local governments, fixed capital-investment expenditures and the value of goods exported are all components of peacetime final deliveries. Total value added is the objective function of our linear-programming problem.

The minimum final deliveries must be sufficient to provide both a tolerable standard of living for the survivors and minimal government operations at various levels. Opinions differ on what these minima should be. Several alternatives were actually employed in our exercise of the model, some of which also included the initial capital expenditures of an acceptable economic recovery.

On the other hand, final deliveries should not exceed the maximum amounts that could conceivably be absorbed. There is little point in diverting resources and labor to produce a postattack glut of newspapers, cement, or women's apparel.

The model employs the familiar production relationships of static open-ended input-output systems.[2] All of the economy's producing sectors require inputs and labor in fixed proportions to gross outputs. Furthermore, all interindustry and final deliveries must be made from current production. Stockpiles, inventories, and salvage are not included as possible sources for storable commodities. The restrictions of our linear programming problem include a set of input-output relationships, one for each industry. The gross output of a sector equals the sum of the interindustry demands of producing sectors and final deliveries. Activity levels are also restricted by a labor constraint. The use of labor is not permitted to exceed a fixed proportion of the surviving population. Thus labor is treated as a homogeneous and mobile factor of production.

Finally, the effects of a nuclear attack on fixed capital stocks are represented as upper limits on the gross output of each producing sector. Conceptually, these limits are the maximum amounts that can be produced by fully utilizing surviving fixed-capital stocks of each sector on an emergency basis. The maximum potential capacities for each industrial sector are computed as the product of preattack gross output, surviving fraction of national output, and the ratio of emergency to normal usage of fixed-capital stocks.

The number of people who survive a nuclear attack influence postattack economic potential in several ways. The upper and lower bounds of the constraints on final deliveries are based on estimates of per capita minimum requirements and per capita 1975 final deliveries. The labor force is assumed to be a constant fraction of the surviving population.

<u>The Activity Problem</u>

Our model has a formal mathematical structure; it is a linear programming problem.[3] The variables of the problem are annual rates for aggregate national production and consumption activities. All quantities of goods and services are measured in base-period dollars at annual rates. Labor is measured in man-years.

Notation:

$i, j=1, \ldots, n$ - indices of sectors and/or the goods and services they produce.

V - total value added minus imports (Gross National Product).

X_i - final deliveries of the ith good or service.

Y_i - gross output of the ith good or service.

X_i^L - minimum final deliveries of the ith good or service.

X_i^u - maximum final deliveries of the ith good or service.

Y_i^c - maximum gross output (capacity) of the ith sector.

M - size of the postattack labor force.

a_{ij} - the amount of the ith good or service consumed in the production of one unit of the jth good or service.

b_j - the amount of labor used in the production of one unit of the jth good or service.

The linear programming problem is to find solution values for final deliveries X_i^o, i=1, ..., n and gross outputs Y_i^o, i-1, ..., n that:

Maximize: $\sum_{i=1}^{n} X_i = V$ (value-added. Imports are subtracted from value added.)

Subject to:

$X_i \geq X_i^L$ i-1, ..., n (minimum final demands)

$X_i \leq X_i^u$ i=1, ..., n (maximum final demands)

$Y_i - \sum_{j=1}^{n} a_{ij} Y_j - X_i = 0$ i=1, ..., n (input-output relationships)

$Y_i \leq Y_i^c$ i=1, ..., n (capacity constraints)

$\sum_{j=1}^{n} b_j Y_j \leq M$ (labor force constraint)

$Y_i \geq 0;\ X_i \geq 0$ i=1, ..., n (nonnegative activities)

The solution to this linear programming problem is, in effect, a complete and optimal plan for the producing sector of the economy.

The Value Problem

Linear programming problems come in pairs. Coupled with any activity problem such as ours is a dual-value problem that is also a linear program. The variables of the value problem are imputed prices, one for each constraint of the activity problem.

Notation:

S_i - the imputed price of the minimum deliveries of the ith good or service.

T_i - the imputed price of the maximum deliveries of the ith good or service.

P_i - the imputed postattack price of actual final deliveries of the ith good or service.

R_i - the imputed price of the ith industry's capacity.

W - the imputed wage of labor.

The formal mathematical structure of the value problem is to find those imputed prices S_i^o, T_i^o, P_i^o, and R_i^o, i=1, ..., n and W^o that:

$$\text{Minimize: } -\sum_{i=1}^{n} X_i^L S_i + \sum_{i=1}^{n} X_i^U T_i + \sum_{i=1}^{n} Y_i^C R_i + MW$$

$$\text{Subject to: } -P_j + \sum_{i=1}^{n} a_{ij} P_i + R_j + b_j W \geq 0 \quad j=1, \ldots, n$$

$$-S_j + T_j + P_j \geq 1 \quad j=1, \ldots, n$$

$$S_i \geq 0, \; T_i \geq 0, \; R_i \geq 0, \; i=1, \ldots, n \text{ and } W \geq 0$$

The solution to this value problem is an assignment of values to scarce resources and difficult delivery requirements.

Consider, first, the constraints of the problem. Any one of the first set of constraints may be rewritten as:

$$P_j = \sum_{i=1}^{n} a_{ij} P_i + R_j + b_j W$$

In words, this constraint states that the postattack value of one unit of the jth good or service must be less than or equal to its cost of production. This production cost consists of the value of the inputs consumed in producing one unit of the jth good

$$\left(\sum_{i=1}^{n} a_{ij} P_i \right)$$

plus the value of the capacity required (R_j) plus the value of the labor used ($b_j W$).

Any one of the second constraints may be rewritten as:

$$P_j \geq 1 + S_j - T_j$$

This constraint states that the postattack value of one unit of the jth good or service must be greater than or equal to the preattack value of one unit; i.e., one base-period dollar, plus or minus any opportunity costs inflicted by the minimum and maximum delivery requirements. If there were no upper and lower bounds on final deliveries of the jth good or service then the postattack value of one unit would be one base-period dollar. The delivery requirements may change this situation. Production of the minimum deliveries may involve an opportunity cost, S_j, the amount that value added could be increased by reducing required minimum deliveries by one unit. The maximum allowable deliveries may also impose an opportunity cost. This cost, T_j, is the amount that value added would be reduced if the maximum deliveries of the jth good or service were cut by one unit.

The objective of the dual problem is to find a set of prices, one for each restriction of the activity problem, that collectively minimize the imputed cost of using limited postattack resources in production processes whose output ultimately takes the form of final deliveries of goods and services. The components of the objective function may be interpreted as follows:

$\sum_{i=1}^{n} X_i^L S_i$ - the value of the opportunities sacrificed to produce the minimum required deliveries.

$\sum_{i=1}^{n} X_i^u T_i$ - the value of the opportunities represented by the maximum allowable deliveries.

$\sum_{i=1}^{n} Y_i^c R_i$ - the imputed value of the surviving industrial capacity.

MW - the imputed value of the postattack labor force.

By minimizing the expression:

$$- \sum_{i=1}^{n} X_i^L S_i + \sum_{i=1}^{n} X_i^u T_i + \sum_{i=1}^{n} Y_i^c R_i + MW$$

we are, in effect, finding a set of prices that collectively minimize the force of the delivery requirements and capacity and labor limitations of the activity problem.

Activities and Values

There is a well-known series of relationships between the solution to an activity problem and the solution to its dual.[3] These relationships show, in general, that the solution to the value problem provides an ideal identification of postattack scarcities.

First, and most important, the values of the objective functions for the solutions are identical. Maximum postattack value added is equal to the minimum total imputed cost of operating the producing sector of the economy. Value added is completely imputed by the solution of the value problem to the delivery requirements, the limited capacities and labor.

The solution value of an imputed price can be nonzero only if the corresponding constraint of the activity problem is binding. Similarly, a nonbinding constraint must be accompanied by a dual price that is zero. In symbols:

1. either $S_i^o > 0$ and $X_i^o = X_i^L$

   or $S_i^o = 0$ and $X_i^o \geq X_i^L$ $i=1, \ldots, n.$

2. either $T_i^o > 0$ and $X_i^o = X_i^u$

   or $T_i^o = 0$ and $X_i^o \leq X_i^u$ $i=1, \ldots, n.$

3. since $Y_i^o - \sum_{j=1}^{n} a_{ij} Y_j^o - X_i^o = 0$ is always binding,

   P_i^o is normally nonzero. $i=1, \ldots, n.$

4. either $R_i^o > 0$ and $Y_i^o = Y_i^c$

or $R_i^o = 0$ and $Y_i^o \leq Y_i^c$ $\quad i=1, \ldots, n.$

5. either $W^o > 0$ and $\sum_{j=1}^{n} b_j Y_j^o = M$

or $W^o = 0$ and $\sum_{j=1}^{n} b_j Y_j^o \leq M.$

In brief, the solution to the dual assigns nonzero prices only where legitimate scarcities have arisen in the solution to the activity problem. If we wish to identify postattack scarcities we need look no further than the solution to the value problem. At the margin, the solution to the value problem is an accurate indication of the extent to which postattack value added may be increased by relaxing the delivery requirements, increasing capacities or enlarging the labor force.

An analogous relationship exists between the variables of the activity problem and the constraints of the value problem. The solution values of the activity variables X_i^o, i=1, ..., n and Y_i^o, i=1, ..., n may be positive only if their corresponding dual constraints are exactly satisfied. A nonbinding constraint must correspond to a zero activity level. In symbols:

1. either $Y_j^o > 0$ and $P_j^o = \sum_{i=1}^{n} a_{ij} P_i^o + R_j^o + b_j W^o$

or $Y_j^o = 0$ and $P_j^o \leq \sum_{i=1}^{n} a_{ij} P_i^o + R_j^o + b_j W^o$ $\quad j=1, \ldots, n.$

2. either $X_j^o > 0$ and $P_j^o = 1 + S_j^o - T_j^o$

or $X_j^o = 0$ and $P_j^o \geq 1 + S_j^o - T_j^o$ $\quad j=1, \ldots, n.$

Normally we may expect all gross-output levels Y_j^o, j=1, ..., n and most final deliveries X_j^o, j=1, ..., n to be positive. If a good or service is produced, $Y_j^o > 0$, then its postattack value, P_j^o, is equal to its imputed cost of production, $\sum_{i=1}^{n} a_{ij} P_i^o + R_j^o + b_j W^o$. If final deliveries of a good or service are made, $X_j^o > 0$, then the postattack value of the good or service, P_j^o, must also equal its preattack value plus or minus the opportunity costs inflicted by delivery requirements, $1 + S_j^o - T_j^o$.

On the Direct and Indirect Use of Resources

Most of the useful information provided by the model is contained in the solutions to the activity problem and the dual-value problem or may be obtained by using these solutions in some self-evident additional calculations. The computations for the direct and indirect use of labor and capacity required to make final deliveries are the only exception.

Ultimately, labor is employed and capacity is used to produce final deliveries of one good or service or another. To produce, for example, a dollar's worth of refinery products requires the use of a dollar's worth of refinery capacity. However, not all of this output goes directly to consumers. Some of it finds its way to consumers by more indirect routes, possibly as a fuel for trucks and buses. In this case, we would say that final deliveries of transportation services were indirectly responsible for the use of part of the dollar's worth of refinery capacity.

The direct and indirect use of labor and capacity to make final deliveries may be computed by solving the input-output relationships. The relationships:

$$Y_i^o - \sum_{j=1}^{n} a_{ij} Y_j^o = X_i^o \qquad i=1, \ldots, n$$

are solved to obtain:

$$Y_i^o = \sum_{j=1}^{n} C_{ij} X_j^o \qquad i=1, \ldots, n.$$

The desired information is found as follows:

$C_{ij} X_j^o$ - direct or indirect use of the ith sector's capacity required to deliver X_j^o.

$\sum_{i=1}^{n} b_i C_{ij} X_j^o$ - direct and indirect employment of labor required to deliver X_j^o.

These computations are worth making. They may reveal to us, for example, that a bottleneck in the iron-ore mining sector may be the result of an over-ambitious plan to repair or build new structures during the first year following the attack.

Limitations of the Model

The model provides results that are capable of supporting the limited conclusions that we have drawn in a later section. Nevertheless, the model is a highly limited operations-research tool.

On the whole, the model probably understates the nation's postattack economic potential. There are several reasons for this. First, substitutions in production processes are virtually excluded. Using preattack input proportions means, for example, that automobile production may be restricted by a shortage of chrome. Nor have we permitted substitutions among the minimal final deliveries. Yet it is a fact that a failure to deliver the minimum amount of fuel oil for domestic heating would be no disaster with higher deliveries of clothing, blankets, insulation materials, and even food. Various sources for goods and services have also been excluded. Several of these excluded sources are stockpiles and inventories, salvage, and the possible use of the armed forces to provide emergency services. Finally, fixed capital stocks and, therefore, sectoral capacities may be transferable to a certain extent. Ignoring these considerations tend to bias our results towards a lower standard of living.

Arrayed against these biases are several factors with uncertain effects. It is impossible to determine how changes in the product mix of an industry aggregate will bias our results. Equally uncertain are the effects of unbalanced destruction within an industry aggregate or changes in the skill composition of the labor force. On balance, we suspect that the nation's economic potential is generally more resiliant than its representation in the model.

Although the output of the model may tell us a great deal about the initial potential of the nation's postattack economy, there are many interesting economic questions that remain open. The model's treatment of capital-investment decisions following an attack is unsatisfactory. Minimum and maximum deliveries of capital goods are treated as inputs to the model. Optimal flows of capital goods to the producing sectors cannot really be ascertained a priori. The output of capital goods should move to the sectors where additional capacity is most needed. Also, the standard of living of consumers is more sensibly related to total stocks of durable consumer goods rather than the current flows of such goods to consumers. Ideally, it would be preferable to work with a dynamic model in which capital-investment activities have been fully integrated. Such a model could identify not only initial scarcities but also those bottlenecks that might arise in later stages of a postattack recovery.

The model does not distinguish shortages of labor or capacity that are confined to a particular region of the country. The estimates of optimum activity levels are national aggregates and may conceal infeasible labor movements or interregional shipments.

Finally, and most important, our solutions are statements of what can be done using normal production processes with the human and nonhuman resources that have survived. They are not necessarily predictions of what would be done. Even if preferences and processes have been correctly represented, and if damages and survivors have been accurately estimated, some serious problems remain unexamined. There is no assurance that the economy can be organized and stimulated to produce goods and services at the levels we have estimated.

DATA AND MODEL EXERCISE

The model was employed to assess the potential of a postattack 1975 economy. In such a study, the numbers operated upon are not data in the purest sense; rather, they are estimates and projections. Alternative estimates of preattack 1975 technology, output, and final deliveries either existed or could be derived from existing data. Nor is there a consensus on the minimum final deliveries required by the survivors of a nuclear attack. Finally, confident predictions of enemy capabilities and intentions, or even of the damage resulting from a specific attack, cannot be made.

The Scenario

By 1975 the population of the United States should be about 225 million people.[4] Gross National Product (GNP) is expected to have grown to over $900 billion measured in 1958 dollars.[5] This comes to about $4,000 per person. Given a civilian labor force participation rate of 32 percent and a labor share of GNP of 52 percent, the average annual wage of labor will be approximately $7,000.

In 1975, presumably an enemy will be capable of launching heavy nuclear attack using a large arsenal of ballistic missiles and other weapon carriers. The United States' civil-defense posture against such an attack is assumed to consist primarily of a fallout-shelter system. (No blast-shelter-construction program has been undertaken nor has an extensive anti-ballistic-missile system been installed.) The assumed date of both attacks is June 1975.

Attack A is a counterforce attack. People are killed and industrial damage is inflicted mostly as a by-product. Nevertheless, about 50 million people and 13 to 17 percent of the nation's physical capital stocks would be lost.

Attack B differs from Attack A in that part of the enemy strike force was diverted from military targets and used against the civilian population. Approximately 90 million people would not be expected to survive and 34 to 41 percent of the nation's capital stocks would be left unusable.

Although estimates of the numbers of survivors were available, the surviving population was typically treated as a parameter and varied to produce a set of solutions to the model. For the A Attack, runs were made for between 135 and 225 million survivors in steps of 10 million. The range for Attack B was from 105 to 225 million survivors.

Data

The classification of industries found in the Commerce Department's studies of interindustry relationships was adapted for use in this study.[6] Sectors 74 (research and development), 78 (federal government enterprises), 79 (state and local government enterprises), 81 (business travel, entertainment and gifts), and 82 (office supplies) were combined and renumbered as sector 74. Sector 80 (gross imports of goods and services) was renumbered as sector 78.

1970 projections of the coefficients of the input-output relationships were obtained from the Bureau of Labor Statistics of the Department of Labor.[7] Rates of change were also available and these were applied to the 1970 coefficients to produce estimates of 1975 interindustry relationships. The coefficients for sectors originally numbered 74, 78, 79, 81, and 82 were combined by using estimated 1975 gross outputs to compute weights and then averaging. The coefficients for labor utilization were also obtained from the Bureau of Labor Statistics.

Minimum final deliveries of goods and services were derived from estimates of minimum per capita personal consumption expenditures, federal government expenditures, state and local government expenditures, and fixed capital investment expenditures. Alternative estimates of these minimum per capita deliveries were taken from three sources:

1. Survival Level -- estimates of minimum per capita personal-consumption expenditures required to allow survivors to subsist productively for a reasonably long period following the attack.[8]

2. Recovery Level -- estimates of minimum per capita deliveries required to implement contingency plans during the first year following a nuclear attack.

3. 1958 and 1962 Final Deliveries -- estimates of per capita final deliveries of goods and services as reported for these years.[9]

The first two estimates and that for 1958 were combined by choosing the largest estimate in each category to form a fifth minimum final delivery requirement vector for a bounding case, constructed from the most pessimistic estimates of surviving resources and combinations of greatest minimum demands as a final test of the conclusions of the analysis.

Upper limits on final deliveries of goods and services were derived using estimates of 1970 and 1962 final deliveries obtained from the Bureau of Labor Statistics. The 1975 estimates of final deliveries were obtained by computing the annual rates at which final deliveries were expected to change between 1962 and 1970. The 1970 estimates were then extrapolated to 1975. Using a 1975 population estimate of 225 million people, per capita personal consumption, federal, state and local government costs, and fixed capital investment expenditures were computed. These estimates were then compared to the minimum per capita expenditures. In several sectors the extraordinary postattack requirements of the Recovery Level Demand generated minimum per capita expenditures in excess of predicted normal 1975 deliveries. In such cases the 1975 estimate was replaced by the minimum per capita expenditure. Upper limits on final deliveries of goods and services were produced by multiplying per capita personal consumption, federal, state and local government costs, and fixed capital investment expenditures by the number of survivors for that case and then adding predicted exports in 1975.

Estimates of postattack capacities were obtained using the formula:

Postattack capacity = (Preattack gross output)
x (Fraction destroyed)
x (Emergency Usage/Normal Usage)

Estimates of gross outputs in 1975 were available or could be derived from three sources:

1. Jack Faucett Associates -- Annual estimates of gross outputs by primary product for the years 1958 to 1966 were developed by Jack Faucett Associates, Inc.[10]

These estimates were used to fit the following regression for each sector:

$$Y_T = a\ Y_{T-1}$$

where Y_T denotes the gross output of the sector during year T. Estimates of gross outputs in 1975 were obtained by extrapolating from the 1966 estimates.

2. Bureau of Labor Statistics -- The input-output relationships were solved to determine gross outputs for the estimated 1975 final deliveries described earlier.

3. Engineer Strategic Study Group - Gross outputs in 1975 were developed from shipment estimates for counties within the largest 100 standard metropolitan statistical areas and rest of state areas.[11]

These alternative estimates of preattack gross output were combined to form the gross output data for the bounding case by selecting for each sector the smallest estimate of gross output among the three alternative estimates.

Alternative estimates of damage were also available:

1. National Resource Analysis Center -- Estimates of damages were based on weapon size, ground zero positions and the recorded geographic locations of large manufacturing plants. Other sources were used to estimate damage to non-manufacturing industries.

2. Office of Civil Defense -- Estimates of damages were based upon a geographic distribution of value added. Damage estimates for all sectors were available.

Most procedures for calculating damage to industrial facilities classify the facility in damage categories depending upon the overpressure and the hardness of the facility. These categories usually are -- destroyed, severe damage, moderate damage, light damage, and no damage. For the actual attacks under study, runs were made with damage considered to be the sum of destroyed and severe damage, called "severe damage" and with damage considered to be the sum of destroyed, severe damage and moderate damage, called "moderate damage." Moderately damaged facilities are considered to be worth repairing, if necessary.

For the bounding case, moderately damaged structures and equipment that normally would be worth repairing were considered lost and further the alternative estimates of damages were combined by selecting the largest fractions destroyed among the two assessments.

During normal peacetime operations the nation's industrial facilities are rarely fully utilized. The amounts that could be produced in an emergency with a labor-intensive use of existing capital often far exceeds normal peacetime output. Ratios of emergency to peacetime output of goods and services for the mining and manufacturing industries were obtained from data compiled by the National Planning Association for the Office of Emergency Planning.[12] Independent estimating procedures were used for the remaining sectors.

By 1975 the private civilian labor force is expected to consist of approximately 32 percent of the nation's population. A labor force participation rate of 30 percent was used to obtain the results presented in this paper except when this parameter was specifically varied.

RESULTS AND CONCLUSIONS

Underlying many of the nation's current programs and plans is a pessimistic assessment of our economic condition following a large-scale nuclear attack. The assumption is made that the surviving capital structure will probably provide survivors with a near-subsistence standard of living during the initial stages of a gradual economic recovery. Although this pessimistic assessment may be valid, it cannot be justified on the grounds of a lack of surviving economic potential. This study of two sample attacks points out that the basic physical components of the economy -- labor and capital goods -- survive in such proportions as to ensure a reasonably high standard of living. If the chaos envisioned after a nuclear attack can be overcome, and a re-organization achieved to properly utilize the surviving resources, then the survivors of an attack in 1975 may be able to attain a standard of living comparing favorably with that of the late nineteen fifties.

If people and resources survive together in nearly equal proportions then, on a per capita basis, the economy has the potential of being as viable as before an attack. However, if resources survive in greater proportions than the population available, labor will restrict total output. On the other hand, if fewer resources survive in proportion to the population, intensive use of the available productive facilities -- working additional shifts or other means of more fully utilizing capacities -- a relatively high standard of per capita value added may be achieved. Output would also be adversely affected if seriously disproportionate damages occur within industry aggregates. Fortunately, American industry is characterized by a multiplicity of most essentials which tend to reduce this potentiality. Furthermore, many industries do not normally operate at full capacity; thus, quite large inbalances of nominal capacities can be corrected by selective operations at emergency levels. The details of the results show that the viability of the economy is particularly sensitive to the availability of emergency capacity, to the employment ratio and to the components of the minimum demand requirements. On the other hand, the postattack economy seems somewhat insensitive to the weight of the attack.

These points are illustrated by the results shown in Figures 1 through 5 which are discussed below.

Value Added Per Capita (Figure 1)

The per capita value-added as a function of surviving population is shown in Figure 1. This illustrates the effect of changes in surviving population on the postattack economy. The curves show the effect of different final demands in association with the industrial capacities surviving after the attacks.

When the model is tested with the low survival-level demand, the per capita value-added maintains a relatively high level for both attacks. With sufficient industrial capacity surviving or operable on an emergency basis, the labor force, up to high levels of surviving populations is fully utilized. Further, the specific requirements of the low survival-level demand impose few binding restrictions on the mix of final deliveries.

However, if the minimal demand to be met is the postattack-recovery level final demand, then certain difficulties become apparent. The recovery-level-demand vector requires that the 1975 peacetime maximum delivery from sector 77 (medical and education services, etc.) be exceeded. The minimum in fact becomes at the same time a new component of the maximum-demand vector. This postattack demand requires more from that sector than is presently predicted to be available under peacetime 1975 conditions. Although some emergency capacity is available, it appears insufficient to meet the minimum demand beyond the points marked on the curves. The model ceased to produce a solution at these points. In practice, either sufficient medical supplies could be stockpiled or the deficiencies would have to be accepted; therefore, tests were run beyond this restriction. Rather than change the demand, the available capacity was increased to a high level to remove the restriction. Under these conditions, the economy maintained a comparatively high level for Attack A with the recovery-level vector -- slightly lower than for the same attack using the survival-level minimum final demand. The reason for the lower value is that the recovery level demand places more stringent specific requirements on the economy. Hence the model has less choice as to which goods or services to utilize to produce maximum value-added per capita.

For Attack B, using the recovery-level demand, the curve falls off quite sharply as the survivor level reaches 200 million, because

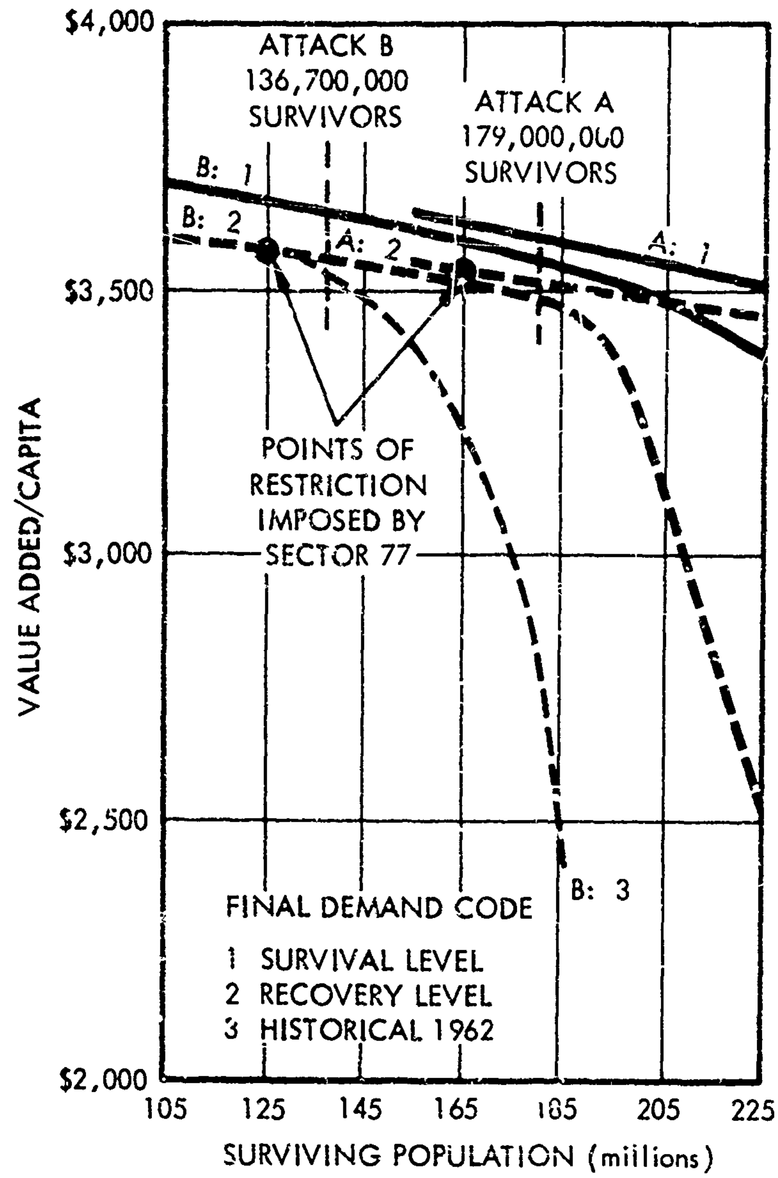


Figure 1. Value Added/Capita/Surviving Population.

available capacities were becoming the limiting factor in maintaining the relatively high level of this demand. The data showed the most critical element to be a lack of capacity in sector 66 (communications). Telephone services are used extensively throughout industry and it is not surprising that this sector affects many others. No emergency capacity was allowed this sector and the damage to it was arbitarily set to the same percentage as the percentage of the population killed in the attack. It was reasoned that communications facilities -- mainly telephone services -- are closely co-located with people.

The analysis shows the economy to be viable after either Attack A or Attack B for the surviving population levels as given. It further indicates that the viability as expressed in terms of the value-added per capita is generally insensitive to the numbers of the population surviving. The graph also shows that a historical 1962 peacetime final demand vector can be met for the estimated number of survivors, but it becomes increasingly difficult to maintain this level as the number of survivors increases. The per capita values are dependent on the particular minimal demand component values chosen. Thus, some moderate minimal demand requirement could produce a curve between those associated with the minimal demands of the survival level and the recovery level vectors. In fact, in the actual circumstances of the postattack period, it is likely the final demand would adjust itself to some such value.

Total Value-Added Per Population Surviving (Figure 2)

The total national effects of the two attacks as a function of the surviving population are shown in Figure 2. The curves of total value-added are derived from the per capita values displayed in Figure 1. The observation made about the shape of curves in Figure 1 equally apply to these. This figure is included to illustrate the relationship between the achieved outputs and the various demand vectors. For example, it will be noted that the total value-added potentially available after Attacks A and B is closer to the estimated 1975 values than to the value experienced in 1962.

Utilization of Available Labor (Figure 3)

Available labor was considered to be no more than 30 percent of the surviving population. With low numbers of survivors, capacity to utilize 100 percent of the labor force was readily available: labor was in fact limiting. These conditions are illustrated in Figure 3. It will be seen that for Attack A the condition that the economy was limited by available labor persisted almost to the 100-percent survivor limit. For Attack B, more than 90 percent of the available labor can be employed even if all the population survives, provided industry is not restricted by more than the survival-level minimum final demand. If the

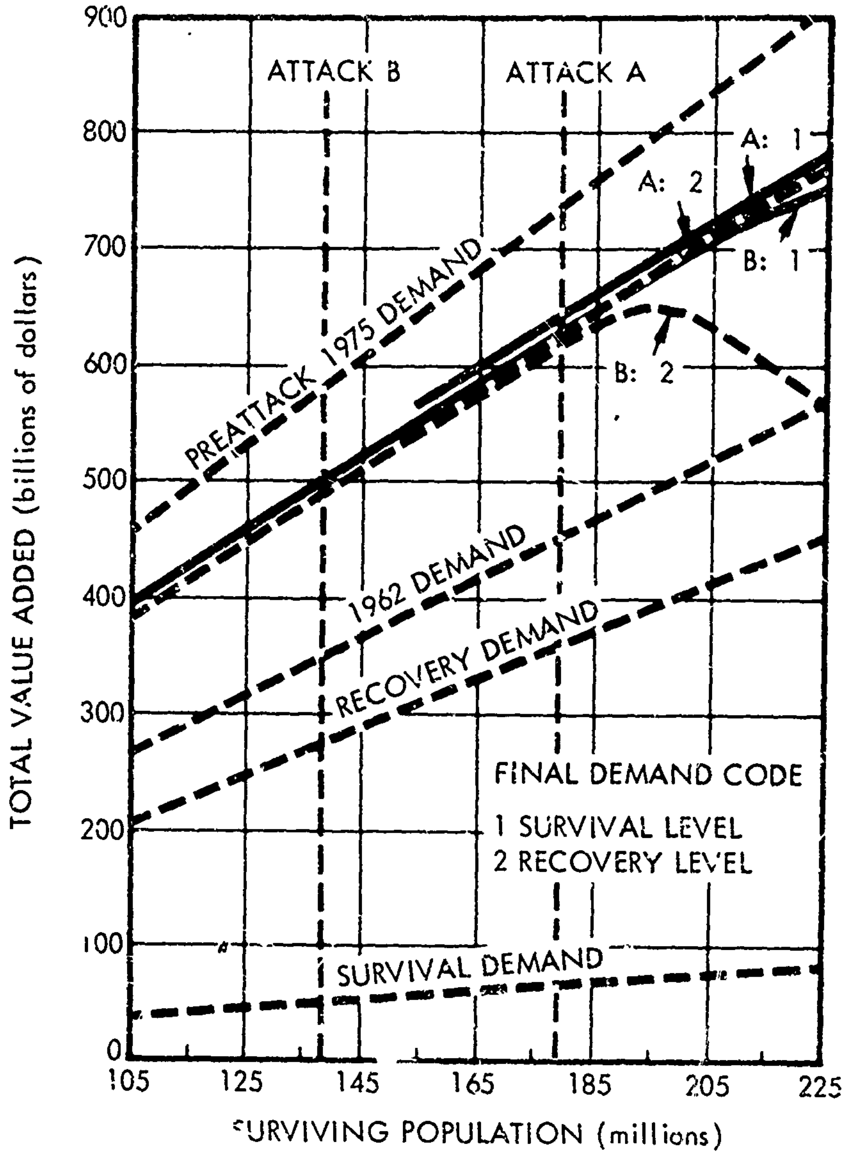
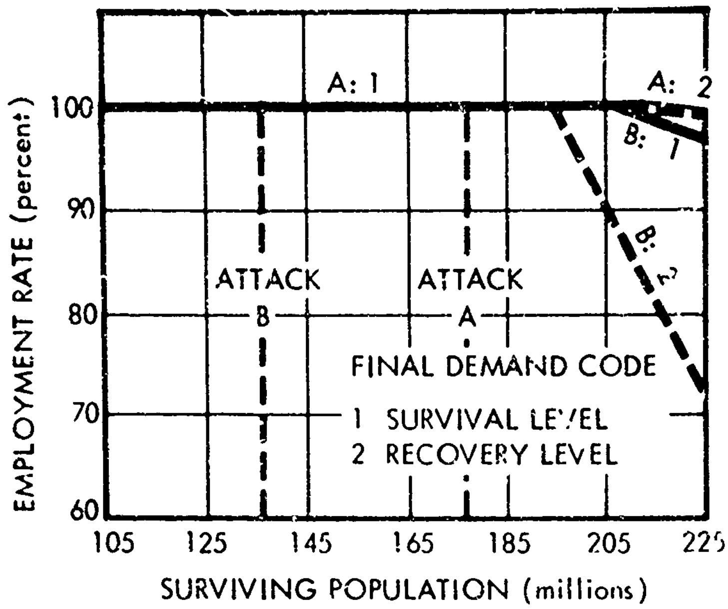


Figure 2. Total Value Added Per Population Surviving.



LABOR FORCE 30% OF SURVIVORS

Figure 3. Utilization of Available Labor

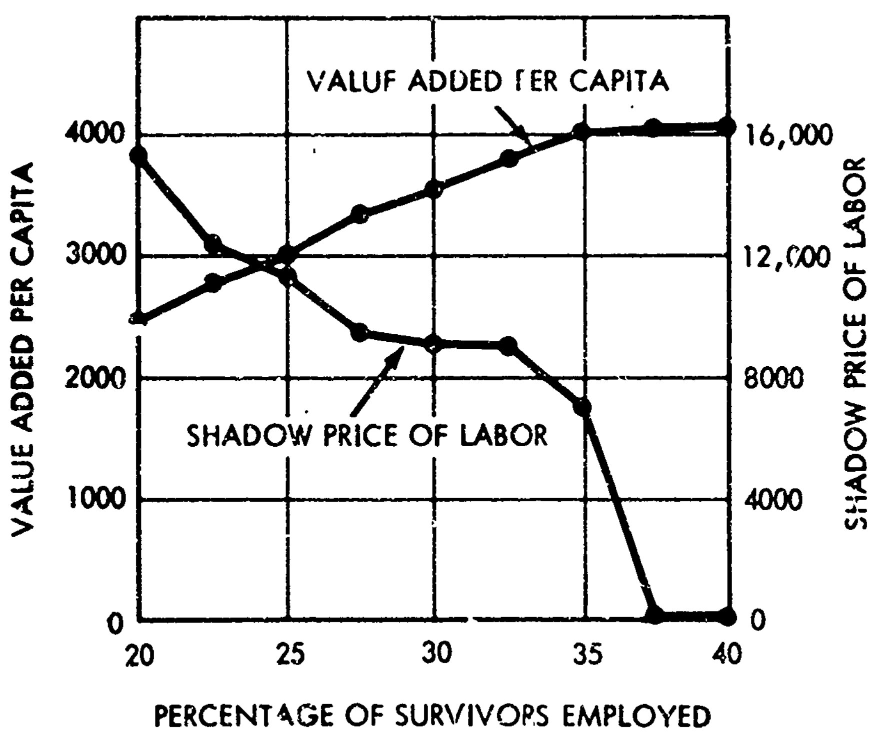


Figure 4. Effect of Varying Labor Ratio.

recovery-level minimum final demand has to be met, then this restriction will cause increasing unemployment as the numbers of survivors increase beyond approximately 200 million.

The Effect of Varying the Percentage of Survivors in the Labor Force (Figure 4)

The preceding figure indicates that labor is largely limiting the output of industry. For this reason a test was run in which the percentage of available labor in the surviving population was varied. This could be accomplished either by varying the percentage of the survivors used or by varying the hours worked per worker. The case studied is for Attack B with severe damage and 137 million survivors. The recovery-level minimum demand was used. Thus a variable work force must satisfy the final demands of a fixed number of survivors. Figure 4 shows the curves derived from the model for value-added per capita and the corresponding shadow price of labor.

At the 20-percent-utilization level the shadow price is high and value-added can be readily increased by increasing the labor participation. At about 35 percent labor participation, the shadow price drops rapidly, and the corresponding value-added reaches its maximum. What has happened is that more labor has been allocated to less productive employment up to the point when, at about 38 percent participation, the available capacity to employ more labor no longer exists. At this point the shadow price drops to zero, signifying that the addition of one more unit of labor at the margin will add nothing to output.

Imports Requirements (Figure 5)

The goal set for the economy is a per capita output equal to the projected level for 1975. Hence the final deliveries per capita, produced as the basic output of the model, contain as many components as possible maximized to the 1975 levels. Imports are therefore necessary to the extent that these peacetime levels can be obtained. The model allows such imports to the extent that the final delivery composition and the interindustry structure may dictate. Therefore the value of imports required to support the economic levels shown in the previous graphs was determined. Figure 5 shows the import requirements for Attacks A and B with both the survival-level and the recovery-level minimum final demand vectors. The demand for imports is shown as a percentage of that value estimated for the peacetime period of 1975. The size of the requirements is a function of the number of survivors. Also, as in the other graphs, the minimal demand to be satisfied has a considerable influence as the survivors increase. In general, the imports required vary from about 35 to 60 percent of the estimated peacetime requirements as the survivors vary from 105 to 225 million. For Attack B with the recovery-level demand, import requirements fall off in keeping with the reduced over-all economic activity noted previously.

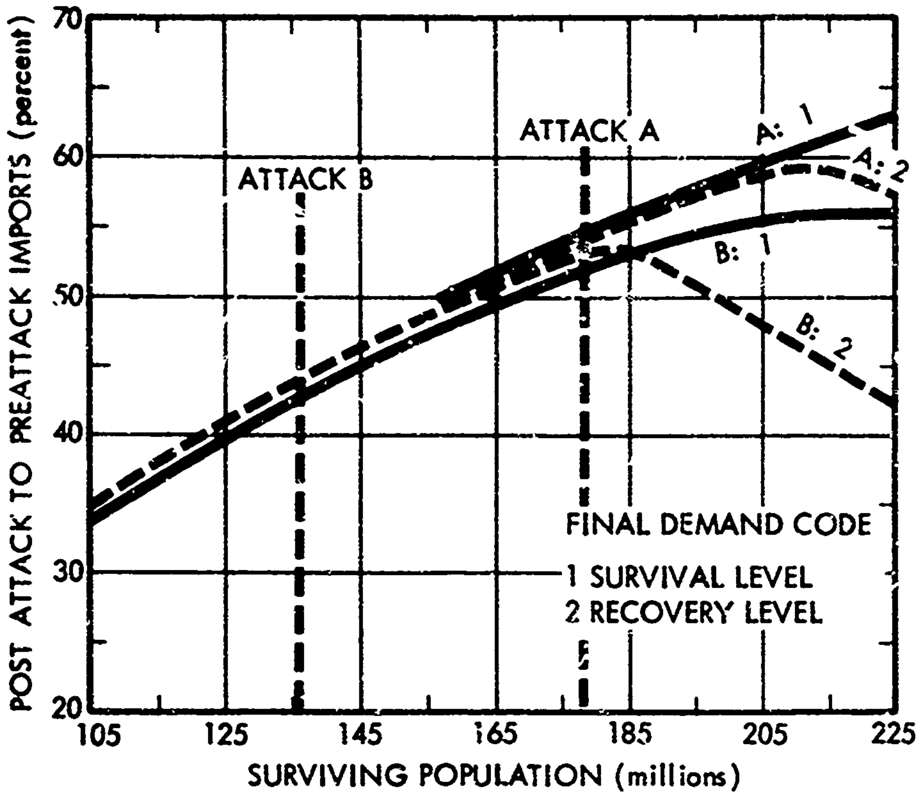


Figure 5. Import Requirements.

To what extent import and export business could continue in the postattack era is admittedly questionable. We can visualize the use of inventory stocks as an interim measure pending the reestablishment of international trade or the finding of substitutes. It should be noted that inventories or stockpiles may be much larger than in peacetime if we view them on a per capita basis. Some resources can survive more easily than people, e.g., ores, minerals, standing timber, metal ingots, etc.

Exports have not been identified specifically, but they are inherent to the levels of output achieved in meeting or approaching the 1975-peacetime maximums. However, it can be stated that so far as the balance of payments is concerned our results show exports consistently exceeding imports in amounts varying from about 150 to 200 percent.

The Bounding Case Results

The initial task was centered around the two attacks as given. Our analysis indicates that the majority of the sectors were able to meet their final demands at the maximum level and, apart from a few in-between, the remainder just met the required minimum. We were interested, therefore, to see the effects of straining the model with more severe conditions and to generally test the sensitivity of the results to the input data. Solutions to the model were obtained with a variety of data reflecting alternative assessments of preattack output, industrial damages, surviving population and postattack final delivery requirements. All of these additional solutions gave estimates of postattack value-added that differed little from those reported in the Figures 1 through 5.

A bounding case was deliberately constructed to establish a lower limit on estimates of the postattack potential of the U. S. economy. The most pessimistic estimates of capacities surviving a B Attack were used together with a composite, most severe, minimum final demand. The lowest estimate of surviving capacities was obtained by assuming that facilities reported as moderately damaged were unusable, selecting the worst damage estimates of these from the two available sources and applying them to the lowest of the three estimates of preattack capacities sector by sector. (Emergency ratios were not changed.) The composite minimum final demand was obtained by selecting the highest component values for the survival level, the recovery level, and the 1958-delivery requirements. If this composite demand could be met it would ensure the survivors a standard of living equivalent at least to the period of 1958.

Analysis of this bounding case revealed only three critically scarce capacities. Minimum-required final deliveries of goods and services could not be met with the expected surviving capacity of the following sectors: Communications, except radio and television (sector 66). Medical and education services (sector 77). Gross imports of goods and services (sector 78). For no other sectors was surviving capacity so limited as to make infeasible the production required directly and indirectly to make minimum final deliveries. This fact was established by solving the model with artificially high capacities inserted for the above sectors. In other exercises of the model no more than two critically scarce capacities were ever found.

A comparison of summary statistics on the predicted performance of the United States economy before, and its potential after, the attack based on the bounding case has been provided in Table I. In general, these results reveal that despite severe losses of both people and physical-capital stocks, a viable balance between human and non-human resources remains. The net effect of the attack indicates a reduction in per capita value-added of approximately $660. Moreover, the stringent minimum final delivery requirements insure the delivery of a product mix that reflects at least a 1958 standard of living.

TABLE I

SUMMARY STATISTICS, BOUNDING CASE

		Postattack	Preattack
Total Surviving Population	(Millions of People)	135.000	227.474
Labor Force	(Millions of People)	40.500	76.132
Labor Employed	(Millions of People)	40.500	73.848
Excess Labor	(Millions of People)	.000	2.284
Employment Rate	(Percent)	100.000	97.000
Labor Shadow Price	(Thousands of 1958 $)	4.983	7.034
Total Value Added	(Billions of 1958 $)	456.230	918.705
Value of Minimum Final Demands	(Billions of 1958 $)	353.907	
Excess Value Added	(Billions of 1958 $)	102.323	
Value Added per Capita	(Thousands of 1958 $)	3.379	4.039

An examination of the details of this solution does not reveal a general shortage of physical-capital stocks. At the margin, an increase in the surviving emergency capacity of only eight sectors will increase value-added. These sectors (including the critical sectors listed above) are:

Agricultural, forestry, and fishery services	(sector 4)
Iron and ferroalloy ores mining	(sector 5)
Paperboard containers and boxes	(sector 25)
Office, computing, and accounting machinery	(sector 51)
Motor vehicles and equipment	(sector 59)
Communications except radio and television	(sector 67)
Medical and educational services	(sector 77)
Gross imports of goods and services	(sector 78)

Excess emergency capacity exists following the attack in all but the eight sectors listed above. For many of the remaining sectors this excess of emergency capacity over gross output is considerable. On the basis of these results, only highly selective measures for preserving nonhuman resources appear justified. The additional protection afforded by systems that do not discriminate between industries, such as an augmented antiballistic missile system, may not be needed.

Conclusions

Our results indicate that measures designed to protect population provide a good opportunity for increasing postattack value-added. Sufficient capacity remains following the attack to provide gainful employment for the entire labor force. The size of the postattack labor force could be increased by instituting postattack measures designed to increase the labor force participation rate. At the same time, a failure to achieve the assumed 30 percent participation would seriously reduce the performance of the postattack economy.

The results obtained with the model do not provide much support for recovery plans calling for the administration in detail of all operations of the postattack economy. We do not propose to discount here the serious problems of relief and reorganization that would have to be faced in the wake of a nuclear attack. Nevertheless, a general system of production and consumption controls does not seem desirable. Final deliveries of only about half of the 78 goods and services of the model are reduced to minimum levels in the bounding case. If a case for administering the use of scarce materials and services can be made at all, it would apply to details within sectors rather than to any sector as a whole.

The most significant aspect of our findings is their tendency to strongly reaffirm the traditional concerns of civil-defense planning which has been to save people from the immediate effects of a nuclear attack. Our results consistently show that this is a proper concern. Surviving physical-capital stocks can reasonably be expected to be sufficient to provide a tolerable standard of living for almost the entire preattack population. As long as the nation's capacity to produce grows as fast or faster than its population, this should remain true.

The input-output analysis itself deals in tangible capacities, interindustry flows, and final demands expressed in dollars. In these terms the effects of physical damage can be assessed. The critical damage to such intangibles as the free market system, the whole financial and credit structure, together with the inherent motivations of business entities and their management objectives are not assessed. We may draw the analogy that we have identified sufficient components to build a fine machine but that we are not sure we have the skills to put it together, and, further, there is uncertainty about the quality of available fuel to run it. Even with a good machine and adequate fuel, the throttle control can speed or slow it down. We might reflect that something did go wrong with the throttle in 1929 to a perfectly good machine.

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SUMMARY STATISTICS

Capacities	Damages	Minimum Final Demands*	Population (mil. of people)	Value Added Per Capita (in 58 $)	Total Value Added (bil. 58 $)	Value of Min. Final Demands (bil. 58 $)	Labor Force (mil. of people)	Employment Rate (percent)	Labor Shadow Price (in 58 $)	Comments[1]
BLS	ESSG-B-MOD	r1	140[4]	3451	483.174	279.832	42.000	100.0	6378	77 at 140 mil.
Faucett	NRAC-A-MOD	s1	175[3]	3588	627.831	63.986	52.500	100.0	6154	
Faucett	NRAC-A-SEV	s1	175[3]	3590	628.221	63.986	52.500	100.0	6154	
Faucett	NRAC-B-SEV	s1	135[4]	3649	492.612	49.361	40.500	100.0	6299	
Faucett	NRAC-B-MOD	r1	135[4]	3507	473.430	269.838	40.500	100.0	8622	77 at 105 mil.; 65 at 185 mil.; 66 at 215 mil.
Faucett	NRAC-B-SEV	r1	135[4]	3564	481.138	269.838	40.500	100.0	9083	77 at 125 mil.
BLS	NRAC-B-MOD	1958	135[4]	3408	460.043	312.488	40.500	100.0	5186	78 at 185 mil.; 66 at 225 mil.
BLS	NRAC-B-SEV	1962	135[4]	3555	479.880	342.239	40.500	100.0	8883	78 at 195 mil.
Faucett	NRAC-B-MOD	r1	135[4]	3561	480.790	269.838	40.500[8]	100.0	8981	77 at 105 mil.
Faucett	NRAC-B-MOD	s1	135[4]	3631	490.188	49.361	40.500	100.0	6179	
Faucett	NRAC-B-MOD	1958	135	3441	464.522	312.488	40.500	100.0	5261	
Faucett	NRAC-B-MOD	Maximum	135	3437	464.034	353.907	40.500	100.0	7892	77
BLS	NRAC-B-MOD	r1	135	3140	423.905	269.838	40.500	89.804	0	77
ESSG	NRAC-B-MOD	r1	135	2220	299.765	269.838	40.500	65.104	0	77, 66
Minimum	NRAC-B-MOD	r1	135	2220	299.765	269.838	40.500	65.104	0	77, 66
Faucett	NRAC-B-MOD	r1	135	1987	268.278	269.838	40.500	61.261	0	Normal capacity util.; 3, 22, 23, 39, 72, 77
Faucett	NRAC-B-SEV	r1	135[4]	3558	480.266	269.838	40.500[8]	100.0	9048	77 at 125 mil.; 65 at 215 mil.

Capacities	Damages	Minimum Final Demands*	Population (mil. of people)	Value Added Per Capita (in 58 $)	Total Value Added (bil. 58 $)	Value of Min. Final Demands (bil. 58 $)	Labor Force (mil. of people)	Employment Rate (percent)	Labor Shadow Price (in 58 $)	Comments[1]
Faucett	NRAC-A-MOD	r1	175	3515	615.064	349.791	52.500	100.0	8995	77 at 155 mil.
Faucett	NRAC-A-SEV	r1	175	3520	615.998	349.791	52.500	100.0	9025	77 at 165 mil.
Faucett	ESSG-B-MOD	r1	135	3499	472.343	269.838	40.500	100.0	7225	77
Faucett	ESSG-B-SEV	r1	135	3565	481.331	269.838	40.500[7]	100.0	9105	
Faucett	ESSG-A-MOD	r1	175	3537	619.015	349.791	52.500	100.0	9019	77
Faucett	ESSG-A-SEV	r1	175	3526	617.079	349.791	52.500	100.0	8992	
Faucett	Maximum B-MOD	r1	135	3497	472.129	269.838	40.500	100.0	7152	77
Minimum	Maximum	Maximum	135	3379	456.230	269.838	40.500	100.0	4983	66, 77 & 78 at 105 mil.; 25 at 165 mil.; 1, 6 & 39 at 185 mil.
Pre-attack 1975 Projections			225	4093	918.705		76.132	97.0	7034	

Footnotes:

1. Critical sectors at population levels where constraints occur: 1-Livestock & livestock sectors; 3-Forestry & fishery products; 6-Nonferrous metal ores mining; 22-Household furniture; 25-Other furniture & fixtures; 25-Paperboard containers & boxes; 39-Metal containers; 65-Transportation & warehousing; 66-Communications, except radio & T. V.; 72-Hotels, pers. & repair services, except auto; 77-Medical, educational service, non-profit org.; 78-Cross imports of goods & services.
2. Exercise begun with 100 mil. population with 10 mil. intervals.
3. Exercise begun with 155 mil. population with 10 mil. intervals.
4. Exercise begun with 105 mil. population with 10 mil. intervals.
5. Labor participation was varied 20 percent to 40 percent of population (135 mil.) at 5 percent intervals to examine changes in value added per capita and labor shadow price.
6. Labor participation was varied 20 percent to 37.5 percent of population (135 mil.) at 2.5 percent intervals to examine changes in value added per capita and labor shadow price.
7. Labor participation was varied 17.5 percent to 37.5 percent of population (135 mil.) at 2.5 percent intervals to examine changes in value added per capita and labor shadow price.
8. Exercise begun with 105 mil. population with 10 mil. intervals but stopped after 185 mil.

* s1 = Survival level; r1 = Recovery level.

RESOURCES MANAGEMENT

Shaw Livermore
University of Arizona

My first objective is to review for you what may be called the early and middle periods of thinking about what are generally termed the second and third phases of post-nuclear-attack resources management. My purpose in so doing is not to review history as such (though this has some value), but to identify some ideas which seem to have dropped through the cracks in recent years. Secondly, I want to present some specific and potentially promising areas for research which I do not find emphasized in the thinking about resources management in the past four or five years.

In the year 1952 I was an Assistant to the Defense Mobilizer, and represented him on the Planning Board of the National Security Council. In the previous fall and winter of 1951-52, I had organized for RAND a pioneer study of a single industry (steel) in terms of its potential recovery cycle following a seriously damaging attack. I continued to direct this engineering study throughout 1952, while at the same time much of my effort in the Office of Defense Mobilization (ODM) was devoted to the range of planning problems growing out of a potential nuclear attack. Bulking large in our work then was the petroleum industry on a worldwide basis - a subject of great interest to the Joint Chiefs in that tail-end period of the Korean War.

In those days, major interest was directed to the first phase of an attack situation: the immediate consequences of attack upon human lives and the viable structure of American life. This was the early meaning of civil defense, and still remains as the accepted sphere of responsibility for that segment of our national planning. Low-yield weapons were envisioned, and usually key cities as the prime target. Consequently, dispersion of plants, outer rings, shelters in urban areas, and the hardening of a few concentrated industrial areas which were potential targets were the major objects of planning attention. Much of this seems archaic now, as you all realize. But there were the first glimmerings then of what is now a primary focus of interest: the morale effects of a widespread attack, the responses of people to panic conditions, and the problems of handling the first-impact responses of the population. Relocation sites, storage of key records, continuity of command in both government and industry, all date from that period. Of course you will recall that large-scale evacuation of urban dwellers was also a prime feature of plan-making in that day--now denigrated to a very low rung on the plans ladder.

In the fall of 1953, Arthur Flemming, then Defense Mobilizer, wanted to widen and deepen the responsibilities of the ODM for the secondary and tertiary phases of a postattack condition. He had inherited the task of maintaining a strong mobilization base for conventional war conditions--the "mobbase" of cherished memory for many old-timers--which had its roots back in the post-World-War II structure of the National Security Resources Board, a sometimes forgotten feature of the 1947 National Security Act. In the light of the atomic bomb, and Russia's possession of it, this responsibility by then obviously seemed narrow and outdated. No other top echelon agency of the federal government was in a position to accept this special task which was seen even then to extend far beyond the limits of the statutory civil defense responsibility.

In that fall of 1953, the late Edwin B. George worked for many weeks with Director Flemming to develop a major turn-around in the internal functioning of ODM. It was obvious that some of the most capable generalist thinkers on the problems involved were by then outside government service. They could render invaluable service as informal and off-the-record advisors in defining the nature and objectives of what was a wholly new area of governmental planning. Establishment of the Program Advisory Committee (PAC) was one of the early steps taken--one which has survived through the ensuing fourteen years. Its members were selected for their capacity as individuals, serving as consultants at the pleasure of the Director and enjoying no formalized status. I served as a member for a decade, acting as Chairman in the transitional year 1960-1961.

For the first five years the primary task of PAC was that of defining the nature and content of this new responsibility, i.e., resources management. No inherited body of knowledge or research existed. There was almost complete lack of public comprehension. People could envision the problem of civil defense from experience in Germany, England and Japan. They had only vague notions of what resources management would mean after a wide and devasting attack, delivered at one point in time. Worse, the problem itself kept changing as advances in weaponry altered the frame of the picture. At times then and since, the seeming folly or idiocy of doing any planning at all for a potentially complete holocaust was a major obstacle. It is to the credit of our small group, and to government servants within ODM, that they remained steadfast to the essential planning assumption: an attack which would be only partially successful, partial in its effect, with wide variations between resulting conditions in undamaged, partially damaged, and devastated portions of our country. This assumption still stands, subject to variations of degree and intensity over the years as the offensive-defensive balance and the capabilities of weapons have ebbed and flowed.

In those earliest years, attention was first devoted to four or five pressing challenges. One was the very nature of a civilian controlling or directing authority which could gradually assume recovery responsibility -- after the first or civil defense phase had passed - on either a centralized or decentralized basis. A second was the data-flow problem. What information and parameters could be given to those directing recovery? This second challenge resulted in the damage-assessment undertaking, now embodied in National Resource Analysis Center (NRAC). The PAC was a prime mover in pushing this idea into tangible reality, as Burke Horton (its first guiding hand) has so often liked to recall. A third early target of studies was the need for a systematic war-gaming undertaking, as a continuous and effective way of enlisting and applying brain power to the many ramifications of an unknown problem. A fourth was the question of economic stabilization -- e.g., to what extent could conventional ideas of price, wage and rent stabilizing, and rationing be applicable to such new dimensions of the economic-management concept. The fifth was the relationship between military and civilian authority under severe disaster conditions. Of these, the third objective has been pretty well lost. It was partially carried out in successive Operations Alerts -- the "OPALS" of the Eisenhower administration -- on an exceedingly constricted basis with all the disadvantages of publicity and brevity. The fourth problem of stabilization procedures has been with us ever since. Progress was slow and tortuous before we reached the presently accepted ideas of the assumptions and methods we would follow in economic stabilization if a disaster did occur. The fifth is an ostensibly settled issue. The first has had continuous attention. The third I shall return to later.

In the course of the first two years of addressing the attention of both PAC and the staff of CDM to these fairly obvious holes in the planning fabric, the PAC reached the conviction that progress would be uneven and even self-stultifying unless the whole task of resources management were laid out in front of us. If we could stake out the whole field, even roughly, the relative priority and significance of discrete steps within those boundaries could be better assessed. I may add that in those years Director Flemming was wrestling with his own problem of staff organization, and with the status of his small agency within the White House organization vis-a-vis the other great federal departments and the state-and-local government structure. Delegations and assignments of responsibility were a pressing need, given the peculiar status of ODM and the attitudes of congressional leaders toward any pure planning agency. To help solve this problem, comprehensive overview or staking-out was an indispensable tool.

This confluence of needs resulted in the famous "Bedsheet." As a historical document, it is almost unknown to today's researchers even though it was never restricted by a security classification. It is quite clearly the foundation beneath today's National Plan. It has been reflected in the evolving internal organization of ODM and its successor bodies. It is most clearly reflected in those executive orders assigning responsibility to departments and agencies within the federal structure which were issued soon after the Cuban crisis. Since I was primarily responsible for its construction-- with the able help of Eddie George, George Steiner, and Mel Anshen-- I may be pardoned for saying something about its scope and content here today. I might say that we were selfishly interested in its creation as a means of planning the successive agenda of the PAC. We wanted to guide the probings of the group so that we would discharge our responsibility of dealing with the whole range of resources management in the secondary and tertiary periods. What was that range? No one knew. Many individual researchers had pet projects or ideas. How did these relate to the whole responsibility of an ODM or an Office of Emergency Planning (OEP)? We were not quite so grandiose. All we wanted then was a reference document that would help Eddie George and myself in our month-to-month task of developing agenda for oncoming PAC meetings. We shared that responsibility pretty steadily for over six years.

I have not seen any better framework than the Bedsheet in the years since. Maybe there is something I have missed. During 1962, I was engaged as a consultant by the Office of Civil Defense (OCD) to prepare an internal manual for employees of the agency as training and instructional material. I searched for a better structural approach; I found none.

There were seven major rubrics. Under these heads-- the management structure, human resources, material resources and production, essential services, economic stabilization, civil government and public morale, and relations with allied and friendly nations-- were included all of the subproblems which we assembled in the years from 1954 through 1959. Between 75 and 80 discrete problems were included in the Bedsheet in summary or outline form, grouped within these seven categories. The full title of that document was, incidentally, "Planning for Control and Direction of Total Wartime Resources by Non-Military Authority."

Quite early in this process we began to make a distinction between planning as such, and research to implement planning. In dealing with the nebulous and iffy world of a postattack situation, the distinction is a very important one. The first is the concept of thinking in advance how we would set about meeting novel conditions, in full recognition of the probability that the actual means and methods of dealing with problems would have to be worked out by leaders at all levels facing an inherently uncertain situation. This first concept stresses the limits to which planning can fruitfully be extended. The second concept, in contrast, stresses the value of digging into the innards of a series of separable and highly specific problems, in order to derive concrete and usable preattack actions, or to give specific guidance to future administrators. If we can say that the nature and extent of responsibility will be set by a planning framework, well and good. But if we can also provide some specific guidance to administrators, in advance of the event, research would be yielding a decent payoff. At the very best, we could assemble data and procedures during peacetime that we could be confident would have an almost-certain use value in the actual crisis. We should have bequeathed to burden-laden managers, in some never-never time in the future, a partial set of tools for their unwelcome task. I may say that the damage-assessment machinery we now have in being comes close to being the ideal example of this latter purpose.

If we glance at the sixteen chapters of the National Plan, we can see the imprint of the Big Seven categories which we as a committee finalized in 1957. One of our areas, essential services, has been expanded into five chapters of that document to reflect a peculiar pattern of federal responsibility and regulatory "homes" for industries in this subarea. That of material resources and production is reflected in four chapters for the same reason. Since we provided in our second area, human resources, for a three-way breakdown -- people as victims, as consumers, and as workers -- we can say that the three chapters of the present plan correspond accurately with this area. One chapter of the plan deals with civil defense, or first-phase problems, which we did not consider as within our purview, although for the four years 1958-61, the two approaches were combined in the single agency of the Office of Civil and Defense Mobilization (OCDM), now a dim and unregretted memory. Three chapters deal with our three areas of management structure, stabilization, and civil government. One of our areas the last, is completely missing from the plan -- that of relationships with other nations.

Looking back over the past decade, it is immediately obvious that disproportionate attention has been given to four of our original seven sectors, both by intra- and extra-governmental workers and commentators. These have been the management structure, essential services, resources and production, and stabilization.

I have been much encouraged in the past few years by the efforts of many individuals, mostly outside the government, but also by consultants working under the direction of OCD and other government agencies, to intensify study of our second and sixth areas (human resources, and civil government and public morale). We do not have time today to explore the reasons for this welcome revival of interest. Suffice it to say that I personally have always believed that they rank high up in importance as a factor in third-phase management; in difficulty and complexity I feel as strongly as I did a decade ago that the sixth ranks first among all the planning sectors within the gross parameters.

As for the neglected area, that of relationships with allied and friendly nations (those who might remain!), we must face up to an almost blank wall. The PAC, in our continuous process of circling the perimeter of the staked-out total area, was never able to get off the ground in analyzing the implications of this sector. Here again we do not have time to probe into the reasons for this neglect. I am sure you can imagine some of the reasons. It must be added that there has been an encouraging start made in the first-phase or civil-defense aspects of this area, particularly with our NATO partners.

We must now leave this too-personalized discussion of the evolution of a total concept in planning, and return to my stated problem of winnowing out particular subproblems which can be distinguished as research tasks to support the planning process and systems analysis. These are the subject areas where there is some reasonable prospect of securing a payoff in usable guidance to administrators who will face the entire spectrum of decision-making after a disaster shall have occurred. Over the years, the PAC made several valiant attempts to tackle this problem on a generalized basis. Our advocacy of a table-gaming or war-gaming technique on a repetitive and systemized basis, to force study of the content of particular problems, was our earliest effort as I have already mentioned. It remained a favorite subject of Melvin Ashen's for many years. I must say that the National Academy of Sciences itself has come closest to an actual effort to do this, beginning with one of the subcommittee reports in the 1958 report: "The Adequacy of Government Research Programs in Non-Military Defense." My good friend George Steiner, longtime continuous member of the PAC, has much to do with the scope and content of that section of the 1958 report under the chairmanship of Gerry Bleicken, later to be our colleague as a PAC member. Our second effort was to try to establish a new and distinctive institute for the study of second- and third-phase problems, either as a direct government agency or as a nonprofit enterprise of the RAND type. At other times, we urged successive directors to seek budget support for greatly expanded research activity within the agency itself. That last line of attack came pretty much to an end in the budget cuts of 1963.

Beginning about 1960, we turned more or less in desperation to the approach of singling out problems, one by one, where the potential double payoff seemed to be uniquely high if some good digging research were undertaken. In 1959-62 we spent a great deal of time pinpointing these, and recommending in fairly exact terms the character and dimensions of research undertakings that we felt were of high priority in the terms I have stated. I have taken occasion to review these recently because I want to place major emphasis here today on examples of potential research undertakings that those in the audience may wish to discuss more intensively. One of these round-ups was PAC report Number 37, which went through successive drafts and discussions in 1959-60. There was a 17-page status report on this document as late as 1961. In the 1962 manual to which I referred earlier, I adverted to many of the same specific topics.

I believe you will realize from other discussions at this conference that the approach I am talking about has been well and extensively applied by the civil-defense organization in the Department of Defense in the past three or four years. It has also been rewardingly used in the study of stabilization procedures by OEP and several delegate agencies; and by OEP in our first major area of the postattack management problem, beginning with the Office of Defense Resources concept on down through the state and local arrangements which comprise such a dominant feature of the National Plan.

I want to outline for you ten problems in postattack resources management which I feel illustrate possible applications of this criterion. You may not agree, and I think some argumentative discussion will be of value.

I must add that any such random and illustrative selection of problems in which I happen to have been personally interested violates one of my own principles. I don't think we have made much progress in fifteen years in getting away from a bad habit of the people interested in this difficult subject. This is the habit of selecting problems for discussion or investigation, or for the letting of research contracts, which happen to fit the personal predilections or particular personal interests of the individual. It is a variant on the old allegory of the blind men and the elephant: many mice approach the elephant, select one tiny portion of his anatomy at random, study it intensively, then rush back to their colleagues with an impressive study of the elephant's second toenail on his right hind foot. There is little effort at coordination, at surveying the whole problem, laying it out in all its perplexing dimensions. Why I called the Bedsheet "famous" was simply that it did try to apply this indispensable concept. No extra-governmental agency I know of has tried to plot the whole range of the task, nor has any group tried to exercise any sensible discipline over the efforts of men with high talent who could and would, if properly directed, grapple with a wide variety of problems. I won't stress the obvious waste of scarce resources and talent implicit in this helter-skelter attack. The OEP deserves something better from its helpers.

Nevertheless, we must make do here today with the old bad-habit approach, since it does have some minimal value in illustrating the range of problems that are researchable. I will not include any examples from what I term the first and fourth areas of the total problem: management structure, and essential services. This is because there are many ongoing studies in both these, within the federal government itself, and to a lesser extent among state-local groups on the one hand and industry groups on the other. Nor do I indicate any particular order of essentiality or importance of my examples. This is because I do not feel that anyone can make such a judgment until there has been a more rigorous analysis of what the entire extent of resources management really is-- a bringing-up-to-date of the Bedsheet approach.

(1) Implicit always in the development of NRAC's present strength to rapidly and accurately assess damage on a nationwide basis following attack has been the follow-up inspection by ad hoc teams of on-site inspectors as soon as possible after the second phase ends. Two considerations have always been foremost. One is the decision to abandon, or abandon-plus-cannibalize each badly damaged plant. We could not waste resources in permitting rebuilding just because of local pride, desires of owners or managers, or the availability of war-risk insurance. Just what would be the basis of decision, case-by-case? This can be made the subject of research quite feasibly. A single industry could be selected for shadow study by teams of scientists and engineers and construction specialists. NRAC could furnish the hypothetical damage situation, in three dimensions: suppliers to the industry, other producing plants of the same nature, and customer industries. I would suggest scientific-control instruments, pharmaceuticals, chemical intermediates, electronic equipment for both consumer and military end-purposes, heavy construction equipment, as possible candidates. Two or three degress of damage could be posited. Such field research would force answers to such questions as: What do we mean by cannibalization? is it feasible? worth the manpower and transportation, resource outlays implied? Could a given plant be partially restored? the rest of it abandoned? What level of total output, given knowledge of similar damage in sister plants, would be desirable? What shortcuts could be employed? or within-the-single-plant cannibalization steps applied? The field test could include NRAC parameters on losses by attack of the plant's labor force, and in its community. The end-result of course would be guidelines, and processes of reasoning, that could be

circulated preattack to design and engineering personnel, equipment builders, plant managers, and to several thousand men who would, if they survived, serve on such inspection teams for industries other than their own (as checks on the parochial views of the damaged plant's own managerial team). Costs might seem enormous to do this for several key cases; but much of the time and study involved would be donated, I am sure.

(2) Allied to this problem is that of the relatively few items of long-lead-time equipment which, if destroyed, would radically extend the time-cycle of recovery for plants which would be clearly essential. Most of you are aware that the rebuilding cycle in many industries could be surprisingly short, as a number of studies (made by Stanford Research Institute and others) similar to that on steel which I directed in 1951 and 1952 have since shown. It is in the order of 6 to 10 months. But the items I speak of would require from 24 to 36 months, even if we had undamaged builders' plants. I tried for several years, valiantly, to have such a study given high priority in a research program. There are surprisingly few such items, but they can be identified in photographic equipment, ceramics, steel, machine tools, electrical supply, and transportation equipment. They could be stockpiled on a modest scale -- one or two in each case, safely placed in hard storage and sold and replaced periodically. Several technical industry associations, the American Society of Mechanical Engineers (ASME), and trade publications could be enlisted to help out in such a study at low cost.

(3) A third problem of this same type is a simple one: What methods exist, mostly from the historical past, to short-cut restoration of a low level of output suitable for the stricken nation? The most spectacular possibility exists in petroleum refining, to obtain low but vital amounts of gasoline and kerosene. This is an example of a technical research problem that has fallen between the cracks. The stills used as late as 1900 or 1910 were simple and cheap. They could be either stockpiled or the simple materials stored. This is of the first importance because several careful analyses have shown that a flow of the simpler petroleum derivatives would be the hardest to re-establish within the needed time limits to avoid social death. There are other potential cases: drugs and medicines; coke; foundry machinery; road-repair procedures; port-unloading methods; and many others. This is an ideal research subject because much of it would be armchair exploration of historical technology as it existed in older and less affluent times.

(4) We may now switch to a different area, for variety. Back in 1959, the PAC concocted a long document setting forth some 31 needed research undertakings, as its Report Number 37 to the Director of OCDM. One of these urged a new look at the whole concept of rationing to

consumers, and stated that: "Lack of an approach to rationing is currently the greatest deficiency in the stabilization planning field." In the current National Plan, rationing is emphasized as a primary responsibility of local authorities, acting under direction of state governors. But nothing is said on the how of rationing, with the exception that it is stressed that austere rationing would be needed "notwithstanding the fact that some areas might appear to have supplies surplus to their own needs."

The take-off point for a research task here might be the idea of variable-bundle rationing. Much work has been done to develop suitable diets on a calorie and vital-element basis, so that a tremendous variety of foods can be combined in varying ratios to achieve a minimal intake level. Secondly, the variation in local supply and transport conditions after an attack would mean that a single national standard of points for specified items would be silly. Regional eating habits vary, furthermore. There is crying need for study of a series of thirty or perhaps fifty variants on a weekly bundle of food which could be alternatively adopted in thousands of different communities according to the supplies most readily available. Consumers would be entitled to a simple, single batch of food items without the complexities of points or specific rights to any specific food item. This would be a major step forward in giving exact directions in particular to undamaged-area administrators. They could only release one of several alternative bundles to their local unharmed population. All else available would be automatically cleared for movement to adjacent damaged areas. In partially damaged areas the choice would fall on the particular bundle in the approved list which would necessitate the least and easiest calls on transport from other areas. We sometimes forget that less than 10 percent of the population now live on producing farms of their own, most of whom are dependent on purchased items for a majority of their food needs. Thus the food-rationing system and its impact would need be almost universal. This approach would simplify the early establishment of food shipments via a reviving transport network. It would allow switches in the local bundles as conditions improved.

The same approach could be used for household supplies, sanitary goods, and fuel substitutes. Bottled-gas usage is a special subject in itself that cries out for research study-- to what extent could it be minimally substituted in communities temporarily cut off from natural gas by pipeline damage? At one time we studied this same idea applied to simple building-repair materials for lightly damaged structures.

(5) The question of behavior in undamaged communities is itself a subject for research that has, in my view, a high priority. In discussing it over the years, we found that it was quickly dismissed

because of the pressure to explore problems arising from first-phase damage in an attack. But implicit in all the planning we are talking about here today is the emergence from even the heaviest attacks of some communities and areas in an unscathed condition--except for the fallout hazard in the first and second phases. In local planning and drill the most interesting assumption is, of course, not this one, but rather the situation with severe damage, refugees, destruction and panic.

Yet in terms of the familiar viability race which has so intrigued some investigators in recent years, the earliest behavior of authorities in the undamaged areas might mean the difference between victory and defeat in the race to sustain recovery momentum. The objective here is to discover, by some careful sampling studies, just what could be established as the standard of behavior in such communities. The towns and cities in the population range of 15,000 to 35,000 could be one segment for analysis--there are hundreds of them in all regions, sufficiently far away from urban centers to expect a high proportion of undamaged situations. In the range from 75,000 to 200,000 there are fewer in number, but their potential in contributions to succor of other communities may be just as great. The key is perhaps behavioral response--what level of austerity in local consumption could be enforced, what surpluses of bedding, clothing, medicinal supplies, health personnel, fuel, food, construction equipment and manpower, could be generated? This might be measured in terms of refugees being cared for as one of the conditions-- affecting both behavior and physical ability to perform.

(6) While we are still talking about the performance of undamaged portions of the economic machine, we can refer to one of the research areas I have in mind about which something has been done. As early as 1955, PAC laid great stress on the problem of broken chains of production. With a mixed-damage situation, many undamaged plants and production units would be helpless because of the wiping-out of supplier plants located in heavily damaged areas. The Business and Defense Services Administration in Commerce undertook studies of several industries, notably the truck-building industry. What was the length and complexity of the chain? To what extent would the loss of key suppliers cripple undamaged plants further along the chain? We do not have time today to go into the details of such studies. Suffice it to say they reveal a deeply serious problem, wholly within the parameters of a destruction ratio such as we build into our national assumptions. The major point here is one that I made earlier: research could result in some concrete preattack thinking and planning which would be available instantaneously when the broken chains appeared. Secondly, this problem illustrates what could be done by a little pump-priming work in a few industries. Many trade associations and professional societies ought to be induced to pick up the ball and carry on studies consistently for many years

ahead. Thirdly, the capacity for rapid and wide dissemination of damage-assessment data would thereby have a real and vital place in the actuality of the event. Manufacturers should be able to secure data on destruction and disappearance of their suppliers at the earliest possible time-- even during second-phase conditions. Many states, by the way, need more than the one center in their state capital at which these data could be consulted with minimal movement of persons. We premise the early recovery of some kind of communications flow on a pretty wide front; here is a high priority usage for whatever flow-lines become usable again. Substitutes, simplification, exchanges of stocks, cannibalizing used end-products, use of Canadian or Mexican suppliers, long-unused components or ingredients -- these are some of the improvisations that would be explored. Obviously the doubling or tripling of shift production in remaining key supplier plants would have high priority if the reason therefore were specified preattack to their local administrators.

(7) I could not resist the opportunity to include among these ten examples my own white-haired favorite for research undertakings: the construction industry. If I were the editor of the National Plan, I would devote a whole and separate chapter to this key weapon in any postattack recovery effort.

The role of this industry cuts across almost all the conventional boxes which ordinarily divide disaster planning. Down to even the smallest rural towns, and even to farms, it is ubiquitous in the existence of equipment and skills that would be vital to efforts at recovery in all three phases of a postattack situation. I will not bore you with recounting the problems and setbacks which the PAC encountered over 6 or 7 years in trying to solve the problem of locating responsibility for the pure planning problem which is involved. I use this term in the sense I noted earlier: merely laying out responsibility and developing systematic approaches to thinking about the problem. We are interested here today in the specific research which might yield some preattack guidance comparable to what we now have in many other sub-segments, even though planning as such is still inchoate.

The industry is robust, mobile, ingenious; it utilizes a labor force which would rank high in potential response to incentives and to semi-military mobilization actions. In the city of Kalamazoo some years ago, an experimental study was made which confirmed the high degree of mobility and responsiveness which might be expected. In total volume of equipment, in the variety of techniques and labor skills, in the dispersion of executive and engineering talent, the industry is unique. It has had varied experience with disaster conditions. It has some strong central leadership in the Associated General Contractors, who represent about 85 percent of the industry's volume, though not that high in terms of enterprises.

I seem to be somewhat alone in believing that this situation is one susceptible of highly sophisticated mathematical and machine exploration, on what could eventually be a comprehensive national scale. One way to demonstrate this would be to construct a pattern of random damage in the familiar manner, then determine what construction resources could be brought to bear on one specific area of near-complete destruction, plus several nearby areas of partial damage, utilizing the dispersed equipment and manpower from the nearest adjacent areas which remained undamaged with minimal transport needs (much equipment is either self-mobile, or its owners possess carrier vehicles under ordinary working conditions). I firmly believe that such a demonstration project, carefully done, would show the value of a locational census of the whole industry. If its value were demonstrated, I believe such data could be gathered largely on a cost-free, volunteer basis. The resulting quantitative and locational data on both machines and manpower could then be treated by machine methods in the manner already familiar for analyzing attack damage. The objective would be to attain close approximations of the construction-industry power that could be brought to bear, not only for emergency clearance, but also for a series of specific goals in emergency housing, transport rehabilitation, port and harbor work, quick completion of near-complete structures (of which there are thousands at any point in time), site-clearance, and intensive rebuilding of clearly needed plants and buildings.

An incidental value of such an undertaking, if directed skillfully, could be the training of industry executives in the importance of selective rebuilding (not wasting resources on non-needed replacements) and in the high value of short-cut and speedy-reconstruction methods with austere amounts of equipment. Conversion of off-highway equipment, such as that found in the lumbering and mining industries, use of reserves of highway equipment, the return to use of obsolescent machines, the use of farm and ranch machinery, are some of the other veins in this goldmine of research.

(8) My remaining three examples of needed research are of quite a different mold. They belong to the category of war-gaming or analytical research with minimal fieldwork, but with a potential high payoff. The first in this group is a very simple one. It belongs in the neglected seventh area of the Bedsheet approach. On any given day in all our ports and harbors there are loaded cargoes on ships ready to sail within one to three days. If a given harbor is undamaged, or lightly damaged, which of these cargoes should be held and which released? This involves relationships with other nations around the globe, as well as coastwise and intercoastal shipping. Turning back or accepting inbound cargoes is the obverse of this problem. A research project has always stuck out like an easily grasped thumb. Select a

day, impose a random attack pattern, then subject the cargoes in undamaged or lightly damaged ports to a table-gaming group composed of the same types of administrators who would have the administrative judgments to make with little central guidance. The data are easily obtainable, thanks to a system of port administration as old as the nation.

(9) The second example I have selected in this group is the problem of selective judgment in releasing news and data to the public about damage conditions, not necessarily in the days of the first phase, but as soon thereafter as one or more media of communication become reestablished. What are the military security considerations? What would be the public responses to a news blackout (but plenty of rumors), to partial or distorted information, or to full and complete coverage of damage situations? This is a lot more than studying canons of wisdom on censorship. It goes beyond the problem of permitting personal or intrafamily inquiries about casualties. As a continuous research area, it falls between the cracks because there is literally no agency or group within existent government which has either expertise or responsibility for this novel problem which would require immediate, and enforced decisions.

(10) My third example in this group, and the last of the ten I have imposed on you, is one which has already excited wide interest and upon which work is now being done by many people. Thus we can end on a note of optimism. This is the massive question of responses and motivations of people under postattack conditions in all three phases.

What I have seen of the current work on this problem does disturb me in one sense. In the old PAC approach, we carefully distinguished among the roles of people as victims or potential victims of a second or third attack, people as consumers after attack conditions subside, and people as workers and contributors to recovery. Much of the writing I have seen on this problem jumbles the three aspects together. Moreover, it is at once too vague and speculative, and too reflective of an individual's own psychological or sociological predilections, to be particularly rewarding. Much material is oriented entirely to particular peacetime disasters, or to the reactions of wartime populations under cumulative and repetitive bomb damage, or to the highly selective damage of the Hiroshima or Nagasaki variety. Two steps seem to be essential, and they both seem ideal topics for an NAS type of committee to explore. One is the careful differentiation of which reactions, and which motivations, we need to study. The other is unbiassed study in the scientific sense of the substantive conditions which would be most likely to exist. Here again, the distinction between damaged and undamaged communities would be of the highest importance. Needless to say, a later phase of this problem would be that of translating judgments into understandable and simple language for transmission to local leaders on a nationwide, preattack basis.

My final adjuration is simple and direct. It reminds me of the favorite American joke of speakers during the past decade-- that of the Emperor's clothes, or lack thereof, when he appeared in public. We need two sets of tailors to stitch together some garments for the naked Emperor, one in government and one in the ranks of scientists and industry-- leaders outside the hierarchy of governmental responsibility. There are many bits and pieces of his costume that the two groups could start to work on, independently, well before that figure of so many clichés starts his crucial parade down the avenue of resources management after a disaster.

THE PROBLEM OF EVALUATING AND DISTRIBUTING SURVIVING POSTATTACK ASSETS

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A major purpose of the symposium was to achieve a comprehensive, interdisciplinary examination of postnuclear-attack-recovery problems without constraint as to existing policies and methodologies. As the paper by Shaw Livermore indicated, a government policy does exist. Yet because of the complexities of the massive and unique problems associated with nuclear attack, the Office of Emergency Planning must necessarily join in this critical examination. In this context, and as part of the over-all response to the general assignment for the Economics Session, this paper explores one of several problems arising in a postattack situation: the valuation and distribution of surviving material assets. The paper does not reflect any existing governmental policy.

THE LEGAL QUESTION

Determining the ownership of surviving assets under our present system of law would be a fairly simple matter if each asset and its owner were located together preattack so that both survived or perished together. While this may be true for some assets, e.g., housing, it is hardly the case with many categories, for example, corporate wealth.

In our body of law there exist complex procedures for distributing property in the event of the death of the principal owner. It is well beyond the scope of this paper to explore the question of whether this fabric of law is adequate to deal with postattack property distribution. It seems, however, that employment of present procedures would, at least, mean a considerable loss in time before final property disposition, if present delays are any indication of future delays.

Editor's Note: This is a revised and abridged version of the paper prepared by Dr. Peskin and delivered by Mr. David H. Vance at the symposium. The views expressed in this paper are the author's and are not the views of the Office of Emergency Planning.

The problem does not seem to be grounded in the lack of relevant statutes and common law. The delays can be traced to the difficulties of establishing facts: Is the property owner really dead? Are all papers and wills in order? What are the legitimate claims of creditors and others? Of course, through more extensive registry of both people and property preattack, and with harder protection of records, these problems could be greatly alleviated. But unless factual issues can be essentially eliminated, long delay in the disposition of assets postattack is quite likely simply due to the large numbers involved.

THE MORAL QUESTION

Even if the question of fact could be resolved, current inheritance procedures would undoubtedly mean windfall gains and losses for certain survivors. A nuclear attack would most likely be characterized by an uneven geographical distribution of targets; by missiles that abort or otherwise miss their designated destinations; by winds that take fallout in random directions; and by clouds that limit or accentuate thermal effects. All these factors could lead to a postattack society with millions left untouched, but faced with the moral problem of what to do about the millions who, though alive, find themselves in sudden debt or poverty.

While for some a pragmatic reaction to a capricious asset redistribution would be to leave well enough alone, Americans have traditionally assisted those who have suffered loss through disaster. Although there may be no question of the survivors' altruistic intent, there remains the question of the extent of their generosity. In recent years, the more wealthy Americans have been accepting, without too much objection, some transfer of their wealth to the less fortunate, primarily through the mechanism of taxation and government expenditure. Equally true, however, is the fact that this transfer has been slow. Whether the taxation mechanism can be used to bring about a sudden and substantial wealth transfer is an open question.

THE ECONOMIC QUESTION

The economic problem is ultimately one of determining proper asset valuations. The relative value of assets in dollar terms serves not only the practical purpose of allowing a comparison of a person's or corporation's heterogenous collection of real assets with his liabilities, but also the purpose of directing the pattern of distribution and economic growth. For example, a very expensive asset that promised only a small return would be avoided by entrepreneurs who would prefer to develop assets with prices more commensurate with their probable returns. Furthermore, any plan for assuring postattack solvency, for the financing of indemnification through taxation, for determining an appropriate supply of currency, or for equalizing wealth distribution through taxation that does not account for the expected radical change in the real values of surviving assets, may cause severe misallocations and hardship. Consider a firm whose principal assets consist of a professional football team valued, preattack, at about $15 million. Suppose that the players survived the attack and that all debts of the team were fully paid up. Any plan to levy, for example, a net-worth tax postattack must face up to the fact that this firm's relative net worth in real terms is certainly not going to be the same as preattack. Indeed, considering the probable market-determined postattack valuation, the owner of this firm would hardly be able to pay the taxes assessed on the preattack value. Another way to emphasize the importance of proper postattack valuations is to investigate the potential postattack output of the country under conditions of prices frozen at their preattack values. An earlier study by the author suggested that under these conditions even the most minimal postattack-consumption needs would not be met.[1]

A tempting solution to the asset-valuation problem is to value assets at their preattack prices and then allow market forces to bring about an optimal reevaluation. One immediate problem with this solution is the sudden creation of debt, since paper liabilities will not suffer a destruction equivalent to that of real assets. As serious as this problem may seem, it is amenable to technical solutions through such means as debt cancellation by government decree, issuance of government bonds to cover asset loss, or assumption of debt by governmental finance institutions.

A more fundamental problem involves the concept of optimality and the ability of the postattack market to bring it about. The economists' often-used definition of optimality -- Pareto optimality -- amounts to a criterion of amoral efficiency: given an initial distribution of wealth, an optimum exists if it is impossible to make someone better off in his own view without making others worse off in their own view. It can be seen that this definition avoids the moral questions discussed above.

Yet even assuming a socially more acceptable definition of optimality, there is a serious question whether the postattack market can assure its realization. Although various reasons for postattack market failure have been discussed thoroughly elsewhere,[2] it is desirable to expand on one of the more important aspects: planning production over time.

The problem is one of uncertainty: will future demand justify present expansion? As Sidney Winter points out, a functioning futures market would assure an affirmative answer; but lack of such a market may mean abnormal profits and losses. One could add that with enough uncertainty, it may be quite likely that investment, and hence growth, would cease.

This problem, present in any economy but especially severe in the postattack economy, would be greatly alleviated by a government that established a climate of stability and faith in the future. Uncertainty would also be diminished if surviving real assets found their way into the hands of those entrepreneurs who could best exploit their potential. But unfortunately, a postattack market economy will not assure that the skilled manufacturer or farmer, surviving without any wealth, will be able to purchase the machines or land that he can best use.

CRITERIA FOR POLICY

It is probably true that an economical, socially acceptable, and efficient allocation of wealth postattack may entail some legal and governmental changes. This conclusion would hardly raise any arguments if all could agree on the extent of the changes. Differences of opinion fall between two extremes: that the only solution is to institute a free, unfettered market economy, and that the only practical solution is to institute an admittedly nondemocratic, centralized system of control.

This paper reflects the view that neither of these extremes is practical. Disaster socialism is rejected because of the view that any postattack system should not rely on too complex a political structure, either in the form of a centralized government bureaucracy or in the form of our present decentralized state and local bureaucracies. Whether or not a complex bureaucracy could effectively survive attack is too uncertain a prospect upon which to base a recovery plan, since governments are more geographically concentrated than private establishments, and hence, more vulnerable to attack. Disaster laissez-faire is similarly rejected because it is well-known that, while a freely competitive economy has many desirable features, it cannot and does not claim to cope with problems of socially unacceptable wealth distributions.

This paper takes to the middle position shared by many economists: they admit to the necessity of some centralized authority in the immediate survival phase but deem it best as soon as possible to restore a market economy that is as free as possible of centralized government control. Frequently not too well spelled out, however, is how this restoration is to be made and, at the same time, how to overcome the legal, moral, and economic problems discussed above.

Without attempting to formulate the policy that answers this question, it is possible to anticipate certain features of a suitable policy. In the first place, any workable plan should recognize that the severity of legal, moral, and economic problems is most likely directly related to the severity of the attack. Thus a recovery plan relevant to the destruction of a single city would differ from a plan relevant to the destruction of the entire nation. Indeed, it could be postulated that, if an attack were light enough, no planning would have been required since the surviving institutions of government and industry would probably be able to handle the situation on an ad hoc basis.

Second, because an inordinate delay in effecting a proper asset distribution could have substantial and unfortunate consequences in terms of postattack economic growth, the policy should be simple, easily administered, and capable of being activated without extensive training of bureaucrats. Straightforward procedures and rules-of-thumb should be triggered by easily observable events. At the cost of losing some flexibility, it is probably best for these rules to be agreed upon preattack.

Finally, it is quite likely that the resultant policy will be unprecedented and, perhaps, generally unpopular. One should not expect general popularity for policies that are designed to bring about rapid shifts in wealth distribution, for no one likes to see his wealth reduced. But chances for general acceptability of the policy would be increased if the public could be educated to the severity of the problem preattack. It is also quite likely that the general public finds the thought of nuclear attack so horrible that the additional horror of a postattack policy for wealth distribution would be considered of marginal importance. If this is the case, it does not seem out of the question for the public to acquiesce to the policy preattack.

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THE FEDERAL ROLE IN POSTATTACK ECONOMIC ORGANIZATION

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INTRODUCTION AND SUMMARY

In addition to killing and injuring a great many people, and destroying or damaging vast amounts of property, a nuclear attack on the United States would produce enormous confusion and chaos. Particularly in the realm of economic activity, the disruption produced by an attack would have effects as serious as those of the outright destruction.

If we ask why the American economic system as we know it today is not characterized by confusion and chaos, the most important part of the answer is the simple continuity of events, the finiteness of the changes that occur over finite periods of time. Untold numbers of economic decisions are made every day which involve the implicit prediction that the future will closely resemble the present, and only occasionally is the decision regretted because the prediction was seriously in error. These predictions form a coordinated, mutually consistent pattern precisely because they have common roots in the present.

More than Pearl Harbor, more than the most massive invasion by conventional armies, nuclear attack would break those threads of continuity. The survivors will not find it helpful in their decision-making to compare the first three months after a nuclear attack with "same quarter last year." Neither will they, in looking ahead, have any confidence in whatever picture of the future they are able to form.

Secondly, economic life is coordinated and regulated by the basic institutions of private property and voluntary exchange, the facilitating institutions dealing with money and credit, and the invisible hand of market forces. Within limits, it is clear who has control of particular resources, and relatively little effort is required to investigate the possible uses of those resources -- thanks to the information provided by money prices and to the communications industries and educational systems that distribute this information and much else besides. By and large, the economy offers material rewards to those who use resources in ways that contribute to the satisfaction of the material wants of others, and punishes the waste of scarce resources. In the aftermath of a nuclear attack, the legal ownership and control of a substantial fraction of the nation's surviving real wealth would be left uncertain by the destruction of records, the collapse of normal processes of estate settlement in the face of millions of deaths, and the chaos introduced into balance sheets by the massive and haphazard destruction of wealth. The elaborate system of organized commodity exchanges would be hard hit, and markets of all kinds would suddenly be fragmented by the breakdown of communications and transportation.

Equally fundamental are the legal and political institutions that make, modify and enforce the rules of the economic game. Contracts are usually performed and checks are usually redeemed, but when they are not, the law and the courts are there. If a citizen feels that tax or condemnation proceedings by a governmental unit have violated his rights, he has orderly procedures for seeking redress. If a group feels itself unfairly disadvantaged in the economic competition, it can work through political channels to change the economic rules. Doubts are sometimes expressed as to the effectiveness and timeliness of functioning of these social devices under normal conditions. It goes without saying that nuclear war would increase enormously the volume of problems of these kinds to be handled, at the same time increasing the urgency of solution, and destroy a substantial portion of the people, records and facilities normally involved in finding solutions.

Finally, the functioning of the economic system is shaped to some extent by a varied assortment of economic regulation and control mechanisms imposed by governmental units at all levels, and by taxation systems which serve partly as regulatory devices and partly to finance the government. Objects of regulation include the services and prices of transportation and utilities industries, methods and types of construction, the conduct of collective bargaining, the quality of food and drugs, and so on through a long list. Here, no less than in the other cases, a substantial nuclear attack would take a heavy toll. Expertise, records and facilities relevant to the old tasks would be casualties. Long-standing procedures and precedents will suddenly be infeasible or hopelessly irrelevant. Much of the information and expertise that does survive will relate to the preattack world, and not at all to the postattack world. Old tasks will simply disappear and new ones spring up.

This is the problem of postattack economic organization. Institutions and mechanisms in each of these four categories would be severely shaken by a nuclear attack. What is the best solution to this problem, in terms of preparedness measures and concepts to guide postattack activities?

Curiously, it is a widely accepted axiom that reliance must be placed upon a rapid recovery of the capabilities in category four -- the governmental regulatory and control capabilities. Indeed, what is envisioned is not merely a recovery of these capabilities, but a rapid surpassing of preattack levels, to the point where the government would engage in detailed control of the directions of economic activity on an unprecedented scale. The reasons for the wide acceptance of this axiom are many, and some of them will be examined below. What mainly is involved seems to be simple horror at the complexity of the problems and the immensity of the stakes, a simple reaction that something should be done about it, and the simple observation that, in past national crises, it has been up to the federal government to do something about it.

There is a flaw in this simple logic: What is fundamentally at issue in planning for a nuclear emergency is not the desirability of coping with the problems, or the desirability of trying to cope, but the feasibility of coping effectively. Neither historical precedents nor the incapacities of other institutions will confer upon the surviving elements of the federal government the needed capabilities. These propositions are widely accepted -- but mainly among opponents of civil defense and economic preparedness. In the absence of a closely argued case that the federal government could do the job, they naturally assume that it, like the rest of the society, would be incapable of performing even its normal peacetime functions. If it is replied that preparedness measures could assure the existence of the required capabilities, the questions will come back: For what range of attack levels? With what confidence? And at what price?

A few quotations from the National Plan for Emergency Preparedness will establish the point that the basic axiom identified above is fundamental to the plan, and the subsidiary point that overemphasis upon the requirements for governmental action, as opposed to the capabilities, lies behind the axiom.

From Chapter 1, Basic Principles:

> If the United States were attacked, or gravely threatened with attack, the Federal Government by virtue of its war powers must exercise pervasive direction and control in the interest of national survival.[1]

"War powers" refers to constitutional authority, and that authority certainly does not imply a commitment to the operating concept, "pervasive direction and control."

From Chapter 12, Resource Management:

> The Federal Government would direct and control production, distribution, acquisition, and use of critical resources to meet essential civilian,

military atomic energy, civil defense, emergency government and foreign requirements when warranted by emergency conditions.[1]

One might add "except when made infeasible by emergency conditions."

> Civil authorities at all levels of government would have to act immediately, and in accordance with the resource chapters of this Plan, to control all available resources and to assign them to priority activities.[1]
>
> Mandatory direct control measures to be used include priority and allocation systems, production directives, conservation measures, consumer rationing orders, inventory control and antihoarding orders, construction regulations, import and export controls, and requisitioning orders.[1]

The Plan does recognize that there may be some doubt as to the ability of the federal government to discharge all of these responsibilities soon after the attack. This point and the Plan's response to it are well-summarized in Chapter 13, Economic Stabilization:

> The Federal Government probably could not direct centrally all of the emergency economic control measures immediately required. In that event, Local, State, and certain Federal field authorities would have to direct many of these measures postattack until the Federal Government could effectively consolidate operations into a cohesive national stabilization program.[1]

Is it absolutely clear that these federal capabilities would come into being before the need for them has passed?

This paper challenges the basic axiom that direct governmental control of economic activity is a sound policy for the postattack situation:

(1) The necessity of such control is disputed on the grounds that the normally operative economic incentives would be reasonably compatible with national needs in most of the plausible postattack situations -- much more so than in World War II, for example.

(2) In the absence of extensive and expensive preparations, the required resource-management capabilities at the federal level could

only be brought into existence so long after the attack that the crucial question of economic viability versus economic collapse would already have been decided.

(3) The most illuminating question to ask about preparedness planning is not "What needs to be done?" but "What useful things can be done at a given budget level?" When this question is asked, it appears that the relative urgency of preparations for direct control is low -- unless the budget levels investigated are at least two orders of magnitude larger than the present ones.

(4) The relatively urgent tasks involve the repair of the regulating mechanisms in the first three categories noted above:

(a) Guide expectations: attempt to promote a consensus about the shape of the future.
(b) Restore basic economic institutions: especially private property, the monetary system.
(c) Restore the legal and political framework: especially preservation of national unity and of federal authority in matters of central importance to the nation's future, and restoration of the legal framework of economic activity.

(5) The central problem in the area of governmental regulation and control of the economy is not the extension of controls into new spheres of responsibility, but the adaptation of existing control devices and policies to the drastically changed requirements of the postattack situation.

Time does not permit me to make a detailed case for these propositions, or to explore the complications, qualifications and nuances. Needless to say, the strength of the case depends on the assumptions made as to attack weight and pattern, and as to preparedness measures. I think of the case as being strong for low-preparedness budget levels (the present entire civil defense budget would still be a low budget for economic preparedness even if it were all devoted to that purpose), and for the heavier of the two attacks considered at this symposium - UNCLEX. I am also assuming that significant postattack production for military purposes is either unnecessary or manifestly impossible, and that the U. S. receives no significant aid from other countries. Lastly, the case is stronger if Washington is hit, and especially if it is hit with little warning.

In the remainder of my time, I want to do five things: (1) Sketch the postattack economic problem, and note the implications for economic organization; (2) Sketch what seems to me to be an appropriate federal role in the postattack economy; (3) Argue that this role is actually an alternative, and not a complement, to the direct control functions mentioned in the National Plan; (4) Mention the main drawbacks of reliance on controls; (5) Put forward some research suggestions in line with this view.

THE POSTATTACK ECONOMIC PROBLEM

In the early days and weeks after a nuclear attack, the primary task facing the nation would be to save as many people as possible from immediate threats to survival. The goods needed for this task -- food, medical supplies, clothing, etc. -- would be drawn almost entirely from inventories, including emergency stocks. Partial restoration of production of basic services, i.e., transportation, communications, power, gas and water, would be necessary at an early date, but the material inputs to industries for fuel, and tools and materials for repair and patchup would be drawn from inventory.

The central problems of economic organization during this time period would relate, of course, to the restoration of utilities and transportation, and the control and distribution of stocks of essentials. There is probably little disagreement as to the character of the organizational devices required, e.g., rationing, or as to the desirability and difficulty of establishing in state and local governments the capability to deal with these emergency tasks. In any case, I will pass over these problems and concentrate on the economic problems of a later time period -- perhaps two months to a year or two postattack.

During this period, which I call the <u>reorganization phase</u>, the basic economic problem is posed by the declining inventories of essentials. Production must be restarted, and it must be restarted in time to meet the subsistence needs of the population when those needs can no longer be met from inventory. Production of some foods must be resumed at quite an early date if the average diet is to be nutritionally adequate, and even in the case of feed grains there will have to be some production in the second postattack growing season. Inventories of refined petroleum products are likely to be a focus of concern, given the vulnerability of the refineries and the essentiality of fuel for agriculture and transportation. The effort to reestablish a functioning, viable economic organization must meet deadlines determined by the levels of surviving inventories and the rates at which they are used up.

It is worth commenting briefly on the alternative to viability -- on the meaning of failure in this situation. If one focuses on physiological subsistence requirements, postulates a very effective rationing system, and assumes that the physical destruction resulting from the attack is the main source of production losses, then it is easy to convince oneself that a situation in which economic viability would be threatened is quite implausible. But a much more plausible view of a viability crisis can be described, one which combines the factors of hungry populations, social and political breakdown, and failures of economic organization. Such a crisis would involve decisions on the part of individuals to withdraw from socially productive employments and procedures in favor of alternatives offering larger private rewards -- which might involve anything from black-market activities to joining a roving mob looking for food. Political subdivisions, or regional groupings, might similarly withdraw from the questing for national solutions to national problems, with disastrous consequences for populations in other regions. Voluntary compliance with systems of economic control, especially those aiming at equitable distribution of necessities, is likely to be an early casualty if those systems appear to be incapable of solving the problem. Attempts at strict enforcement would consume resources and risk political difficulties. To weigh the dangers of a catastrophic collapse, do not inquire as to how long the food will last; ask when the cry "Every man for himself!" gets persuasive. If enough people respond to that cry, the division of labor will break down and starvation will eventually come.

If it is granted that this is a reasonable characterization of a plausible postattack problem, if not _the_ postattack problem, certain implications for economic organization may be noted -- particularly, implications which distinguish the postattack economic-viability problem from the more familiar problem of economic mobilization in wartime. First, viability is largely a matter of the adequacy of current and near-future consumption. Hence, there is a broad consistency between the private goals of individuals and the national interest: As individuals, the members of the population want to survive, and it is in the national interest that the population survive. The organizational requirements are to provide a framework in which the private pursuit of private interests will not be socially counterproductive, and to provide some degree of equity in the distribution of necessities. This degree of consistency between private and national goals is not found when the government is trying to extract large amounts of production from the economy for war or economic development.

Secondly, in contrast to the wartime situation, the government's policy objectives do not directly imply an attempt to determine details of the output mix. In World War II, the government necessarily concerned itself with the allocation of resources among aircraft, rifles, ships, tanks and landing cra . Postattack, it would not have a comparably direct interest in he allocation of corn stocks between cornmeal production and chicken feed. In war mobilization, information on military requirements and strategic plans is largely monopolized by the government. Postattack, information on, for example, consumer acceptance of different foods would be scattered and diffused. Thus, both the incentives for detailed economic control and the information base to support it would be much weaker in the postattack situation.

Finally, the timetable for the achievement of viability must be considered in relation to the leadtimes for the construction of the institutional apparatus of detailed economic control. The course of postattack economic events is likely to be determined to a large degree by what happens in the period from three to nine months after the attack. If the control organizations have to be formed postattack, they are not likely to be well-staffed by that time, let alone shaken down and functioning with workable procedures.

A PROPOSED FEDERAL ROLE

Turning now to my sketch of a more realistic view of the federal role than that which envisages comprehensive central planning, let me first propose a basic perspective: Rather than constructing lists of the multitudinous requirements for federal action in the postattack emergency, it will be helpful to ask what the government should do if what it can do is very limited. Envisage a situation in which, as a result of very low preparedness budgets and a heavy attack on Washington and other cities, federal capabilities are almost nonexistent. The economy, if it recovers at all, will recover pretty much on its own. But, given that there are some surviving federal capabilities, how should they be employed? Presumably, they should be used to facilitate spontaneous recovery processes and to influence the decisions with the largest implications for the nation's future. Certainly, they should not be used in an attempt to override spontaneous processes, or to influence decisions of less than crucial importance. While I cannot take the time to inquire into the existence, character and effectiveness of spontaneous recovery processes, I believe that the prescription to follow is broadly consistent with the perspective just set forth.

First, the government should guide the expectations of the public by acquiring, analyzing and distributing information on current and prospective economic conditions. Although the government will lack the information base for detailed control, it should be capable of learning the over-all picture and using that knowledge as a basis for some predictions about the future -- for example, of supply and demand conditions for basic commodities. By its predictions, and simply by authoritative descriptions of the situation, the government could not only restore some coherence to the economic decisions of individuals and firms, but could probably influence the main directions of these decisions. For example, a governmental pronouncement that a particular region will have to be evacuated and its rebuilding deferred might well be self-enforcing. In some cases, the government would lend weight to its predictions by commiting itself to act if necessary to make the prediction come true.

Second, the recovery of basic economic institutions should be a major concern. Speedy, decentralized systems for achieving a quick clarification of property rights and for freeing the economy from the tangle of preattack commitments should be developed preattack and implemented postattack. In developing concepts for these emergency procedures, a minimum of attention should be to the similarity to normal procedures, and the dominating concerns should be speed and applicability at the local level, on a massive scale, by people relatively unschooled in the intricacies of the normal procedures. Similarly, in designing measures to assure the acceptability of the currency or the solvency of the banking system, the focus must be on the functional requirements of the postattack situation. Such ideas as using government-owned food stocks as backing for the currency deserve serious consideration.

The restoration of the legal and political framework of economic activity is another problem area requiring emphasis in preparedness planning and postattack operations. While a good deal of attention has been given to the problem of continuity of government, almost none of it seems to have been focused on the specific aspects relevant to economic activity. Perhaps the assumption that the economy would be run by comprehensive direct controls explains the lack of interest in these matters.

A fourth area involves the control and regulatory functions now performed by government. For example, transportation and utilities services must somehow be priced and allocated in ways that are responsive to the realities of the postattack situation. Those realities are likely to be very different from one locality to another, and the existing agencies are likely to be unable to cope with the complex and rapidly changing situation.

We come now to an area of activity that is somewhat more demanding in terms of governmental capabilities -- but much less demanding than detailed planning and direct controls. This is the problem of making resources available for essential investment activity. There are many ways of accomplishing this; one of the simplest may be some sort of expenditure ration system: e.g., a system in which earnings above a certain amount are placed in blocked accounts, or automatically invested in recovery bonds, and thus made unavailable for expenditure until after the emergency has passed.

Finally, there are some possibilities under the heading "blunt uses of government power." Not much analytical subtlety should be required to draw up a list of things that should not be produced post-attack, and very simple control devises should suffice for enforcement; for example, turn off the electric power.

Similarly, the government could force the evacuation of particular regions, or turn "have-not" areas into "have" areas by relocating food stocks. Rather than trying to chart the path to the achievement of the nation's goals, the government would simply try to block off routes that seemed particularly likely to lead away from the goals.

INSTITUTIONAL RECOVERY VERSUS DIRECT CONTROLS

It might reasonably be asked why the proposed federal role just sketched is an alternative to reliance on direct controls. Since most of these functions and tasks are at least mentioned in the National Plan, some must believe that they are complementary to the various direct control devices discussed.

The first argument against such complementarity is that the limited federal role advocated here still leaves the federal government with enormous tasks, both in preparedness and in postattack operations. Indeed, actual accomplishment of this preparedness task will probably take many years unless federal preparedness budgets are increased substantially. Hence, as mentioned earlier, the question is not what should be done to meet the requirements but what can be done with the available budget. The role described here can be defined in very austere versions, and useful progress toward the required capabilities is not out of the question with budgets on the present order of magnitude. On the other hand, the actual development of the capability for centralized planning and control, and its maintenance in a state of readiness that would permit it to go into operation in the relevant postattack time frame, would be expensive indeed. As an add-on to the program of institutional recovery, realistic preparations for direct control are a luxury that should not even be aspired to under present budgets.

If one could realistically expect the government to be capable of detailed planning and control, it is not at all clear that the institutional recovery program outlined would be desirable. Aside from the ideological values associated with private enterprise -- which accounts for the Plan's lip service to a "basically free economy and private operation of industry"[1] -- the main point to private ownership and control is that private incentives are offered for sound decisions on how resources are to be used. But a manager's task when faced with a desk full of production directives is implementing decisions, not making them. Any private incentives to which he is subjected can only tend to distract him from the national interest, as interpreted by the paperwork on his desk. What the government wants from him is the behavior of a loyal employee, and that is precisely the status that should be conferred upon him.

Of course, no planning and control system ever treats all of the detailed resource-management decisions that have to be made. Government directives can usefully be supplemented by private-profitability calculations. But in planning for a postattack situation, the costs of achieving a quick clarification of property rights have to be considered, and these seem excessive if only incidental and peripheral reliance is to be placed on private incentives. It would be much simpler to nationalize any property that is subject to control ambiguities.

Thus, the program of direct controls is an expensive and low priority adjunct of a program of institutional recovery, while the program of institutional recovery is an expensive, inessential and perhaps counterproductive adjunct of a program of detailed planning and direct controls. A choice is called for.

CONVENTIONAL PLANS AND THERMONUCLEAR REALITIES

I have referred to the high cost of preparing for detailed direct controls, and to the probable delays in getting such a system in operation postattack. To provide systematic quantitative documentation for these assertions, or to make a cost-effectiveness analysis of alternative forms of organization, is clearly impossible. The alternatives are not sufficiently defined to allow their costs to be estimated, and the methods for assessing effectiveness do not exist. The best we can do is to rely on some crude comparisons. One comparison we might make is with the planning systems of Communist countries. It has been estimated that, in the Soviet Union, "over ten million specialized officials are engaged in collecting and processing economic data"[2] -- and still the amount of effective control over the economy afforded to top decisionmakers is quite small.

For the present audience, a comparison with World War II experience in the U. S. may be more helpful. I ask you to recall that experience -- the number of people involved, the false starts with impractical methods and the time that passed before the Controlled Materials Plan was in effective operation. Then, consider the more elaborate character of the controls apparently envisaged by the present National Plan, the impossibility of anticipating with high confidence which resources will be in short supply, and the much greater diversity of conditions from one locale or region to another that a nuclear attack would leave in its wake. Reflect finally on the difficulties of assembling the necessary personnel, getting the forms printed, making initial inventories of surviving resources, and communicating information and directives, all in a badly damaged economy -- and perhaps with many of those who today are relatively expert on such problems numbered among the injured, missing or dead. This adds up to a task which surpasses the World War II task in difficulty by a margin which is well-proportioned to the difference in the explosive power of nuclear and high-explosive weapons.

It may be true that this task could be accomplished as soon as possible postattack. But the preparations will have to be spectacularly more extensive than the present ones if "as soon as possible" is to be soon enough. And if these capabilities are to be acquired, the question of their vulnerability to attack, deliberate or otherwise, will have to be faced. At some price, a relatively invulnerable standby system for central control of the economy, capable of going into action in time to make an important difference, could probably be purchased. I hope it is clear that the price would be high.

SOME SUGGESTIONS FOR RESEARCH

Let me recast some of the foregoing ideas into a list of research topics that have high priority. These mainly involve the related problems of assessing the difficulty of preparing the government to perform the suggested postattack role, and of finding ways to perform it.

A first project is to design speedy, decentralized systems for clarifying property rights postattack. A range of situations should be considered, both in terms of local conditions and national attack impact, and a corresponding range of methods developed. Estimates of the amount of time and resources involved in postattack implementation should be made. The problems of clarifying property rights and those of dealing with insolvency are obviously interrelated, and the banking system should probably be the focus of preparedness measures in both cases.

Secondly, there is a class of problems having a common basis in the fact that the proposal made here envisages a form of economic organization more decentralized in some respects than the present one. Practical ways must be found of increasing the discretion of persons in direct contact with local economic conditions. Examples include the problem of providing autonomy of operation for particular plants of large private corporations, and that mentioned earlier of pricing and allocating utilities and transportation services. In the latter case, the possibilities of abuse of monopoly positions are an obvious objection to letting the profit motive guide the decisions. A rather complicated problem, deserving of careful study, is thus posed.

Considerable thought has already been given to postattack monetary problems. But here, as in the case of property rights, it would probably be desirable to explore a range of alternative policies that would be responsive to a range of possible situations. For example, it would probably be more useful to attempt to determine what postattack circumstances would make an early currency reform desirable, and what circumstances would make it undesirable, than to try to decide about currency reforms without reference to the character of the attack and its economic aftermath.

In my brief description of what it would mean to fail in the attempt to achieve economic viability, I have suggested that a viability crisis is likely to be a social and organizational phenomenon. A better understanding of the conditions of failure of economic organization would contribute both to the assessment of our vulnerability to various levels of attack, and to the design of a failure-resistant form of organization. Comparative analysis of historical instances of severe economic stress, and the behavior that resulted from and contributed to the crisis, should be informative. Under what conditions do hunger riots occur? What circumstances make for voluntary compliance with price control and rationing schemes? What is the relationship between absenteeism and the food rationing system? To the best of my knowledge, even the World War II experiences of various countries have not been subjected to comparative analysis with these sorts of questions in mind.[3]

Let me conclude by reiterating in its general form a point that I have made in specific contexts above: There are probably very few answers to questions about postattack organization that can be shown to be invariant over the entire range of plausible assumptions as to attack levels and targeting, military demands upon the economy, and postattack trade and aid relationships with other countries. We will progress much faster if we all admit that this is the case and if each attempts to be explicit in his assumptions about the situation he is discussing -- at least as explicit as I have been, and preferably a good deal more so.

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SOCIETAL VULNERABILITIES

Peter G. Nordlie, Chairman

DEMOGRAPHIC ANALYSIS AND SOCIETY AFTER A NUCLEAR ATTACK

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The importance of demographic analysis for understanding and anticipating the nature of society after a nuclear attack has been recognized by several investigators since Joseph D. Coker called for such studies at a meeting of The Population Association of American in 1962.[1,2,3,4,5] Even so, many research programs show the need for demographic analysis only by their failure to use it. Unfortunately, that omission lessens the utility of those studies as effective bases for decisions at the policy level. Their failing is all the more to be regretted because available demographic research, if properly used, is sufficient to establish the relevant parameters for policy-oriented research while showing what aspects of that research require demographic information. The purpose of this paper is to review existing research and the problems toward which it was directed, point out some of its implications and suggest what additional research is needed.

The demographic changes associated with nuclear attacks are quite different from those that occur in society during normal periods. Ordinarily, demographic changes occur slowly--over decades. The planner can anticipate well in advance changes in the manpower pool and in the demand for those services that are demographically related such as education, hospital care, etc. For example, an examination of the small cohorts of the thirties enabled the planner to anticipate a small military manpower pool in the fifties and a large college population in the sixties. The impact of these demographic changes on the society, even though anticipated, was large. A case in point was the outbreak of the Korean War. Though the causes for conflicts such as the Korean War are manifold and complex; it is nonetheless instructive to observe that the pool of manpower entering military age in the United States at the time of that conflict was the smallest pool since the twenties and smaller than any that could be anticipated during the fifties or sixties.

Since nuclear war could lead to more dramatic changes in the population of the country than any it has experienced in so short a time, a reasonable question for research has been the determination of what those changes might be and how anticipating them could be advantageous in expediting recovery and designing countermeasures.

KINDS OF DEMOGRAPHIC EFFECTS

The demographic effects of a nuclear attack are of two kinds: those pertaining to the size of the population and those pertaining to its composition. Establishing the relevance of changes in size is a trivial problem. Given the proper configuration of attacks, almost any number could be lost and only the most limited set of possible attacks would cause what might be termed an "insignificant" number of deaths.*

The compositional effects raise more complicated questions because many factors that might ameliorate or aggravate these effects cannot be quantified with much precision. Compositional effects result from differential death rates for people with different demographic characteristics. There are two basic sources for compositional effects: differential susceptibility to the destructiveness of nuclear weapons, and differential exposure to those effects. For simplification, we may divide the second of these into three factors that affect exposure: (1) the points of detonation; (2) the distribution of the population at the time of the attack; and (3) differential sheltering for the population. It is unwise to assume that specific points of detonation can be anticipated, even though certain targets might have high priority in the attack plan of an enemy. Moreover, the distribution of a population at the time of an attack cannot be wholly anticipated. Many distributions ranging from "at home in bed" to "wholly evacuated" are possible. That people would enter shelters differentially has been established, but the demographic parameters of their differential sheltering would vary with the nature of the sheltering program and the kind of warning they receive.

These complexities have forced investigators to use restrictive methodological assumptions that have in some instances misled them in their findings. (I hasten to add that the degree of misleading involved is dependent upon the extent to which methodological qualifications and sensitivity analysis have been employed and reported.)

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* It should not be assumed that because the set of possible attacks that would cause an "insignificant" number of deaths is small with respect to the total set of possible attacks that they are trivial in all respects. As countermeasures improve and the possibility of small nuclear attacks grows, their importance will become greater. Under no circumstances, however, would we expect them to exhaust the possibilities in the foreseeable future.

SOME EARLIER STUDIES

As might be expected, research in the area of compositional effects falls under two headings: those that support the view that there is no compositional dimension to the problem or that compositional effects are trivial, and those arguing that compositional effects are important.

The first group is represented by David Heer, who concludes that:

> "The preceding detailed analysis has presented us with the variety of changes which the composition of the United States population might undergo as an immediate result of a nuclear attack. For the most part these changes would be small. The one exception to the pattern of small change would be the shift in family status."[3]

The second group is represented by Cutright and Dentler, who conclude that significant changes would occur in the religious, occupational, political, and ethnic characteristics of the nation, if attacks were relatively small and concentrated on urban areas. They further argued that, as the size of the attack increases, the number of deaths is incompatible with survival and compositional changes are of little consequence.[2]

Because of methodological considerations, both researchers oversimplified the range of conditions that they faced. Cutright and Dentler, for example, were concerned only with the population in residence as reported by the Census Bureau, and attacks on population centers. Heer constrained the compositional effects of attacks by allowing differential survival only with respect to central city versus ring distinctions.[4]

SOME MORE RECENT RESULTS

More recent research has elaborated upon and overcome some of the difficulties of these analyses.[4,5,6,7] Examining the four factors above in conjunction with the others -- namely, the three factors associated with exposure and the factor of susceptibility -- recent research concludes that each of them could contribute significantly to the composition of surviving populations as generated under a variety of assumptions. "Significant" is used in a statistical sense; i.e., these changes are significant in that they are not compatible with a model of randomly generated deaths in the population.

The basic strategy of the research is as follows: first, urban areas of the nation were examined to determine to what extent the population was segregated in terms of demographic and social characteristics. It is clear that if the degree of segregation in the population is extremely small, i.e., people of all kinds are thoroughly mixed together, then as long as they remain in that mixture, compositional effects of a nuclear attack would be small.[4]

Using a modification of the technique developed by Shevky and Bell, the social areas of several American cities were examined.[8] Illustrative maps for New Orleans showing the distribution of indices of occupation, education and fertility are shown on Figures 1, 2 and 3. The standard scores for all these figures are based on a range of 0 - 100 through the formula: $100 - [\ x\ (r - o)\ ]$, where x and o are quantities determined for standardizing the range, and r represents a measure of the variables in question: namely, occupation, education, and fertility. For occupation, r is the total number of craftsmen, operatives, and laborers per 1,000 employed persons in the population. For education, r is defined as the number of persons who have completed no more than grade school per 1,000 persons 25 years old and over. The r for fertility is defined as the number of children under five years of age per 1,000 females age 15 to 44.

The areas shown differ dramatically from each other on a number of characteristics; moreover, they are quite large, implying that significantly different rates of survival would be expected by the residents of the different areas were they at home at the time of the attack.[9] That contention was tested by applying a survivorship grid and comparing attacks assumed to take place in various parts of the city. The results showed that the composition of the city would change significantly when the city was attacked. In addition, different points of detonation had different compositional effects. Moreover, the kinds and ranges of compositional effects varied from city to city.[4,5] The kinds of changes involved are illustrated in Table I entitled "Changes in Selected Indices Following a Simulated Nuclear Attack."

Two questions were raised at this point: Would compositional effects occur if the population assumed a different areal distribution in anticipation of the attack or in the course of living before the attack? And does the compositional effect on specific occupational groupings of people reflect the changes in the broader categories used to report census-tract data? Additional research was initiated to answer these questions in part:[5]

1. The daytime or at-work population, because it reflects greater ecological segregation, gives rise to larger compositional changes than the nighttime population on the average, though the differences were generally small.

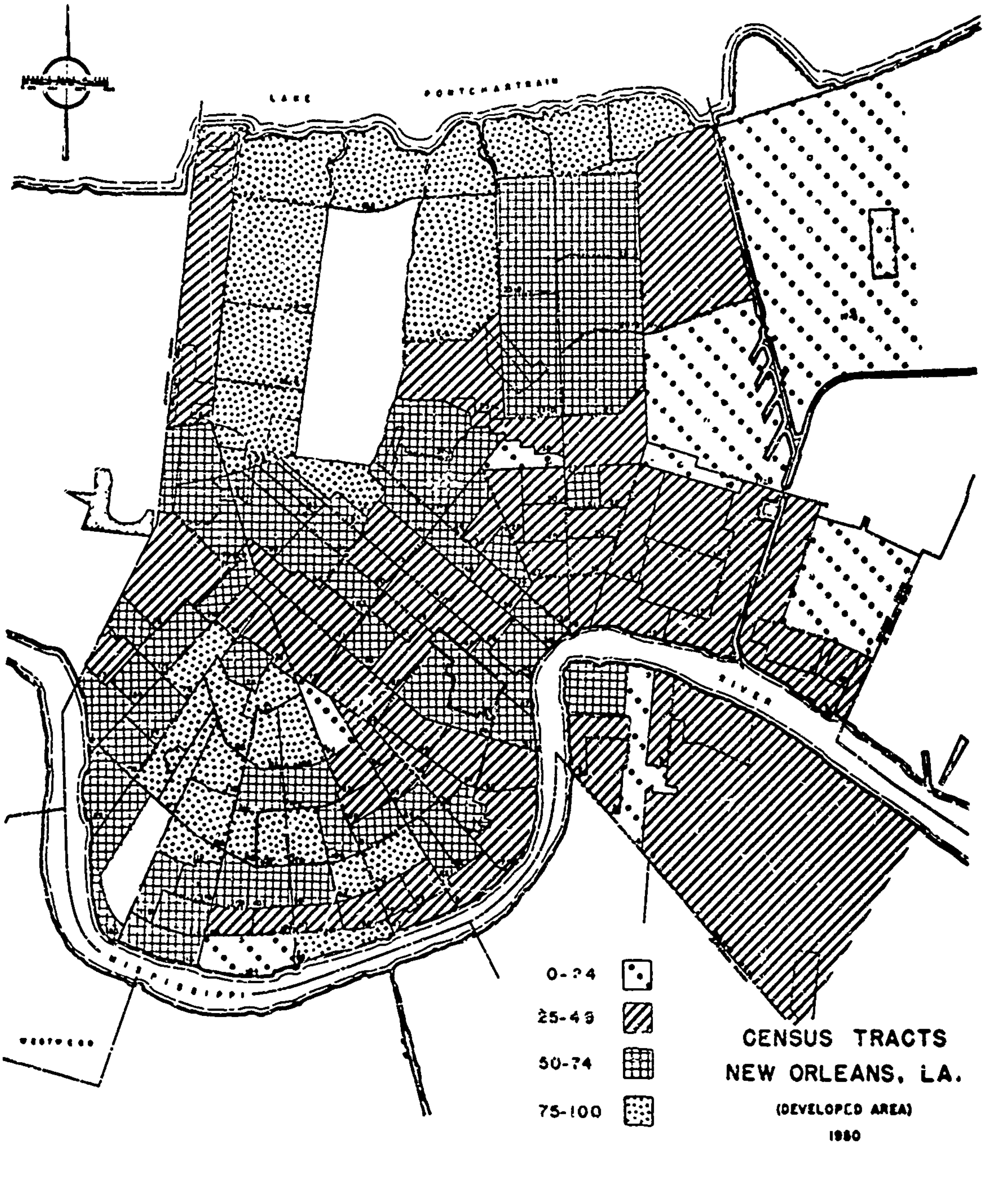

Figure 1. Occupation Standard Score.

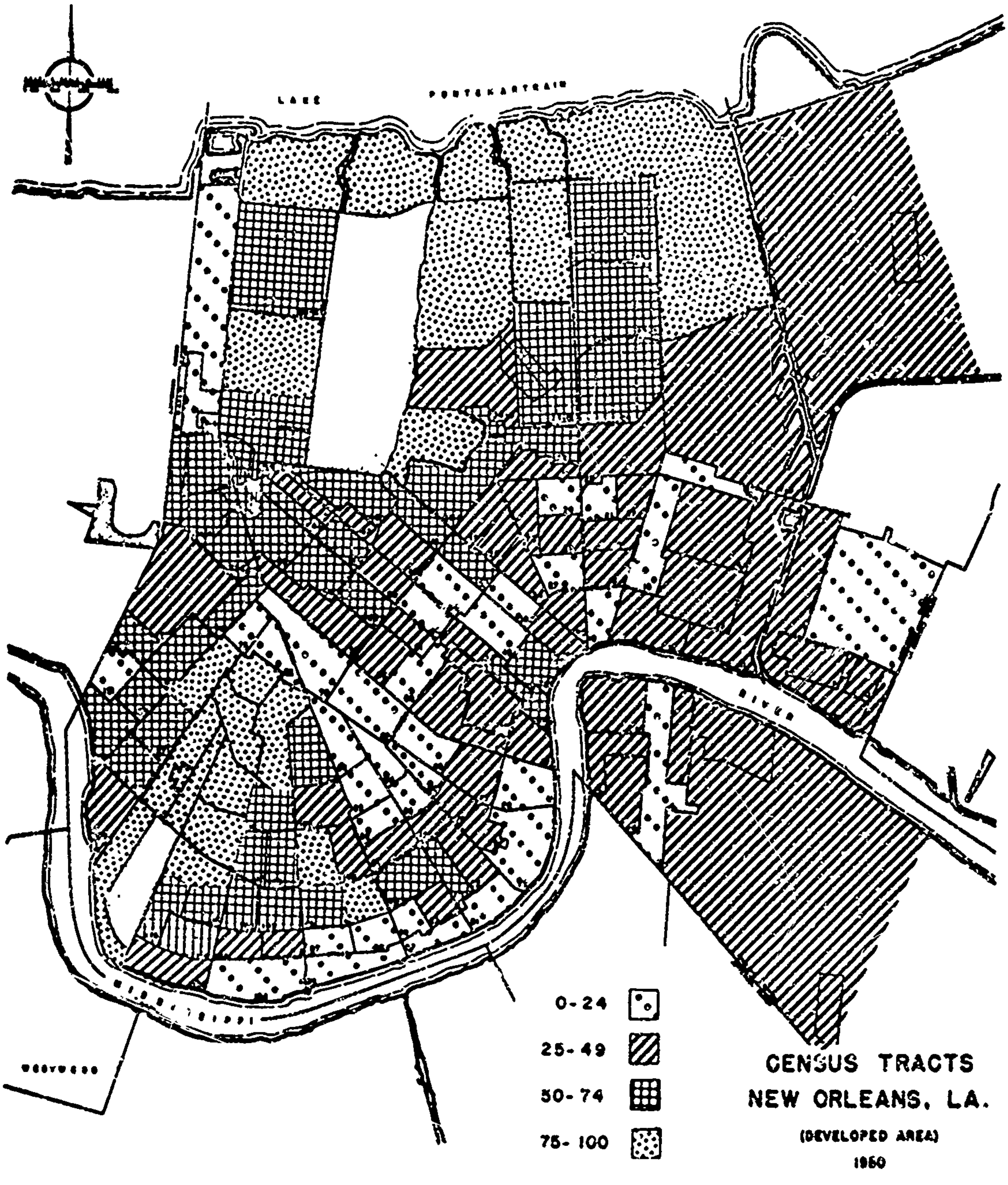

Figure 2. Education Standard Score.

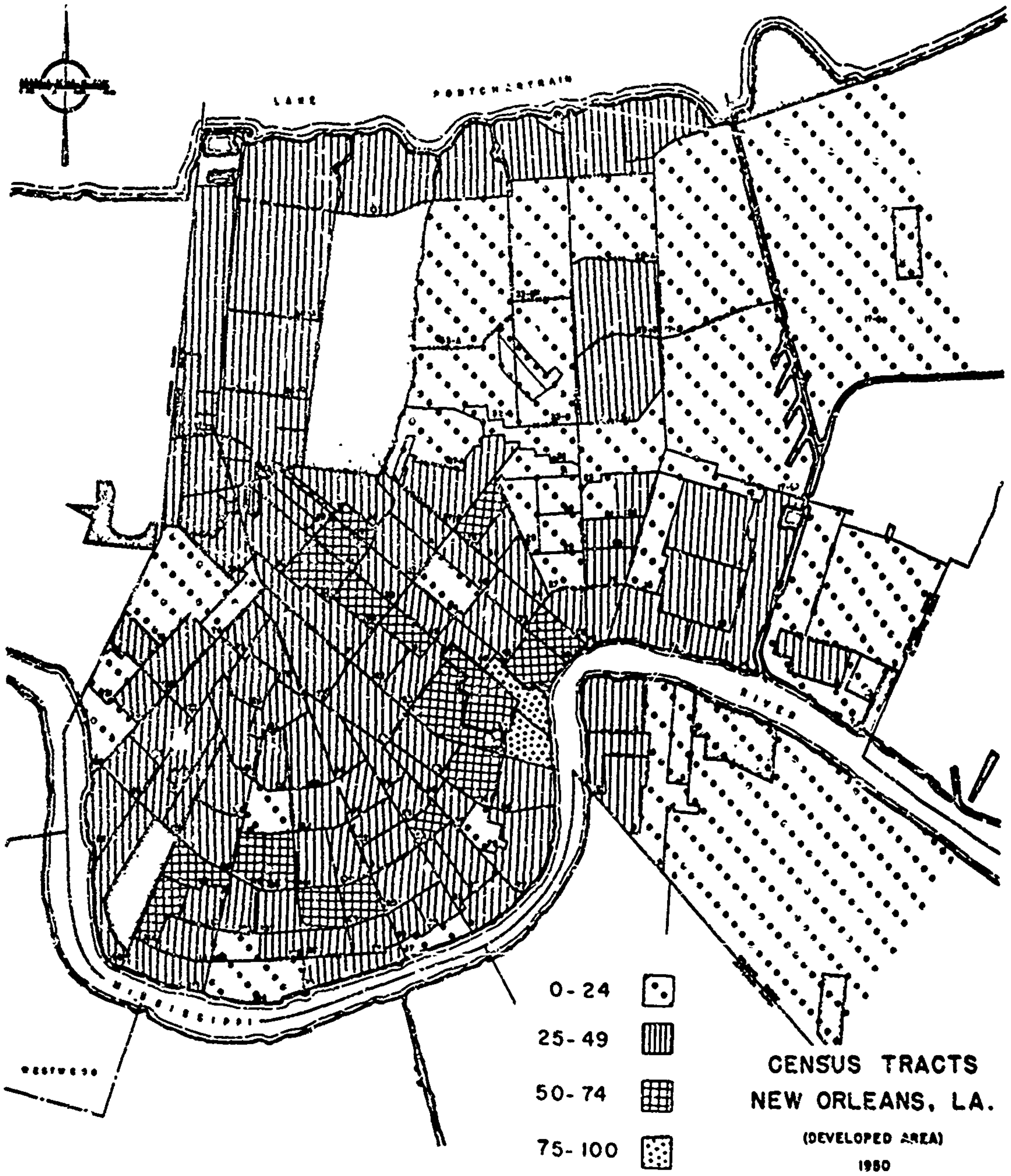

Figure 3. Fertility Standard Score.

TABLE I.

CHANGES IN SELECTED DEMOGRAPHIC INDICES

FOLLOWING A SIMULATED NUCLEAR ATTACK[5]

Variable	City: Albuquerque Preattack	After Attack on Census Tract 4	City: New Orleans Preattack	After Attack on Census Tract 80
Sex Ratio (Males per 1000 Females)	992	1023	924	983
Dependency Index (Those under 15 and those 65 and over divided by those between 15 and 64)	712	774	668	744
Mean Age	26.8	25.8	30.5	26.9

2. A population that evacuates in whole or in part will show greater compositional effects if the evacuation itself is selective on the basis of demographic characteristics. If the evacuation is random or complete, the degree of segregation in the evacuated areas would determine the compositional effects if those areas were attacked. It should be noted that many evacuation plans might reduce attack effects on the size of the population dramatically, thereby offsetting small compositional effects.

3. The changes in specific occupational categories do not reflect those in general census categories. Although this conclusion has been documented in only one city, there is no reason to doubt that it is widely applicable.[5] Using data from Polk's Detroit City Directory, a sample of various occupations were selected and assigned to the groupings shown in Table II, "Occupational Classifications."

The individuals in these occupational groupings were assigned to their appropriate census tracts and two attacks were simulated on the city. One attack was centered on Census Tract 458A and the other on Census Tract 539. The resulting percentages in each category, along with those for the preattack population, are shown in Tables III and IV. An examination of this data reveals the following: (a) the occupational distribution of the postattack population differs from that of the preattack population; (b) the occupational distribution of the populations resulting from the two different attacks differ from each other; and (c) the differences within census categories do not reflect the changes in the categories as wholes. For example, the percentage classified as "nurses" does not change as a result of an attack on Tract 539, but that for professionals as a whole does, and is reflected, though not duplicated, by the changes in the percentages of doctors and dentists.

The major conclusions that flow from the research on the demography of nuclear war are that the surviving population will be affected by those compositional differences.[4] Moreover, these changes are all significant in that they cannot be accounted for by a model of random change in the composition of the population.

IMPORTANCE AND RELEVANCE OF THE FINDINGS

The remaining questions are: first, is the magnitude of these changes sufficient to modify, in an important way, the social and economic structure of the surviving society when considered with respect to other changes in the conditions that society will face? and second, to the extent that such an interpretation can be made, are there policy and practical decisions that can be taken in order to ameliorate their impact?

T A B L E II.

OCCUPATIONAL CLASSIFICATIONS

1. Census Classification	2. Special Skills
1. Professional	1. Physicians
2. Managers	2. Dentists
3. Clerical	3. Nurses
4. Sales	4. Other Health
5. Craftsmen	5. Engineers
6. Operatives	6. Teachers
7. Service	7. Ministers
8. Laborers	8. Policemen
9. Noncivilian	9. Firemen
10. Employee	10. Public Officials
11. Student	11. Other

T A B L E III.

PRE- AND POSTATTACK COMPOSITION OF A SAMPLE OF THE POPULATION OF DETROIT ASSIGNED TO CENSUS CLASSIFICATIONS

	Preattack (%)	Attack on 458-A (%)	Attack on 539 (%)
Professionals	7.43	6.47	9.44
Managers	8.41	7.55	10.78
Clerical	8.70	8.18	10.28
Sales	3.28	2.87	4.33
Craftsmen	7.47	7.29	8.61
Operatives	8.01	8.46	7.68
Service	7.53	7.82	6.59
Laborers	2.61	2.91	1.79
Noncivilian	1.08	1.06	1 17
Employees	11.56	12.14	9.64
Students	3.98	3.40	4.97
Retired	6.01	5.97	6.15
Unknown	23.93	25.88	18.57

TABLE IV.

PRE- AND POSTATTACK COMPOSITION OF A SAMPLE
OF THE POPULATION OF DETROIT
ASSIGNED TO SPECIFIC OCCUPATIONAL GROUPINGS

	Preattack (%)	Attack on 458-A (%)	Attack on 539 (%)
Physicians	0.38	0.31	0.50
Dentists	0.21	0.17	0.32
Nurses	0.80	0.72	0.80
Other health	1.57	1.53	1.47
Engineers	1.14	0.99	1.68
Teachers	1.62	1.34	2.04
Ministers	0.22	0.22	0.16
Policemen	0.68	0.57	0.99
Firemen	0.32	0.26	0.47
Public Officials	0.13	0.11	0.18
Other	92.93	93.78	91.39

An answer to the first question cannot be made unequivocally. In and of themselves, none of the compositional changes observed are of a magnitude sufficient to prevent demographic regeneration or economic restructuring. Though some projections show unusual variations, the compositional effects that have been generated in this research are likely to be representative in magnitude of those that would follow a nuclear attack unless the patterns of differential susceptibility acting on the population are radically different from those answered in the analysis.[4] Therefore, the conclusions we reach with respect to these changes are generalizable to the problem in abstract. Considering them in turn:

1. Changes in the age-sex structure of American cities are not dramatic, though they are real. The major cause for concern is the likelihood of an increased dependent population and an increase in the number of broken families.[11] These two elements occurring together would tend to reinforce each other; since familial resources would not be available for many of those in the dependent categories on the same basis as before an attack.

Suggested countermeasures and policy considerations in this area are: increases in the proportion of resources allocated for the support of the dependent population, which could be done only at the expense of other economic goals, and the avoidance of countermeasures such as selective evacuation that would increase the proportion of dependent persons in the surviving population. The latter raises the dilemma of saving lives versus saving skills -- a problem that needs more careful consideration than can be given here.

2. Changes in the composition of the labor force appear to be larger than changes in the age-sex structure. Since these changes are likely to affect fairly rapidly the ability of the economy to produce, they would appear serious. Certain additional factors, however, will operate to lessen their impact: the substitutability of skills and the offsetting of compositional effects among communities.[11] Both these processes, however, will require relocation of elements in the surviving population which in turn requires a rational and equitable basis for new assignments. In addition, the damage assessment on which these new assignments and substitutions would be made must be sensitive to the compositional effects as they occur. Whether that sensitivity can be incorporated in the early simulations of damage assessment is a question that requires further exploration. If such is not the case, then some method for rapidly collecting data on the surviving population should be devised and plans laid for its utilization.

3. Because the effects vary from community to community, summary data for the nation may well be misleading as a basis for postattack decision-making. Summaries of simulated data will certainly be misleading for preattack planning. Even though the specific compositional effects of an attack on a community will vary from attack to attack, the established parameters of such change should be used when assessing the attack effects whenever it is impossible to simulate those effects directly by using a matrix of social-demographic characteristics for each standard location area along with factors of susceptibility as were employed in much of the research mentioned above.

ADDITIONAL PROBLEMS

The paramount problem yet to be solved is the design of an adequate postattack population policy for the nation and a statement of the attendant research that would be necessary for the implementation of the policy. Such a task is formidable, since it is unlikely that a single policy -- even one with considerable flexibility -- will be applicable to all possible attack conditions. Moreover, the population policy would have to take into account regional and local economic needs for manpower, desirable rates of growth, the efficiency of various means of growth, and the demographic state of the population while combining all of these in a series of crucial time phasings. This is because what is desirable at one time may not be at another, and what is possible at one time may not be at another.

Though a great deal of effort has gone into an examination of these problems already, further development will rest upon, and be a part of, our efforts to solve the problem of social vulnerability and societal recovery.

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SOCIAL INDICATORS OF SOCIAL EFFECTS AND THE SOCIAL INVENTORY AFTER ATTACK

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THE PLACE OF SOCIAL EFFECTS IN POSTATTACK POLICY

Underlying many particular discussions of the effects of nuclear attack is a pervasive concern about what people themselves will do, in both their individual and collective roles.

For the economist the discovery that substantial technological-material resources and capacities may survive many forms of attack encourages him to shift his analytic emphasis especially toward organizational problems.[1] How can surviving resources be organized? What policies are required? But this immediately leads to a nagging worry: Will people continue to act individually, collectively, and in institutions as they have before attack? What important variations from pre-attack behavior might occur, to influence the economist's ability to assume comfortably that there will be sufficient continuity in the social preconditions of complex economic activity to warrant thinking that his "other things being equal" assumptions will still hold?

The demographer will be especially sensitive to the kinds of variations in population composition that may occur because of nuclear attack, as is illustrated by another paper in this panel on societal vulnerabilities. Very quickly, his concern also turns to questions of social policy -- and to the social assumptions that might underly this policy. The discovery that under particular forms of attack particular drops in birth rates may be expected leads naturally to a concern with the kinds of policies that might be developed to stimulate recovery of desired population growth rates. But a generalized question about people's social behavior underlies any population growth policy: Will people give -- or be able to give -- high priority to reproductive and

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Editors Note: This is a revised version of the paper given at the symposium.

family-maintenance activities? What other social demands will compete? For example, will manpower requirements draw disproportionate numbers of women into the labor force and away from reproductive and family-maintenance activities? What conflicts between motivations to work and motivations to raise families might be expected? Will people be motivated to rebuild families?

In yet another area of postattack planning, the ecologist quickly encounters the need to consider social and behavioral assumptions. In considering the extent to which the natural environment of the human society has been altered by attack, the dominant policy concern of the ecologist is to determine those critical environmental characteristics and population-environment balances that must be restored, if a self-maintaining human population is to continue. But for each principal time period after attack, the ecologist must wonder whether people will be capable of adapting to changes in basic environmental characteristics. In the very short run, will groups dissolve into massive panic, so that human population movement becomes a disorganized flood of organisms scattering around the physical environment and competing to shape it in selfish ways? In the longer run, will social organizational and institutional capacities exist which are capable of discovering and managing potential upsets in resource balances and environmental-equilibrium states which form the ecological setting for society?

In important ways, the concerns of the ecologist overlap with those of the public-health specialist. A principal direct concern of the public-health specialist who is projecting consequences of attack will be with requirements to control disease vectors. Many of these requirements result from the potential disorganization of the balances and controls which American society has achieved in managing a range of nonhuman populations. The capacity to restore control over vectors of disease implies the same social organizational capacities which are of concern to the ecologist. Beyond this, however, the public-health specialist has additional crucial categories of distinctly social concerns. These center on the kinds of adjustments people can make to death and trauma. They begin in the question of whether nuclear attack will create distinctive stresses on the social roles of being a patient, of dying, of administering therapy, or of providing support to a suddenly expanded population of individuals who can legitimately describe themselves -- and be described -- as sick. How many social institutional forms, which have been developed for defining and managing illness and death, be undermined by the consequences of nuclear attack? What kinds of shifts of priorities in medical concerns may occur, and how might these shifts create anxiety and social stress in their own right? Are large increases in the numbers of mentally ill individuals to be expected? If so, what relations between postattack mental illness and general social disorganization are to be expected?

Underlying the approach of any particular professional or academic discipline to the description and management of postattack effects are a set of distinctive questions about how people will respond to attack. In one sense, all specific disciplines which are concerned with post-attack effects and postattack management are branches of a general social science of postattack society. This is because every definable arena of postattack systems and policy design must be predicated on assumptions and propositions about what will happen to individuals, social groups, and social institutions after attack. At the least, these assumptions and propositions should enable the analyst to say with some degree of confidence that his proposed systems and policies are relevant to the way people will want to act and will actually live after attack. At their most fruitful and creative, these assumptions and propositions should tell the analyst with particular concerns something about what to expect, as people react to both the basic facts of attack and to the conditions created by particular systems and policies.

Clearly, this present paper cannot provide full answers even to the four groups of questions which have just been suggested. Much less can it outline a social science of postattack society. On the other hand, what does seem possible is to consider two general questions. First, what kinds of things seem to be known now about how human behavior and society are likely to respond to nuclear attack? Second, what kinds of tools are needed in order to develop and use information about the social effects of nuclear attack, for more effective postattack planning?

The study of the social effects of nuclear attack is both peculiarly critical and peculiarly elusive. The reasons for the criticality of this study have already been suggested. The reasons for its elusive quality lie in uncertainties about both the effects of weapons on human society and the best kinds of social models and social dimensions which might be used to project attack effects. Even if actual, recent experience with weapons effects in large social systems were available, the problems of studying the interactions of these effects in complex society and projecting their trends and outcomes would be formidable in their own right.[2,3] But when actual experience with these effects is lacking or sharply limited, the problem of choosing dimensions and models for expressing possible effects becomes a fundamental analytic problem of constructing dimensions and models of society which will permit projecting a potentially vast array of social contingencies in the total social system.

In considering what kinds of things are known now about social effects and what kinds of analytic tools are needed, this paper follows a strategy which recognizes the existence of many unresolved analytic problems. First, the case history of a particular, distinctly social finding about the possible effects of nuclear attack will be presented. These questions will be briefly considered:

> What makes this finding an important finding about social effects?
>
> Assuming that it is an important social finding, what are the possibilities and problems in using it?

After this case history, the discussion turns toward a general review of the kinds of findings that are available for postattack planning. This review is not meant to be a full inventory of findings about post-attack social behavior. Rather, the findings in this review are presented for the purpose of showing how an integrated approach toward describing critical postattack social effects and processes can be developed. This integrated approach emphasizes the utility of constructing a system of social indicators of the social effects of attack. For illustration, a general system of social indicators will be applied to tracing some of the critical social effects and conditions which appear to be created by a fallout-shelter system. Through developing a system for examining changes in critical social indicators as a fallout-shelter system shapes the effects of nuclear attack, planners and managers with particular concerns can see the kinds of actual behaviors and social processes which attack creates and which form the basis for particular planning and management problems.

THE CASE HISTORY OF A SOCIAL EFFECT: ORPHANS AFTER ATTACK

A Confusion in Terms, and Its Consequences

The term "social effect" has both a general and a special meaning in discussions of attack effects and emergency operations. Taken most generally, social effects can include all those social phenomena whose particulars can be revealed by the perspectives of particular social-science disciplines. In its more specific sense, social effect can refer to a limited range of concrete subject matter, one which seems the distinct province of students of social effects.

In the first sense, economic effects, demographic effects, certain effects on health, political effects, religious effects, effects on values, small group behavioral effects, and individual psychological effects are all classes of what are fundamentally social effects. All of these classes of effects describe man's capacity to function in society in some way. While each of these classes describes human activity in a particular sector or from a particular point of view, all classes contribute to a general description of man's capacity to organize and maintain social systems. All classes are necessary to a full understanding of how individual behavior and social processes of groups might be affected by nuclear attack.

By contrast, the term "social effect" is commonly used to describe a more limited group of individual, small group, collective, and organizational phenomena. Here, phenomena such as changes in individual attitudes and behaviors, group responses to stress, and the ways specific organizations, localities, communities, governmental entities, and larger social institutions generate new characteristics are taken as the typical subject matter of studies of social effects. In certain respects, the term "social effects" tends to be used as a residual category. Social effects are what are left over after economic, political, demographic, ecological, health, and all the other specific categories of effects have been considered. True, practitioners of the particular disciplinary skills required to uncover and describe these specific categories of effects frequently acknowledge that their findings depend on the extent to which underlying social and behavioral assumptions hold true. But there is frequently a lack of precision about just what these assumptions are, and about which ones may or may not be important to scrutinize closely.

The widespread temptation to see social effects as the critical residual category for study has some definite consequences of how information about social effects is sought and used by those who need it. Questions directed to social scientists about social effects are seldom cast in the form of queries about how the whole social system or its major sectors of individual personal behavior or institutional process might, under attack, form the shaping framework in which specific categories of effects might occur after attack. Usually, questions about social effects follow one or two directions. First, the questioner may see knowledge of social effects as a convenient pool of information into which he may dip in order to supply those additional assumptions he needs to make in order to study the specific subject of primary in rest to him. Second, the questioner may see information about social effects as a way of allaying his anxieties. Will there be mass panic after attack? Will the crime rate go up? Will there be a sudden increase in suicides? Will people go berserk? Will people retire to their families or shelters, thereby destroying the division of labor in society? Frequently the answer to such questions is "No". The problem is, however, that the questioner often has his anxiety allayed without seeing the ways in which the reassuring answer is part of a larger view of what will happen in society after attack.

These directions of questioning also have real consequences for the way in which the analyst of social effects conducts his work. It may be his judgment that the most fruitful, long-term approach to the study of social effects is to try not only to project particular kinds of social effects but also to create a general view of society within which the different kinds and consequences of social effects can be evaluated under different attack conditions. To follow this judgment is necessarily to develop some conceptual tools and models for describing individual human actors as they exist in a social network. But to do this is to court the danger of appearing to answer legitimate queries with social-science jargon. Yet, if he takes as his mission the providing of particular residual assumptions or anxiety-allaying findings, the social analyst may purchase an increase in apparent relevance and acceptance of his work at the price of a long-term decrease in the real significance of what he has to say.

These questions go beyond this symposium; they cannot be settled here. But to make a start on considering the kinds of findings on social effects that do exist and do appear to have importance beyond their capacity to provide residual assumptions or allay anxieties, consider now the finding that under even low levels of attack, there is likely to be a substantial increase in the number of orphans in American society.

From Demography to Analysis of Social Structure

In 1965, David Heer reported that for two relatively low-level attacks (the Holifield attack, 1,466 megatons directed at both cities and military targets; the Spadefork attack, 1,779 megatons directed primarily at military targets), the most important population composition changes would be in family status.[4]

On children, Heer reports:

> For the national total of boys and girls surviving the Holifield attack, 7.9 percent would have lost both parents, and the proportion losing father alone or mother alone would each be 9.1 percent. The proportion losing both parents would range from 22.5 percent in the SMSA's* of the Northeast to 0.8 percent in the nonmetropolitan part of the North Central region. The proportion losing father alone or mother alone would range from 15.9 percent in the SMSA's of the Northeast to 2.2 percent in the nonmetropolitan West. The national total of boys and girls surviving the Spadefork attack who would lose both parents would be 4.4 percent. The

* Standard Metropolitan Statistical Area

proportions losing mother alone or father alone would each be 8.6 percent. The proportion of Spadefork survivors losing both parents would range from 8.8 percent in the SMSA's of the West to 1.1 percent in the nonmetropolitan part of the West. The proportions losing mother alone or father alone would range from 15.1 percent in the metropolitan West to 3.8 percent in the nonmetropolitan South.[4]

The importance of these findings is not so much in the absolute numbers of orphans created in this particular set of attacks as in the emergence, even at low attack levels, of what appear to be significant increments of orphans. Even making allowance for possible effects resulting from Heer's computational models, the emergence of these proportions of orphans at this low level of attack merits attention, when it is kept in mind that for almost all other possible categories of compositional changes Heer found only slight shifts. (The only other major change was in the closely related category of numbers of widows and widowers created by the attacks.)

To calculate the numbers of orphans which might be created, Heer used what are basically demographic techniques. That is to say, the whole population was taken as a collection of attributes of each of its members. The most important individual attributes in calculating the incidence of orphans were age, sex, and likely membership in family units. On the basis of this total population inventory of individual attributes, proportions and sums of orphans could be calculated through application of a mathematical model, once attack coefficients could be entered for a total set of study areas covering the whole country.

But the demography of orphan incidence alone does not tell how or why orphans may be a significant postattack policy problem. Even for the Northeastern SMSA's, where as many as 22.5 percent of the children in the Holifield attack stand to lose both parents, it might be argued that there are many potentially far-more-urgent problems. The prima facie claim to attention that orphans might have, simply because the creation of orphans was one of the few major changes Heer found, might be countered by saying, "If that is so, let the kids fend for themselves, as they have done in other great disasters. Let's turn our attention to organizing scarce resources for survival."

The potential meaning of the problem of orphans cannot be understood until the problem of orphans is seen not as a demographic consequence of attack but as a problem in the analysis and management of social structure. The crucial fact about the creation of orphans is that for every orphan created, there has been a rupture of a principal social relationship which supports him in a family. A family is defined not only by simple attributes of each of its members, but, much more importantly, by the existence of a series of social relationships among its members which form a durable unit of social structure. The crucial event that occurs when an orphan is created is that the exchange relationship of mutual support and dependency which had existed between the orphan and his parent or parents is now broken. The vital functions performed by that ongoing social-structural relationship have now ceased or been significantly impaired. It is in this particular way that the demographic fact of being an orphan is translated into the social-structural problem of supporting an orphan.

It is in developing policies to support orphans that the full jump is made from requirements for basic demographic information about attack effects to requirements for social-structural information about attack effects. It appears likely within the American value system that the existence of even a small number of socially dislocated orphans would constitute a severe emotional burden on the population at large. Some policy for dealing with them would be likely to have many post-attack benefits -- benefits which would go beyond meeting the immediate needs of the orphans themselves. But what should the policy be? A policy of desperation in the short run might be simply to let the orphans drift, and eventually to provide official subsidies for whomever they ultimately found to meet their needs for families. At the opposite extreme might be the creation of a system of orphanages or camps, into which large groups of orphans could be systematically placed. Such orphanages might be developed in close relation to preattack schools. But beyond the many problems that might be associated with such a system for ingathering emotionally and physically deprived children is the question of whether such an orphanage system is, in fact, a high-priority preattack allocation of what are now scarce civil-defense resources. Somewhere between these policy extremes might be the development of a national system for assigning potential orphans to kin. In principle, for many children in the society a rank-ordered list of kin with whom they might be placed might be created. In the event a child became an orphan, he would be placed with one of these kin, and formal subsidies of money, food, or general rights and claims would be payable to these kin, to help them in meeting this new responsibility.

Would such a national orphan assignment plan be feasible? Deferring for elsewhere most of the legal, moral, and emotional issues in such a plan, the most important immediate issue would be whether there are likely to be sufficient numbers of available kin for enough potential orphans to warrant making kin placement the basis of a social policy for managing orphans. Much current folklore about the isolation of the American family and the frequent mobility of families suggests that many Americans are cut off from kin. In fact, the only way of finding out whether there would be available kin for orphan placement would be to make a census of American kinship ties. Evidence from the few existing local-area studies, such as that presented by Greer and Winch for a Chicago suburb and for the state of Wisconsin, suggests that, far more than is commonly realized, individuals do have available kin and kinship networks relatively close at hand. The presence or absence of available kin is especially closely associated with ethnic-religious background: Protestants are likely to have relatively few available kin; Jews are likely to have a relatively large number; Catholics are likely to fall between Protestants and Jews.[5]

To determine the feasibility of a plan for assigning orphans with kin, therefore, it is necessary to survey the kinds of kinship ties that exist for children of varying social backgrounds. To do this is to create two new and difficult survey requirements. First, standard demographic questions must be supplemented by questions designed specifically to measure the social relationships of individuals. Not only must the existence of social-structural ties such as family relationships be determined; equally important, measures of the extent to which these relationships are meaningful must be included. Thus, any specific survey of kinship bonds must deal with the frequency, kinds, and intensity of contacts among the members of a kinship network centered in a given locality. This means that survey techniques must be developed which measure not only traits of individuals as individuals but also patterns of social structure in local areas and in the nation at large. Second, to uncover these patterns of social relationships and to determine their ranges of variations, the survey must be permitted to ask the relevant questions. It happens that among the most powerful single indicators of variation in patterns of available kin in this society are answers to questions about ethnic-religious background. This puts the government or its agents in the position of seeking information about which there is much sensitivity among respondents. Thus, the kind of survey necessary to establish the national feasibility of an orphan assignment plan must seek not only a new kind of information - information about social structure -- it must also develop that information through questions which are often avoided in survey or census inventories done under official auspices.

Wrapped up in this consideration of the single problem of what to do with the orphans are many of the major, basic problems in developing information and policy for coping with the social effects of nuclear attack. The lack of information about available kin is but one illustration of the most striking single gap in the tools available for studying possible social effects of attack: the lack of any comprehensive, nationally based inventory of the social relationships and value patterns which exist within the American population. The lack of nationally based information on kinship ties is part of a more general lack of information about such critical social facts as national variations in patterns of voluntary organization and participation, patterns of informal and formal community organization, patterns of influence over individual and group opinions, patterns of both criminal and noncriminal deviation from accepted social values, and kinds of social organization which are to be found within the full range of geographic areas and physical tracts which make up the total society. Without a national inventory which presents not only classic individual-attribute demographic information but also information about social-structural relationships and value patterns, it is impossible to construct direct indicators of the effects of attack on key patterns of relationships and values which appear to hold American society together. For this reason, the lessons being learned in present studies of how to measure kinship and voluntary organizational ties in local areas have potentially wide importance in learning how to construct more adequate national inventories of key social data.[5]

As a matter of policy priority, what to do with orphans is subject to many other competing demands for the attention of civil-defense and emergency-planning officials. The urgency of the orphan problem might be diminished if it could be argued that findings such as Heer's were the results of the weaknesses of his methods. Or, the problem might be shunted to another sector of government. After all, isn't the care of orphans basically a longer-term social-welfare problem? Couldn't the emergency operations sector of government simply turn the whole problem over to the social-welfare sector of government?

In spite of the different kinds of reasons that might be advanced for minimizing the urgency of the problem of postattack orphans, the example of orphans remains a compelling example of what the social analyst means by an important potential social effect of attack. As a result of not merely killing individual people but of breaking a critical social tie among people, a new social burden is created for society. This burden is the translation of dependency burdens carried heretofore by family units to the society outside the family. In measuring the incidence of this burden, in calculating its social, emotional, and physical-resource costs, and in devising optimum ways in which the society can meet new requirements for managing this burden, it is impossible to proceed without information which describes both the critical social relationships and the kinds of needs which participants in these relationships have. For the orphan, the target of attack was not his father or mother or the social welfare agency that could meet the functions of his parents; the target was the social relationships that met his needs as a child. For the orphan, the postattack problem is to restore those relationships.

SOCIAL TARGETS AND SOCIAL INDICATORS OF ATTACK

Social Targets

The potentially distracting, emotion-charged problem of orphans after attack is but one of many conceivable, particular problems which could occur when social targets are brought under nuclear attack. Looking beyond the case of orphans and other problems which might be created by rupturing specific social relationships, the analyst discerns a fundamental question: In what ways does the organized individual behavior and social life of society become a set of targets for attack? An answer to this question would tell something about where to look for the most significant kinds of social effects and social problems after attack, especially if a way could be developed for considering all the different kinds of social targets which might exist in a society. To answer this question, however, it is necessary to consider the ways in which society is not only a collection of physical individuals and physical resources, but also a set of social entities which can become targets as social entities.

In answering this question, it is necessary to start with a brief excursion into general social science. It is necessary to begin by considering what can be inferred from the visible behavior of individuals, the ultimate concrete data with which both social scientists and attack analysts work. The ultimate answer rests on the proposition that from the visible behavior of individuals, it is possible to infer the existence of four broad categories of system which become targets of attack. These systems are different ways of viewing individual patterns of behavior, but they are both analytically distinct and real in the consequences they have for individuals.

As biological entities, individual humans can be seen for analytic purposes as individual systems, each one a discretely defined, continuing organism in continuing relation with its environment. When a population of these entities has achieved such a degree of continuing balance with its nonhuman environment that, short of unanticipated catastrophe, it can maintain itself indefinitely, it has become an ecological system. Both of these categories of system are formed from individual human entities; both depend upon the physically defined human organism to exist as a discrete entity and to participate in the conditions for maintaining himself, as a physical entity in a physical world. Both depend upon individuals to create ecological balances so that further individuals can be created. As both individuals and as a population of individuals, the human actors of society form an analytic category of organic entity targets. Before as well as after attack, it is individuals who must adapt to changing conditions in the world, while it is the ecological system which maintains the basic continuity of the human population.

Beyond the isolated individual or his population aggregation are a group of behavioral entities, which can be inferred from the patterns and regularities of groups of individuals. In groups, individuals form not only populations in the sense of ecological systems, but they also exhibit collective properties, properties drawn from the behavioral outputs of individuals but not necessarily dependent for their stability on the acts of any one particular individual.

From these regularities of individual behavior, two additional basic behavioral systems in society can be discerned. The system which can be discerned from the interaction of individuals in stable patterns of role and organization existing over time is the social system. Here, social system is taken in a very general meaning: the total structure of interpersonal relations which both provides and reflects the organization of individual behavior into social roles, primary groups, kinship networks, secondary groups, associations, organizations, and class and status positions, as well as into less clearly specified and transitory groupings. Depending on the theoretical persuasion of the analyst, this whole structure of relations will provide a society with a social structure that has more or less coherence and integration, and more or less predictability in ordering determinants of individual behavior. In all cases, however, the social structure composed of various levels and forms of social systems uniting in one total social system, is a pattern of behavior abstracted analytically from acts of individual behavior.

Beyond the level of the social system, there is another level of behavioral organization to which individuals can be seen to respond, as individuals or as participants in a social structure. This level provides the continuing body of values, symbolic meanings, techniques for symbolic manipulation (especially language and lexical devices), and generalized perceptions of not only the existential but the desirable which characterizes the total society. This body of values, perceptions, symbolic capacities, and their concrete manifestations in the real artifacts used in the transactions of social life form the cultural system of the society. As a behavioral entity known by being abstracted from patterns of action and action-products displayed by individuals and groups, the culture of the society guides ongoing behavior by providing a body of values and techniques against which past acts can be evaluated, present acts can be guided and structured, and future behavior drawn from a broad range of basic human capacities.

Parallel to the two basic organic-entity targets, then, are two basic behavioral entities which are targets. The crucial distinction which divides this total group into two categories acknowledges that organic unity, relationship with physical environment, and [illegible]itted behavior are all physical traits of individuals, from the point of view of the perceiver. At the same time, relationships -- i.e., elements of the social system -- or rights and belief -- i.e., elements of the cultural system -- require inferences about patterns of behavior, whereas descriptions of organic individuals or ecological systems require categorizing of discrete unities or groups of individuals.

Although their analytic status is different, these groups are all equally real. The same functional difference between the individual system and the ecological system on the organic-entity side exists between the social system and the cultural system on the behavioral-entity side. Before as well as after attack, it is the social system which is the primary center for organizing adaptive action in society, while it is the cultural system which maintains the continuity and coherence of action patterns among individuals and over time.

The relationships among these four potential target systems are outlined in Figure 1.[6]

A Simplifying Device: The Stepped Progression of Determinants[6]

In studying the social effects of attack, the welter of potential classes of effects immediately creates the need to set priorities for analysis and for planning. The isolation of four potential social target systems is a step in the direction of grouping basic-effects variables. But each of these target systems contains many potentially significant orders of phenomena.

If certain kinds of social effects could be shown to be temporally prior to others, an important step could be taken in focusing attention and setting analytic priorities. Without prejudging which orders of social effects are prior in time, it appears possible to present the basic form in which a temporal progression of social effects would be expressed. This form is given in Figure 2a and 2b as a paradigm for a stepped progression of social effects and determinants. The meaning of Figure 2a is simply that Effect A, whatever it may be, is first to occur. As it continues over time, it acts as the precondition (A' in Time t_2) for the appearance of Effect B in the Time t_2 phase. Similarly, Effects A and B create the preconditions for the emergence of Effect C, as well as for continuing sequences of effects which have "A" or "B" characteristics.

The meaning of Figure 2b is that as time passes, Effect A may diminish as a salient effect for planning and countermeasures, even though it remains operative as a precondition for later classes of effects. Similarly, Effect B declines in salience, although this decline necessarily begins later than the change in A.

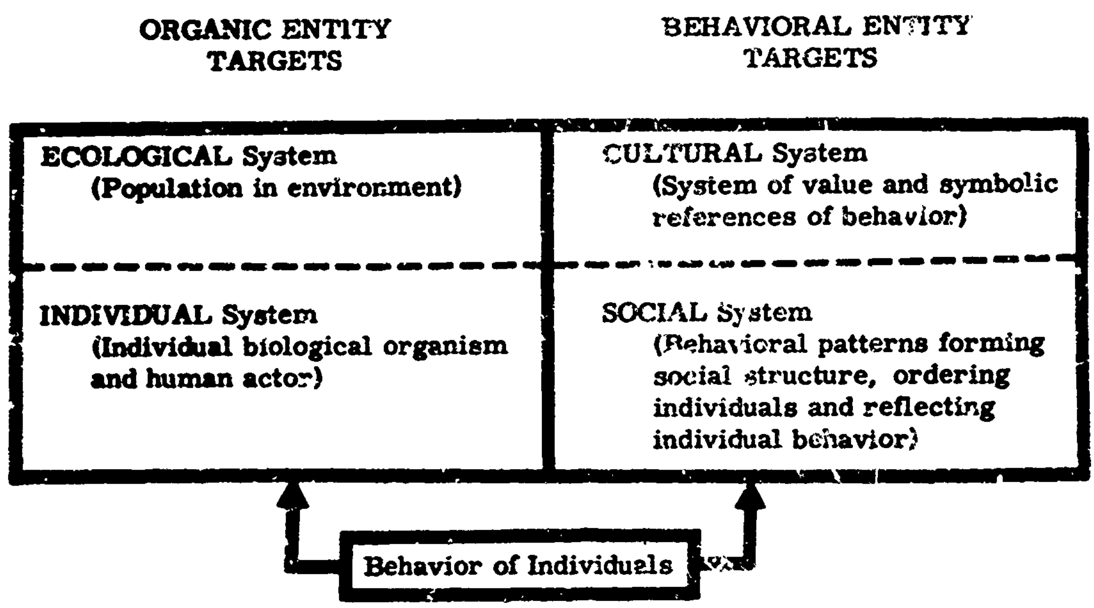

Figure 1. Observable Systems of a Society, as Targets of Attack.

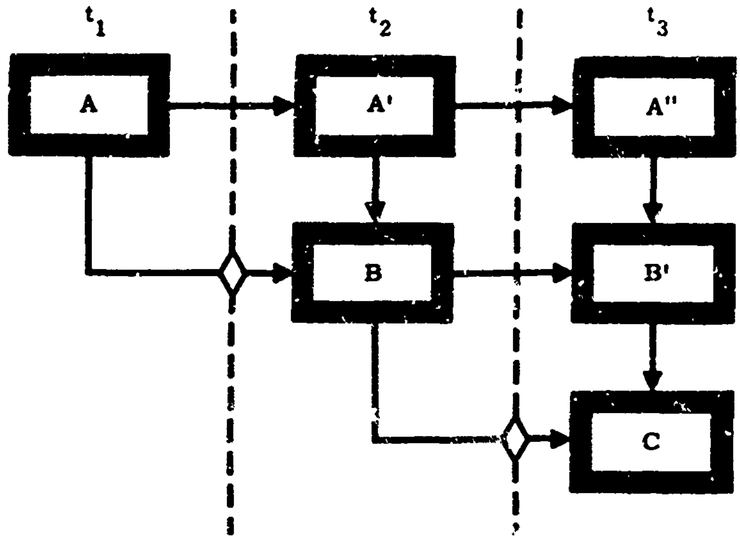

Figure 2a. Paradigm for a Stepped Progression: Sequential Appearance and Ordering of Determinants.

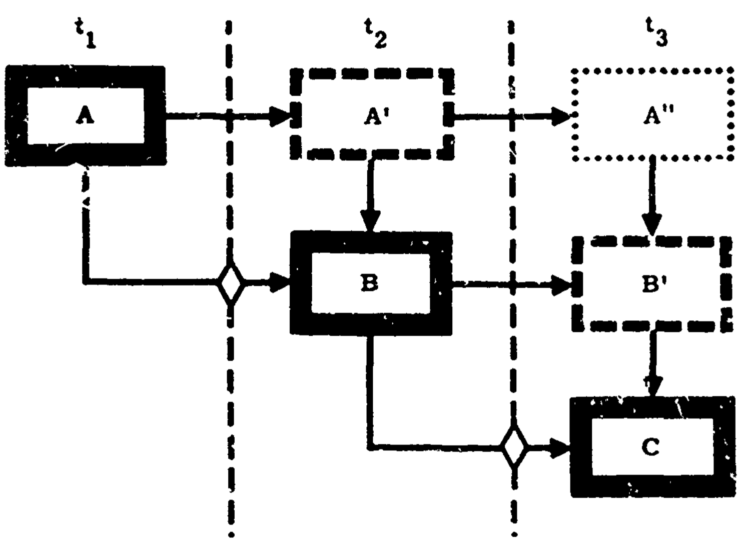

Figure 2b. Paradigm for a Stepped Progression: Sequential Salience and Ordering of Determinants.

Social Effects and Their Indicators, as Ordered by a Fallout Shelter System

Even with the analytic simplification introduced by the four observable target systems (Figure 1) and the metaphor of the stepped progression (Figures 2a and 2b), there is one additional decision which must be made before a sequence of social effects can be traced after attack. This decision must be in answer to this question: What countermeasure systems will exist during and after attack to reduce the ranges of variability which might occur in the kinds of social effects and their interplays that are to be expected after attack? In the analysis of what may happen after attack, perhaps the most crucial feature of a large-scale civil-defense and emergency-operations countermeasure system is that it represents a point of reference as well as an element of stability, within a system of events occurring in a social system.

For example, in considering whether mass panic may occur during and after attack, the existence of a shelter system makes the situation confronting potentially fleeing individuals different from what it might be if there were no shelter system. Without a shelter system, the conditions of panic will occur as a result of seemingly chance interactions between individuals and rapidly changing environmental conditions across the whole range of situations possible within a target area. With a shelter system, however, many individuals will have a means for reducing the chance operation of a threatening environment. Ironically, in the short run, a shelter system may increase the likelihood of mass panic, in that as individuals converge toward what they see as the entrances to safe points, they may see themselves as being blocked from attainable safety, and their alarm may become uncontrollable. In contrast, without shelters, there may be a greater number of locations at which small-group panics could occur, but fewer opportunities for massive pileups at entryways to apparently safe locations. The advantage of a shelter system lies, though, in the prospect that once individuals have been introduced into the shelter system, most of the difficult-to-control conditions of mass panic have been eliminated. Without a shelter system and its accompanying social organizational forms, the social and physical conditions for panic will continue to exist for some time within target areas, with consequences which can magnify other kinds of social effects.

As a general principle of postattack social planning, it is the performance and effects created by particular potential alternatives, policies, strategies, or systems in a social and physical environment that largely determine the significance of the different categories of social effects which planners must consider in the first instance. Seen in this light, the kinds of social information which postattack planners require are not simply information which describe all society in all of its potential states. Instead, this information should be in the form of indicators of both social conditions and social processes which are created by attack. Even though they may also have the power to describe society in more general ways, these indicators must express the relations between the subjects or beneficiaries of a measure, the social and physical environment that measure is intended to influence, and the effects both intended and unintended which the measure creates.

Clearly the most significant single countermeasure system presently planned and being implemented for civil defense and emergency operations in a post-nuclear-attack environment is the fallout-shelter system. As all familiar with the issues point out, without elementary population survival from weapons effects, there is little point to other planning and countermeasures. Nevertheless, the social functions and social effects of a fallout-shelter system appear to create a specific temporal order of social effects which planners for the postattack should consider. The most effective way to consider these effects would be through a system of social indicators which would depict the ways in which a fallout-shelter system orders the social effects of attack and creates a characteristic social inventory.

In the last section of this paper, the characteristics of a system of social indicators for managing the social inventory after attack will be considered in their most general form. That steps toward the creation of such a system of social indicators be undertaken is the major recommendation of this paper. But before outlining the general characteristics of a system of social indicators of attack effects, it may be useful to try to show how particular sets of potential social effects create particular kinds of needs for indicator information in postattack planning. Consider now the ways in which a fallout-shelter system appears to order the social effects of attack and to create a characteristic inventory of social possibilities.

<u>Specifying Particular Social Effects</u>

An analysis of what happens in society after attack must be simultaneously comprehensive and selective. It must be comprehensive in the sense that recognition must be given to the occurrence of social effects in each of the different target systems that comprise organized social life. It must be selective in the sense that some way must be found for avoiding the need to consider everything at once. Among the different categories of social effects that might be considered to be important, how can attention be directed to the most significant ones to consider in planning?

One solution to these problems is to recognize that there are characteristic time periods which define an attack and its consequences.

Most analysts of nuclear attack divide the period of nuclear attack and its aftermath into at least four periods: the preattack period, the transattack period, a period of shorter-term reconstruction, and a period of longer-term recovery. This temporal division recognizes that before certain effects can emerge and certain things can be done, things earlier in time must happen. In studying the occurrence and interdependence of social effects as influenced by a fallout-shelter system, it is especially useful to divide the time over which attack effects are expressed into four time periods divided by a brief transitional period. Here, the time of study begins with the warning and impact period, when individuals take shelter or receive alerts of the likelihood of attack elsewhere, and experience the attack itself. This period is followed immediately by a shelter period, during which individuals remain in shelters or, if outside attacked areas, organize themselves in response to the attack and its effects. The end of the shelter period is marked by a brief transitional period of emergence. For different localities, this period may come at different times. Furthermore, there may be several such periods, of increasingly longer duration as lingering weapons effects decrease in intensity. Upon final emergence from shelters the society enters a period of reorganization, during which scarce resources must be allocated and policies for reorganizing social life be developed, implemented, and modified in response to events. Assuming this reorganization period is successful, the society enters a period of recovery, which may be seen as the attainment of both shorter-term and longer-term recovery objectives.

The central theme in the analysis that now follows is that for each of these postattack time phases, there is a characteristic target system of society to which postattack social analysts and planners must give special attention. The basic characteristics of a fallout-shelter system require that for each postattack time phase, a particular target system becomes the principal locus of critical social effects. As time passes after attack, and effects in an increasing set of target systems are manifested, a lattice of relationships and determinants among social effects is created. The form and rate of total societal recovery will be determined by the specific relationships that exist among the various levels of effects in this lattice.

Figure 3 shows how, for each major period of time after attack, effects in one or more of the four basic target systems become important concerns for postattack social planning, policy, and management. By reading from the left across the horizontal dimension of this figure, it is possible to follow the cumulative effects of a shelter system from the warning and impact period to the period of shorter- and longer-term recovery. For ease of reading, the postattack time periods are shown to be equal. By reading down the vertical dimension of the figure, it is possible to see for any given time period what target system or

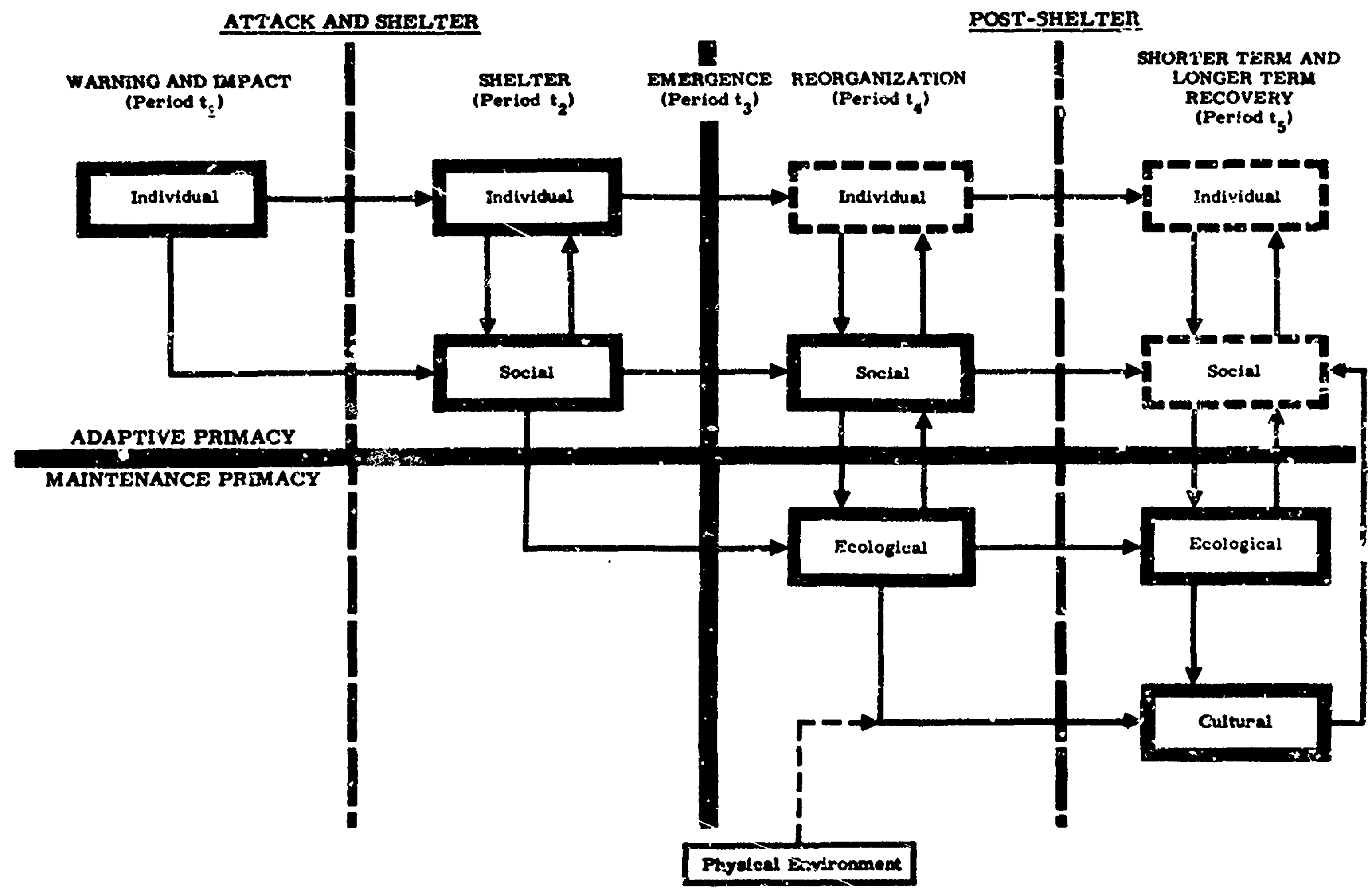

Figure 3. Relations among Determinants in a Sequential Ordering of Postattack Behavioral Domains: Constraints on a Shelter System.

systems constitute the most significant source of social effects for that period. The device of flow-chart arrows is used to suggest linkages of cause and effect among the target systems which are operative sources of significant social effects for each time period. In cases where the cause-effect relation is one-way, i.e., all horizontal relations through time, the intention is to show how one target system is the necessary precondition for the emergence of another target system as a significant source of social effects or for the continuation of that same target system as a significant source later in postattack time. Where the cause-effect relation is two-way, i.e., within particular time periods following warning and impact, the intent is to suggest that in certain particulars, the causally linked target systems stand in a reciprocal, mutually interdependent relation of cause and effect at any given instant of postattack time.

Warning and Impact

For the warning and impact period, individuals taken alone and in aggregate are the most important sources of transattack and postattack effects. For areas of attack impact, the most significant single determinant of postattack social effects will be the power of the shelter system to create a postattack population of individuals with specific attributes. By definition, a shelter system is designed to shelter individuals and groups of individuals. The larger the actual attack, the more the final composition of the whole population of society will be determined by the effectiveness of the shelter program, and the more the basic skills and capabilities of the postattack society can be predicted from the characteristics of the sheltered population. Those factors which govern the ways in which individuals take shelter during warning and which determine the kinds of individuals which are in shelter at the start of attack are, therefore, the most urgent subjects of any social policies which would attempt to shape the composition of the population which might survive attack.

For the warning and impact period, then, the most urgent preoccupation of postattack policy and systems designers must be to try to project the collection of individual attributes that will survive in the postattack population. The most critical single body of social information needed for this purpose is a group of demographic indicators which can describe the attributes of the population that will enter shelters, will exist inside and outside shelters, and will be available for postattack reconstruction. Upon this body of indicators depend all subsequent estimates of the population resources which can be made the basis for any postattack social policy.

In computing these population resources, the special uncertainties created by the conditions of warning and impact require specific attention, from the point of view of both systems designer and social analyst. The characteristics of the surviving population may, for specific local areas, be markedly influenced by the efficiency with which a population can take shelter. While the probability of mass panic in the face of nuclear attack is often exaggerated, it is during the warning and impact period that the specific conditions which are known to be associated with panic are most likely to arise. Mass panic is likely when (1) there is "an immediate, extreme danger that is perceived to be ambiguous in its consequences and uncontrollable by any adaptive human action" and where, most important, there is (2) "a belief that there is only a limited route to escape (or a limited time in which to escape) and that this route is closing."[7] The growing realization that these conditions would be created by many of the earlier plans for tactical evacuation of major metropolitan areas was certainly a factor in the shelving of these plans by civil-defense authorities.

But the problem of anticipating conditions that could lead to panic is still present in various forms. At its most simple, the problem is one of trying to insure that even with an expanded community-fallout-shelter program, the rapid inflow of individuals to shelter spaces can be so managed as to avoid the classic, known, situational conditions which could lead to sudden threats, pileups in queuing, and panic behavior. At its most complex, the panic problem evolves into a general set of population-management problems. While extremely short-term tactical evacuation has been largely abandoned as a major social-management policy, strategic evacuation of cities during periods of mounting crisis may offer some benefits. One of the more compelling reasons for a carefully phased policy of evacuating selected elements of a metropolitan population would be to avoid just those situational conditions of panic that would be present in a sudden attempt to move the varied population elements of a complex metropolitan area.

Any carefully phased, strategic-evacuation program is actually a more general population-management program. This becomes clear if two likely variants of a general program are considered. One variant could be based on the principle of evacuating all dependents from central cities to some set of suburban locations ringing the cities. The immediate consequence of this policy would be, for that increasing number of American cities with substantial Negro populations, to place government authorities in the position of enforcing rapid and at least short-term racial integration in largely white suburbs. Another variant could be based on the principle of total evacuation of central cities. If this were attempted, where would the thousands of jobs located in central cities be relocated? Would such relocation be feasible in any practical sense? If it were, it would be necessary to expect a major redistribution by areas of the characteristics of the metropolitan population, as both workers and dependents adjusted to the required new living patterns.[8]

Control of panic or orderly population movement requires a number of social organizational skills which direct attention to forms of social organization that exist beyond the individual. As these examples suggest, however, there is often a very close relation between measures for controlling the ongoing behavior of masses of individuals and measures for determining the basic composition of a population and, thereby, many of its capacities for social organization.

Shelter and Emergence

While the capacity of individuals to be systematically organized will contribute in important ways to mobilizing and safeguarding the population during warning and attack, the social system as a source of social effects becomes a dominant concern during the shelter period. For both the sheltered population and the population outside shelters, breaks in the social systems which form society will have their first major consequences at this time.

The recognition of this already exists in the steps which have been taken to provide sheltered populations with organizational manuals, clearly organized survival facilities, and the general rudiments for organizing communities within shelters. Given physiological minima required for survival, perhaps less important than particular plans for shelter management are any general measures which will provide some social structure to a group thrown together. The most critical needs confronting the sheltered population will be (1) to allocate scarce survival supplies strictly and judiciously; (2) to care for large numbers of injured and dying individuals, while coping with the special subjective threats created by radiation exposure and by the occurrence of deaths at close range; (3) to contain a variety of emotional reactions, which may range from passivity to overt acting out of frustrations and anxieties; (4) to obtain information about damage outside the shelter and about required times for emergence; (5) to maintain morale, especially as time in shelter lengthens and the emotional consequences of bereavement, fears of life outside shelter, and uncertainties about the future begin to build.[7] Each one of these critical needs can be met only by solving social organizational problems in the shelter, for meeting each individual need requires resources which can be made available only through imposing a coherent group order.

Among the most important sets of social-structural indicators of the degree to which these problems can be solved are measures of the extent to which individuals will carry preexisting social relationships with them into shelters. The fewer of these preexisting relationships that exist within a group, the greater will be the organizational requirements imposed within the shelter community. While there may be certain advantages to starting some shelter communities anew, this does not diminish the crucial need to learn far more than is known now about the kinds of ties that will carry over into the shelter from offices, family kin networks, voluntary organizations, informal community organization, and other forms of social organization. It is a striking fact that there has been little research on the kinds of carry-over social-structural relationships that may exist in different types of sheltered populations -- and on the consequences this may have for not only short-term survival in shelters but also for effective emergence into a postattack environment.

For the nonsheltered population in relatively safe areas, perhaps the most crucial social organizational requirement will be to control tendencies to converge toward attacked areas, while simultaneously to hold individuals and resources in readiness to meet total societal recovery goals.[7] For this population, the principal social-system effects of attack are likely to be, in the first instance, the disorganization of these capacities, particularly through the breakdown of communications, the sudden increase in competing demands to allocate men and resources, the flow of rumors, and the development of ambiguous descriptions of the situation confronting society, in the absence of governmental capacities to describe and to control what is happening.

For both the sheltered and nonsheltered populations, there will be a common social organizational problem, in the requirement to determine when and how to emerge into or enter damaged areas. Pressures will exist on both types of populations to enter these areas prematurely. For both populations, the critical social organizational requirement will be to define the properly phased entry of individuals, teams, groups, and larger collectivities into a threatening physical environment. Since there will be many physical, emotional, and social-policy needs to deal with this disordered environment, it is more than speaking metaphorically to say that the principal initial source of order to be imposed on this environment must come from the orderly behavior which depends on those social organizational capacities of the individuals who are moving into it. For this reason, for the emergence period or entry from safe areas, the most critical body of social information required by authorities will be indicators of the extent to which small social systems can withstand or are withstanding the stresses of moving into and organizing uncertain environments.

Reorganization

During the post-shelter period of reorganization, effects on the level of the ecological system of society join effects on the level of the social system as critical concerns for policy, while overt concern with the individual system as a subject of policy will recede somewhat. For the first time since attack, the main social-policy concern shifts toward a preoccupation with maintenance of the society, instead of with the kinds of adaptations individuals and small social systems must make to attack effects in the short run. During the time of reorganization, the critical policy problem is to use not only the physical but also the social resources which have survived the attack and shelter periods. As a problem of social policy, this problem of organization centers on the complex relationships between, on the one hand, requirements to maintain a stable and growing human population in balance with its physical environment and, on the other hand, the requirements for maintaining a total social system which can meet its own functional requirements.

The most dramatic single general requirement for social organization in this period is meeting the conditions of the race for economic viability. The problem of maintaining and using economic inventories reaches its critical form. Production must recover to "a level adequate to support the survivors before the grace period afforded by surviving inventories comes to an end."[9] The more efficient shelters have been in saving lives in the short run, and the less adequate the protection to survival and recovery inventory items, the more bitter this race is likely to be.

It is in the perspective of such key requirements as those imposed by the economic-viability race that it is possible to evaluate the significance of general social effects and social requirements in the reorganizational period. While such phenomena as crime and other forms of social deviance are often seen as representative of the kinds of social problems that will be of increased major concern after nuclear attack, the most significant social issues are, instead, those which result from the decreased ability of the general social and population system of society to meet its functional needs. In the economic-viability race, for example, one central social issue is whether depletions in the labor force can be met from other sources. Assuming attack conditions under which there were unexpected, excessive losses of males, it would be reasonable to expect entry of large numbers of women into the labor force. But the factors governing the entrance of women or dependent minors into the labor force are imperfectly understood for many conceivable situations. At what point does the entry of women into the labor force depress the population growth rate to unacceptable levels -- particularly when in the short term, labor-force requirements may appear more critical than restoring population growth rates? The parallel issue for dependent minors is to determine at what point the removal of youth from the educational process, in order to meet needs of the labor force or military service, will critically deplete the long-term educational base required for a technical-industrial society.

Here, also, the problem of orphans can be seen in larger perspective. The orphan problem is illustrative of the kinds of needs for restoring basic social relationships that will exist in the reorganization period. During the adaptations imposed by warning, impact, attack, and shelter, short-term adjustments to broken social ties must be made. As the society moves toward restoring its preattack institutional forms, however, short-term adaptations to meet purposes of immediate survival must be replaced by restoration of social relationships which can meet functional needs of individuals and groups. Deferring the issue of whether shelters will become the nuclei for new forms of permanent social organization, it is necessary to ask in what ways the specific needs met by families, voluntary organizations, schools, churches, minority ethnic-group-cultural systems, patterns of participation in daily jobs, and other specific forms of social organization can be met during the reorganization period.

From the point of view of those who would plan for the social requirements of the reorganization period, probably the gravest single present deficiency in social information required for planning is the lack of both indicators and models for describing the full range of primary and secondary ties that are functionally critical to restoring a self-maintaining and relatively decentralized society. This deficiency reflects the current state-of-knowledge about the social structure of American society.

Shorter-Term and Longer-Term Recovery

As time after attack lengthens, it becomes increasingly difficult to link consequences of a particular countermeasure system and damage to particular social target systems. This is especially true of social effects expressed in terms of the cultural system. Elements of the cultural system of the society will affect behavior at all times following attack. Indeed, starting within shelters, the population may be rallied in terms of shared values, which can be evoked intentionally or unintentionally, by formal communication-command-control systems as well as by informal patterns of social control. Many of the decisions which must be made before attack by planners and after attack by operators will be assessed against cultural norms. As a unified system, however, the cultural system does not become critically salient to planning until the period of shorter- and longer-term recovery gradually begins. Then, the effects of a total set of responses made at different levels of the society can be discovered and assessed. This assessment can be performed as political dialogue is restored; one of the most critical signs of long-term value changes will be the extent to which value conflicts arise over the degree of government involvement and institutional mobilization in postattack society. If they occur, these conflicts are likely to be over the desirable conditions of maintaining a complex social and industrial order; it is highly unlikely that society will regress to a more primitive cultural state.[7]

It is in both predicting and monitoring the emergent-cultural forms during longer-term recovery that the study of social effects following nuclear attack becomes most difficult. There are few actual descriptions of the American cultural system which are based on nationally valid, specific data. Even the kinds of elements that constitute the American cultural system are matters of controversy and continuing discussion.[10] Therefore, in trying to determine the effects of nuclear attack on American culture, the social analyst and planner confront lack of clarity about what it is that is changing, great problems of measurement once it can be decided what it is that is changing, and all of the social risks that attend probing the values and styles that characterize a people. The justification for formal attention to these task lies ultimately in the need to subject the long-term recovery of society to scrutiny by its citizens. Just as restoration of political dialogue is an opportunity for determining the kinds of value changes that may be underway in the society, so is the periodic political evaluation of social trends one of the surest signs that highly valued preattack institutional forms have been preserved. Given the magnitude of the social changes that may be required in response to nuclear attack, the social planner has a particular need to be able to examine the basic cultural results of these changes. This is so even when the tools he uses may increase citizens' awareness of the social changes that have occurred, and thereby make it easier for the citizenry to criticize and, ultimately, even to reject planners, managers, systems, and plans.

SOCIAL INDICATORS OF ATTACK EFFECTS: A PROPOSAL

Up to this point in this paper, the discussion has followed two main directions. One has emphasized the kinds of specific social effects which should be of concern to postattack planners. The other direction has emphasized the deficiencies in knowledge about social effects, and what might be done to remedy some of them. While much can be said about the kinds of social effects which ought to be of practical concern, it is evident that many of the most important questions planners will have in the future can be settled only by developing methods for looking at the ways groups of social effects may unfold over time and influence each other. Thus, to answer the economist's questions which began this paper, it is necessary to know the kinds of social organizational demands that will be put on people after attack. It is not enough to speculate that people will not be motivated to work. Far more important to know are the ways in which the composition of the postattack population and either the existence or the rupturing of postattack social ties may create demands which interfere with the kinds of individual behaviors required to sustain the economy. Similarly, the demographer's, physical ecologist's, and health specialist's questions require address at a level which enables consideration of the ways in which damage to the social, ecological, and cultural systems of society create particular kinds of social policy problems.

It appears, therefore, that given the present state and prospects of knowledge about postattack society, one of the most significant investments of social-planning resources that could now be made would be in the intensive development of a method and system for describing the various levels of society in ways which would permit the rapid calculation of the effects of different kinds of countermeasure systems in protecting the elements of society from different kinds of possible attack. The purpose of this final section of this paper is to outline the desirable general characteristics of this system. The system proposed here is a system of social indicators which would be incorporated in a National Social Inventory for Civil Defense.

The Problem of Measurement

Before there can be any kind of indicators of phenomena in the real world, a number of problems of measurement must be resolved. For the study of possible social phenomena following a nuclear attack, the most important problems of measurement begin in these questions:

1. What social entities and processes are affected by attack?
2. What are the most useful and accessible indicators of changes in these entities and processes?
3. What can be known about those critical points within measurable ranges, at which social entities and processes change in ways significant for policy and countermeasures design?
4. What analytic devices are available for selecting important social variables and social phenomena from among the potentially vast array of social effects which can be imagined and considered as potential subjects for policy and countermeasures?
5. What additional resources, in the form of data, methods, and models are required before reputable answers can be ventured to these questions?

Because of the potential breadth of this study, the researcher confronts in unusually direct and pure form the requirement to select the important conceptual entities before he begins measurements in a broad arena of subject matter. In a general sense, the most important immediate problems of postattack social research are those of creating the meaningful conceptual antecedents for significant quantitative measurements of variables in both present and future time.

The Social Inventory

As a first step toward achieving a conceptual organization of post-nuclear-attack social effects which can form the basis for policy and systems design, it is useful to take a new look at the real significance of the whole range of potential postattack social phenomena. From the purely scientific point of view, these phenomena constitute a complex set of facts which, taken together, would represent what is left of capacities for individual behavior and social organization, as well as those discrete acts of individual and collective behavior which are responses to attack. From the point of view of the potential, postattack planner and administrator, however, these social effects constitute the social inventory available for recovery, or, more carefully expressed, they are indicators of what is in that social inventory.

Social inventory here has an even broader connotation than economic inventory in the postattack setting. After attack, problems of managing the economic inventory center on the survival and reorganization phases. As Sidney Winter puts it, "In the reorganization phase, the central problem will be that of getting production restarted and up to the level required to meet essential demands without drawing down inventories."[9] Crucial to achieving economic viability in these terms is stabilizing inventories while meeting essential demands and creating capital resources for reconstruction.

In conceiving of a social inventory, it is necessary to conceive of not only an inventory of existing individual, collective, and institutional capacities whose condition is known by specific indicators of surviving states of their components, but also of an inventory of assessable general capacities of individuals and social organizational forms to meet postattack problems and generate new lines of social development. These general systemic problems and systemic capacities require more general indicators for their assessment. The power of the concept of a total social inventory after attack lies in the requirement that researchers and planners take states of the preattack social system as the necessary starting point for computing surviving, relevant social resources and for evaluating the social phenomena consequent to attack. Instead of centering attention on speculative attempts to predict analytically unrelated but dramatic postattack social problems, the social-inventory concept requires the analyst to think of the ranges of ways in which the preattack social system may be translated into capacities for postattack behavior and social organization. But if the social inventory is to be more than a metaphor, ways must be found for labeling and measuring its elements and their interrelations.

Social Indicators

It is in this specific set of measurement problems that postattack social researchers join their concerns with those of an increasingly large group of analysts who are trying to develop techniques for assessing present social policies and programs in terms of measurable states or conditions of the total social system and its key elements. These developments which are now occurring in the social methodology for government policy represent several lines of evolution.

One of the most important of these lines is the attempt to generalize the budget and program evaluation methodology developed in the Department of Defense since 1960 to all sectors of the executive establishment. Called "potentially the most significant management improvement in the history of American government," the Planning-Programming-Budgeting System (PPBS) has directed the attention of planners and analysts toward the kinds of both direct and indirect outputs which result from budgets, programs, and policies.[11] Instead of directing attention largely to lists of budget and program inputs, this concept of budgeting and programming emphasizes the comparison of alternative potential streams of direct and indirect outputs in relation to a total relevant spectrum of criteria for costing and for allocating resources. Necessarily among the most critical sets of indicators for comparing these outputs are, therefore, indicators of the various states of those social sectors which are affected by policies, programs, and systems. Influencing states of total sectors within a total social system -- or at least recognizing and measuring effects of programs in these sectors -- has increasingly become a necessary goal for program planners and administrators. Evaluating impacts of alternative programs in terms of larger social aims has increasingly depended on tools of social analysis which can provide systematic comparative information on possible alternative future states of these social system sectors. But, in the words of Gross and Springer,

> " ... it soon became clear that among the weakest links in these benefit-output-cost analyses was the lack of... social 'data that are comparable, systematic and periodically gathered'. No conscientious budget-examiner could rely uncritically on the data presented on education, mental illness, crime, delinquency, transportation, and urban problems by scores of competing bureaus anxious

to justify budget proposals of their future contributions to the 'public interest'. Thus, the logic of the new budget system originating in the pioneering work of cost-benefit economists pointed unmistakably toward an enlarged role for transeconomic information particularly information bearing on the 'quality of life'."[11]

Paralleling this development in programming and budgeting, and in part a response to it, has been the movement toward creating a "Social Report of the President" which would reflect a broadened methodology of social accounting. Such a report would present information on the extent to which a total range of individual human and collective social capacities has been developed in American society. It would grapple with stating the kinds of social goals which might inform policy and which might be used to compare alternative social futures to be created by policy. In creating the basis for such a report, one of the most important -- and potentially most controversial -- organizational innovations in government could be the development of an integrated bank of national social data.

Underlying these and other lines of evolution has been the need for the development of new categories of information on the states of the various levels and problems of American society. In short, the need has emerged for a new and conceptually integrated system of social indicators.

Social Indicators and Social Effects of Attack

Since a system of social indicators would provide measures of pre-attack states of the social system, it would necessarily provide an analytic baseline for considering changes in the social system during and after nuclear attack. At the same time, the analytic problems encountered in constructing a system of social indicators for the pre-attack social system carry over into constructing such a system for post-attack society. In fact, one of the probable advantages of approaching the problem of measuring the social effects of attack through a system of social indicators is that what seemed to be distinctive problems created by attempts to project attack effects are largely problems inherent in creating any kind of analytic construction about states of the social system.

Among the most important general characteristics a system of social indicators of attack effects would share with a general system of social indicators would be these:

1. Emphasis on distinct entities. The indicators would be measures of the states of conceptually distinct social

entities, processes, or problems, where such can be meaningfully isolated.

2. Indices of complex interactions. The indicators would provide indices of the values of those interacting sets of social variables which would be required to describe complex social system states.
3. Indices of social change. The indicators would provide indices of social change, in not only certain traditional sectors of social problems, but also in those general institutional processes which provide the framework for social life. In other words, the indicators would provide a variety of trend data.

Among the most important distinctive emphases of a system of social indicators developed to meet needs for appraising social effects of nuclear attack would be these:

1. The ability to assimilate multiple analytic levels. The indicators would assimilate multiple analytic levels where necessary. For example, in the key problem of social-damage assessment, indicators of the traits of social areas would be developed, so that changes in these traits could be directly computed or estimated from the damage done to corresponding physical areas. That is to say, for physical-space tracts which can be expressed in standardized terms, there would be a set of social indicators capable of establishing in comparative terms the surviving social characteristics of each tract after attack.
2. The ability to accommodate time-dependence of effects. The indicators would acknowledge the time-dependency and sequential ordering of the most salient social effects. Obviously, measures of numbers of individual survivors are needed soon after attack. But what other critical social resources and social problems become operative later in postattack time?
3. The ability to establish postattack social alternatives in terms of social goals and priorities. The indicators would provide comparative information which could be used to provide assessments of alternative uses of resources in the postattack social inventory. Such information would require a much clearer idea of postattack social priorities, goals, and social contingency options than presently appears to exist.

With a general system of social indicators, a system of postattack social indicators shares these problems:

1. The problems of disaggregation and relevance. How can the social information upon which indicators are to be based be disaggregated, so that those social processes central to both stability and growth or change in society can be studied as distinct but general problems? How can administratively convenient data be supplemented or replaced with information about such processes?
2. The problem of conceptual ordering of discrete indicators. How can analytically discrete measures of social states and processes be combined into an integrated view of larger institutional and social system processes? What kinds of conceptual models are available? What kinds are needed?

General Types of Social Data[7]

In general, there are four types of social data from which indicators might be constructed:

1. Data on the aggregated attributes of a population. These are obtained by "performing some mathematical operation upon some property of each single member. The mathematical operation may be adding, percentaging, averaging, and so on. Examples of aggregated attributes of a population are proportions of persons of different ages, proportions of persons subscribing to different religious beliefs, and so on."[7] These are among the classic data of demography.
2. Data on rates of behavioral precipitates in a population over time. Examples of such data are rates of voting, religious attendance, crime, suicide, and collective protest. "While at this level, like the first, the investigator deals with the properties of individual members of the social unit, he conceptualizes the properties as a flow of behavioral precipitates within a specified period of time rather than a stock of attributes that may be said to characterize a population at a given point in time."[7]
3. Data on patterned social interaction (social structure). These are obtained by performing analytic operations on information about the relations of the members of a population to each other. "The difference between regularities in a population's attributes and behavioral precipitates on the one hand, and its social-structural arrangements on the other, lies in the way the notions are conceptualized. Social structure, unlike the other two, is conceptualized on the basis of relational aspects among members of a social unit, not on some aggregated version of attributes or behavior of the individual members."[7] These relations are governed by social sanctions and social norms.

4. Data on cultural patterns. These are global properties which characterize whole social units; "they are not based either on aggregated information about individual members of a social unit or on specific relations among the members."[7] As a type, these data are probably the most difficult to define and obtain.

Needed Data for Indicators of Social Effects of Attack

With these types of basic social data in mind, it is possible to outline some of the data which would be required for establishing the beginnings of a linked set of social indicators of attack effects.

Following the analysis of the sequential dependence of social-attack effects which are associated with conditions created by fallout shelters, an outline of social indicators of attack effects begins with the individual. In fact, most social-damage assessment today is confined to the individual as the target. That is to say, social-damage assessment is principally confined to demography based on counting aggregated attributes or changes in rates of behavioral precipitates. Among the aggregated attributes counted are numbers of survivors, surviving age and sex distributions, and surviving levels of occupations and skills. Among the rates of behavioral precipitates that are projected are changes in fertility and mortality rates.

For the individual as a target system, the problem in constructing indicators of attack effects is to supplement the kinds of counts that are taken and rates that are generated. Particularly required are attribute data on background characteristics which may be correlated with the ability to withstand attack stresses. These would include data on educational and ethnic background and on attitudes characteristic of different groups in the population. Required data on behavioral precipitates include estimates of the likely incidence of civil unrest and social deviance.

The object of a full set of indicators based on individual characteristics would be ultimately to derive general indices of individual vulnerability to attack.

Indicators of the social effects of attack expressed in terms of the social system are largely lacking from present social-damage assessments. Such indicators can be based only on data which reveal the relational properties of individuals. The capacity to engage in and sustain social-organizational patterns after stress depends not only upon individual skills in maintaining these relations but also on the kinds of preattack relations individuals have experienced and which they can carry over to the postattack world. Social-system indicators of attack effects would be based on estimates of the kinds of social relationships in which each significant population group participates. For groups with known relational properties, attack damage to social structure would then be calculated on the basis of the number of relations lost as the result of the loss of individuals.

Even more elusive are indicators of social effects of attack expressed in terms of cultural patterns. Because they are data on global properties of collectivities, they are hard to derive within existing methods. How can indicators of changes in knowledge systems, values, characteristic perceptions and assumptions about the real world, and patterns of meaning which guide both individual life styles and total social organizations be derived and used? Probably such indicators will depend on first establishing associations between known cultural patterns and particular attribute, precipitate, or relational characteristics and, then, inferring patterns of cultural change when corresponding attribute, precipitate, or relational indices change. But the methodological problems in trying to develop indicators of changes in cultural patterns should not mask the importance of such changes. Any planning assumption about the ability of the society to preserve its basic values assumes that indicators of attack effects expressed on the level of cultural patterns can be developed and used.

Developing indicators of effects in the ecological system is a problem intermediate to the simplicity of counting aggregated attributes and the difficulty of developing measures of cultural changes. Estimating the surviving population base of the ecological system is a straightforward problem of counting. On the other hand, estimating the ability of a human population to maintain itself in a physical environment appears to require development of measures of relation and dependence between the population and nonhuman, environmental resources. At this point, the boundary of the social scientists' ability has been reached.

In summary form, the general data characteristics of a system of social indicators of attack effects appear as in Table I.

<u>Organization and Implementation of the Indicators System</u>

The general data characteristics which have just been outlined for a system of social indicators of attack effects constitute the basic requirements for the content of what might be called the National Social Inventory for Civil Defense. The actual construction of capacities for such an inventory could follow several lines of possibility. One obvious starting point would be through adding data categories, attack programs, and counting routines to the counts currently conducted by the National Resources Analysis Center. The requirement that new indicators of social effects be developed concurrently with the basic survey research on the characteristics of American society suggests, however, that

TABLE I

DATA CHARACTERISTICS OF A SYSTEM OF SOCIAL INDICATORS OF ATTACK EFFECTS

System in which effect expressed	Required type of data
INDIVIDUAL	Aggregated attribute; Behavioral precipitate (rates); Relational.
SOCIAL	Relational, but as measured through attributes of individuals.
CULTURAL	Global-collective characteristic pattern; Attribute of individual, as basis for inference of pattern.
ECOLOGICAL	Aggregated attribute; Behavioral precipitate (rates); Relational, involving dependence of individuals on resources.

a National Social Inventory for Civil Defense should be established with close connections to the social-welfare sector of government and to universities and other research facilities which have been concerned with the development of basic social information. Possibly the National Social Inventory for Civil Defense could be established as a component of a proposed national social-data bank. The problem with waiting for this development of a national social-data bank is that important national defense purposes may be deferred, while debates over the political acceptability of the national-data bank unfold. In view of the possibility of protracted discussions of a national social-data bank, it would probably be better to begin construction of a National Social Inventory for Civil Defense by extending existing capabilities within the national security sector of government.

In many ways, the central theme of this paper has been that enough knowledge of probable social effects of nuclear attack now exists to justify a much broadened inquiry into what they may be under a full variety of conditions. For this reason, this paper has emphasized the prospects and requirements for learning more about social effects, even though there are many specific findings presented throughout the discussion. An important subsidiary theme has been that the development of postattack social knowledge will be closely tied to developments in general knowledge about human behavior and society.

In many respects, problems of developing social indicators of attack effects are special cases of larger problems of social measurement under noncrisis conditions. But the special nature of the postattack social research as a basis for potential postattack social management can be more clearly understood if two concluding cautionary notes are kept in mind.

First, a nuclear attack of significant scale would create rapid changes in the values of a great many social variables. For this reason, old data baselines would be less relevant than new baselines drawn from postattack conditions. To establish these baselines, a system of applying social indicators to the postattack world must have a continuing capability for conducting both general and special inventories and assessments. Of particular significance would be the capability for conducting trend analyses of changes, based on studies of postattack panels of individual respondents.

Second, it is conceivable that the preattack development of a system of social indicators would represent a commitment to analytic constructs and measures which could prove less relevant than expected to managing postattack social conditions. For this reason, there must be the possibility of redefining social variables and indicators on the basis of postattack experience. One of the most subtle challenges postattack officials may face is to be able to modify the fundamental intellectual tools with which they approach a stressful reality, without losing a sense of the necessary relations this reality has with a pre-attack world.

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POSTATTACK ORGANIZATIONAL PROBLEMS AND SOCIETAL VULNERABILITY

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Some opponents of either passive or active antimissile defense have questioned whether our society, if subjected to a massive nuclear attack, could preserve the values and institutions traditionally associated with the American way of life. Such questioning is extremely difficult to respond to either objectively or persuasively, because it raises issues with intense emotional associations and places a difficult methodological burden on anyone inclined to an optimistic position. Putting aside the problem of reaching agreement on a definition of the American way of life, the optimist has a graver problem of providing assurance that there can exist no subtle and unsuspected "Achilles' heel" that could, if attacked, bring down the U. S. sociopolitical system as a whole or its economic substructure or that could set in motion a chain of developments that could threaten that system.

More than a decade of research on the possible effects of conceivable attack has failed to disclose any physical damage that could present an insurmountable obstacle to the survival of part of our population and to the eventual reestablishment of a viable economy. The most devastating single hazard that has been discovered thus far is the possible loss of all gasoline refining and diesel-fuel production. This would deny us the use of most locomotives, trucks, and automobiles, could virtually immobilize the nation; and would greatly degrade the productivity of surviving industrial capacity at least for the early postattack period.

Herman Kahn, Donald Baer, and others pointed out long ago that more than 20 percent of the manufacturing capacity of the country, as measured by value added, lies outside the Standard Metropolitan Statistical Areas (SMSAs). All significant industrial targets are within the SMSAs, except possibly for a few key railroad bridges or tunnels, major hydroelectric plants, and critical industrial facilities, chiefly petroleum refining. The dispersed industry outside the SMSAs should largely escape damage and, after any necessary decontamination, could be put back in service. The economic life of the country might have to be based on that dispersed industry plus that in any SMSAs that were missed. The exact nature of that fifth of our capacity with fairly well-assured survival is not well-established but all industrial sectors (down to the 3 and 4 digit Standard Industrial Code (SIC) classes) are represented. We can thus count on at least one-fifth of preattack capacity in most economic sectors.

On the other hand, in the case of a pure counterforce attack, the collateral damage to port cities and SMSAs near military targets could range from 10 to 20 percent of preattack capacity, and this places a lower limit on total damage except from accidental or casual detonations. Although the range of damage established by considering these extremes is very broad, it precludes complacency on the one end of the scale and despair at the other.

These limits on damage are significant because they establish relevant facts about institutional and organizational problems that would arise after an attack. These problems are most serious in the heavy damage extreme but could be more affected by loss of mobility than by loss of other capacity. Even in the case of a light counterforce attack, organizational problems arise that could greatly retard recovery if not resolved expeditiously.

Studies of the vulnerability of key networks such as water, power generation and transmission, communications, and transportation systems have not disclosed any reason to expect that damage could deny essential use of these services on a restricted basis within a few days or at most a couple of weeks after an attack. Studies of agriculture, food processing, primary metals, and petroleum have similarly indicated that surviving inventories and surviving productive capacity for these critical industries could meet austere minimum requirements until additional production could be provided. However, the margin of safety is so small and the shortages of products or services from these key industries would be felt so generally that mismanagement could lead to complete economic collapse. The recognition of this fact has led to continued attention to postattack-recovery management in general. Even casual consideration of the management problems raises political and social questions that have yet to be resolved.

The question raised at the outset concerning secondary effects on American institutions and the urgent questions of adapting our political and economic structure to the pressures of the early post-attack period are difficult to answer because of the lack of an applicable theory of social change. The difficulty comes from lack of appropriate observational data or precedent on general disaster and from lack of a suitable methodology for analyzing alternative organizational policies. These needs have resulted in a series of studies sponsored jointly by Office of Civil Defense (OCD) and Office of Emergency Planning (OEP) in the areas of total vulnerability and recovery management. The objectives have been to develop methods for identifying institutional problems that could result from massive attack and for analyzing alternative countermeasures. Without going into the admittedly unsatisfactory methods used, it would be useful to state some of the conclusions reached and support these with heuristic arguments.

The severity of organizational and institutional problems would increase with the general level of damage but the problems would be present in almost any case. They would be greatly magnified if the nation were seriously immobilized. They could also be magnified by poor leadership; however, they would be present in any case because the need for quick response to the unfamiliar environment would conflict with the normal cultural lag that inhibits social change. The social problems of greatest importance are rather immediate consequences of widespread damage to property and casualties to the population, but the immediate social problems give rise to unsatisfactory political and social situations that could produce more fundamental changes. None of the immediate problems would necessarily threaten our basic institutions but the environmental changes would be so great that threats could readily develop.

Even in the light counterforce case, losses would include severe damage to perhaps $100 billion worth of housing and an even larger amount of industrial facilities. Casualties would number in the tens of millions. Immediate problems would relate to medical care, emergency housing, and restoration of vital utilities. Individuals, businesses, and, in particular, savings and loan associations would have lost assets and many would become insolvent by normal standards. Stated national policy promises some form of loss equalization, to the extent that this would not impede recovery, but the mechanism for implementing this policy has not been agreed on. Indecision on this point could lower morale but more significantly could bring into question the solvency of other enterprises dependent on or financially interested in those suffering heavy loss of assets or security. The shift from preattack conditions to an austere postattack economy would be accompanied by a great and sudden change in effective demand that could bankrupt other businesses. Although in the light attack these changes would barely exceed in importance those associated with a mobilization for general war, they would have occurred overnight without giving the economy any chance to adjust. The changes would undoubtedly force the government to invoke standby price freeze orders, rationing, and emergency economic stabilization and control procedures. Such involvement of the government in the economy, however well-motivated and however carefully introduced, would add further uncertainty to an uncertain business climate. The great numbers of casualties, evacuees, orphans, and the temporarily disemployed would create immediate social welfare problems and reduce the utilization and productivity of the surviving labor force. Even with multiple shift operations in essential industry, it is almost certain that these various problems and general economic uncertainty would degrade gross national production far below rated capacity for surviving facilities. The first organizational problem is to arrest this economic downturn and assure full utilization of available capacity and labor force.

Existing plans for postattack rehabilitation entail (1) an initial phase under the control of OCD and local disaster officials, operating in Emergency Operation Centers (EOCs) throughout the country and responsible for alerts, mass instruction, movement to shelter, radiation monitoring, damage assessment, emergence from shelter, decontamination, debris clearance, and restoration of vital utility services; (2) an interim phase during which local agencies (under authority delegated by standby legislation or the emergency powers of the President and the state governors) would disseminate rationing evidence, promulgate price- and rent-freeze orders, take stock of surviving foodstuffs or other essentials, and generally control the economy until the federal government has reconstituted itself and established agencies and organizations for continued recovery management; and (3) a continuing phase of federal control based on the Office of Defense Resources (ODR) and its associated Office of Economic Stabilization (OES). These agencies would act as prime sources of policy or guidance and as arbiters among the traditional federal departments and agencies. The third phase would include the implementation of all necessary economic controls, including manpower controls by the Department of Labor, and the application of the Department of Commerce's Business and Defense Services Administrations (BDSA) managed Defense Material System (DMS) to all allocation of critical materials to industry.

Aside from the question of whether economic controls are ever effective and efficient, such controls in their detailed implementation would place heavy burdens on corporate management and the federal government alike and could quickly escalate to even greater interinvolvement of business and government. The postattack environment would bring many shortages, but the so-called critical materials controlled under the DMS plan would be least likely to be in short supply in the crucial period after emergence from shelter. Plant facilities and production equipment would constitute the immediate prime shortages aside from drugs, medicinals, and other essential survival items. Materials, skills, and productive capacity needed for the bill of goods included in plant and equipment expenditures would be secondary shortages under the circumstances. The major coordinating effort of ODR would concern plans for decontamination, repair, conversion, and replacement of productive capacity -- in normal times a prime responsibility of corporate management. The heavy involvement of ODR in planning for restoration of capacity would represent a development in the history of business-government relations that would greatly exceed all past wartime precedents.

The lack of well-established prices, and hence of costs, in any rationally based postattack value system greatly complicates the analysis of trade-offs and of decisions among alternatives. The disruption of national markets by damage, by increases in real costs of transportation, and by artificial price controls would further obscure real costs, increase uncertainty as to the probable course of managerial actions, and decrease the effectiveness and appropriateness of corporate and government decisions.

Uncertainty about solvency would raise uncertainties as to authority and responsibility. Uncertainty with respect to sources of supply would complicate production planning. Shifts in demand would require drastic reorientation of industry at a time when risk taking would be most discouraged by general uncertainty. Unusual incentives and guarantees would be needed to induce adequate responses from business, if detailed government controls were to be avoided. Preparations for such detailed control would require organization of a new federal field service much larger than anything contemplated or politically palatable in normal peacetime. Finally, all the uncertainties mentioned would combine to disrupt normal arrangements for establishing credit and for enforcing contract performance.

If the institutions of private property, credit, and sanctity of contract were weakened by general lack of confidence and by removal of part of the basis for mutual trust in business, societal ramifications would follow. These could arise even in the case of the light counterforce attack. In the heavy immobilizing attack at the other end of the damage spectrum, all such effects would be greatly magnified. Moreover, environmental changes would have considerable impact on the lives and attitudes of individuals. Loss of housing would require recourse to billeting and doubling up in households. Lack of local transportation would make commuting a concern for plant management and might require creation of mass feeding arrangements and improvised barracks for workers near their places of employment. The wide variety and rapid proliferation of welfare problems would quickly saturate federal agencies and force plant managements and local officials jointly into unfamiliar responsibilities for community welfare planning. Some line of demarcation would have to be drawn between local agencies and federal authorities, but little thought has been given to the details of this problem or for preparing any skeletal organizations for probable postattack roles.

In time of peace, the political climate is not suited to elaborate plans for recovery management and for the creation of standby organizations. This is to be expected and perhaps should be accepted with some degree of relief. Little can be anticipated about the details of postattack decision alternatives, real values and trade-offs, and methods of determining them. Any preattack attempt to develop detailed plans and doctrine would fail so completely to reflect actual postattack conditions that rigid plans prepared in advance would probably prove ridiculous if not disastrous. What is needed are flexible plans capable of being quickly adapted to actual circumstances. Staffing to implement such plans must ultimately depend on an overnight expansion of a cadre of professionals by the addition of a great number of amateurs. For this expansion to work, education and exercise of the professionals would be necessary as would a better recognition of the true nature of the postattack-recovery-management problems.

Recovery management could require attention to such detail (e.g., plant conversion, product-mix decisions, food distribution, reshuffling of residences and places of work, mass feeding, car pools or commuter bussing, day nurseries, community construction, victory gardening) that only local agencies could be in a position to learn the pertinent facts. On the other hand, matters affecting more than one local area or more than one state could not be left to the discretion of local decision-makers. Local pressures would be too intense to expect local agencies to respond to national interests. Centralization, say in ODR, of major decision-making, formulating and publicizing of national goals and policy guidance, and general coordination would be essential as a counterbalance to delegation of considerable responsibility to local emergency agencies. Present plans call for an ODR field service, extending at least to the OEP/OCD regional offices, with responsibilities for coordination of efforts by the states, for liaison with central ODR headquarters, and for regional decision-making. No adequate staffs or facilities have been provided as yet, even on paper, for the regional offices, and the plans for state participation are just beginning to be worked out The apparent evolution of a four-echelon system (geographically speaking) and a departmentalized field service (following the structure of the executive branch of the federal government) seems to have been dictated more by peacetime political realities than any consideration of postattack requirements. A federal echelon is essential to preserve national interests, a local echelon is essential for practical management decisions, and a state echelon is essential for political reasons; however, the case for a regional echelon is based or current expediency and could prove transient under postattack developments. Proper training of regional office staffs could augment the central cadre of professionals and provide experts for the guidance of organizational developments at state and local levels. On completion of this initial mission, such a cadre could easily be absorbed into the state or federal organizations.

Organizational plans for recovery management are good as far as they go, and they go about as far as they can at present. It should be recognized, however, and remembered that they fail to reflect postattack needs adequately and would need great elaboration immediately after the attack. Present insights into probable postattack conditions must be sharpened considerably before organizational and informational requirements can be determined adequately, and this is a legitimate concern of postattack research in the preattack period. Various methods could be exploited to aid in preattack analysis and training. Simulation exercises with a very small number of selected players could be used, for example, in a war-gaming approach as a diagnostic and analytic tool. Economic research directed toward the development of substitutes for market-determined prices could be a second example.

In all such research, due consideration should be given to the institutional aspects of the situation--to the obstacles to rational decision-making that might arise from malfunction of traditional arrangements and mechanisms. Business decisions are normally made in response to and in anticipation of gradual change, but with free use of assumptions of "other things being equal." An attack would produce abrupt changes not only in industrial capacity but in needs, effective demand, and the attitudes and motivations that govern them. Although the changes would occur abruptly and would be followed by secondary shocks, it could take many months to identify and measure them. What decisions would face the postattack-recovery manager and what are the possible consequences of alternative courses of action? Qualitative and cursory examination of this compound question has chiefly elaborated on the question without providing definitive answers. It has suggested, however, that the crucial decisions--those that could greatly affect the evolution of institutions, the time required for recovery, and the chances of national survival--would all have to be made early in the postattack period, chiefly in the first month or two. This would leave little time for getting organized or for bureaucratic procrastination. It virtually requires that most of the relevant analyses be made in the preattack period and filed for immediate postattack updating. While rigid organizational planning is not desirable in the preattack period, contingency planning is feasible and essential. Again this contingency planning could resemble contingency war planning in its case-by-case approach, but it would examine economic trade-offs rather than military ones. Details would not be appropriate here even if they were available, but the general approach can be illustrated by mentioning representative case problems: selection of a product-mix for a plant, scheduling plant construction and equipment installation for a capacity expansion project, examining possible alternatives to restoration of a key location or city, registering voters and holding an election, or finding ways to increase the self-sufficiency of a local area. Such problems should all be considered in the light of possible or probable postattack conditions.

Much has been made of the fact that shelters and other passive defense measures save people but not facilities and thus could lower postattack per capita income--possibly to the range of from 10 to 20 percent of preattack levels. At the heavy end of the damage range, this could mean occupancy rates of ten families per housing unit, no transportation of any kind, complete lack of privacy, and subsistence rations. Under such circumstances, morale could be maintained only by exemplary leadership and by persuasive evidence of progress toward a better future. These conditions require responsive local agencies, firm national policy, and decisive action. The full psychological or sociological impact of the initial shock of an attack has been debated among behavioral scientists with ambiguous or divergent conclusions. The impact of prolonged immobility, loss of privacy, and privation has received less attention but might prove to be more significant for producing institutional change.

Thus far, we have stated general conclusions without supporting evidence. In part, these conclusions flow from consideration of the implications of anticipated attack damage viewed in its entirety. To follow a systematic approach to the organization of scattered bits of intuition and information, an attempt was made to prepare a description of the U. S. sociocultural system which, as defined, is composed of three major subsystems, one social or cultural, one political, and one economic. This analysis was extended to identify different types of input and output variables entering or emanating from about 20 subsystems or institutions. Analysis of possible secondary effects of an attack on the variables of these institutions served as a net for discovering possible problem areas. The intent was to examine these in detail and, if found significant, to look for countermeasures.

Subsequent work has maintained this institutional emphasis but has concentrated on a few specific organizational problems relating to the economic system or the political system. These were:

1. Solvency of individuals and business entities.
2. Mobility of money and credit.
3. Succession of business management and corporate organization.
4. Problems of reestablishing normal business channels.
5. Legislative imbalance at federal, state, and local levels.
6. Problems of reestablishing normal election machinery.

A report now available in draft form discusses these problems and their implications for the assessment of national vulnerability. The findings indicate that none of these problems poses insurmountable difficulties, but each requires prompt attention and appropriate or equitable resolution within the first two months of the postattack period. The postattack period would require unprecedented interaction between government and business with business participating in quasi-governmental activity, particularly at the local level, and government engaged in quasi-industrial decision-making particularly at the federal level and in connection with facility construction. It would also require a greatly increased role for local business management, that is, at the plant-management level. Concomitant with this effort was a study of information requirements for coping with institutional problems identified and those needed for proper coordination and guidance of economic recover efforts. Attention was directed primarily to information needed for monitoring the effects of actions taken by governmental bodies at federal, state, and local levels and for providing business management with the over-all information it needs for making business decisions in the absence of undistorted indicators of economic developments.

The break in traditional economic time series and the need for drastic reorientation of industrial efforts in the postattack period would greatly restrict the amount of information available and expand the amount needed. The imposition of controls; the need for well-directed investment by government, business, and private individuals; and the dominating economic significance of government public works expenditures for projects in the general interest would all complicate the decision process. These factors are all highly relevant to information requirements for policy determination and for day-to-day operations in the first several months of the postattack period. Information requirements have thus been studied with such factors in mind and in the light of available information on plans for ODR, OES, and other relevant government agencies at federal, state, and local levels.

These studies give further support to the general conclusions presented in this summary. The pricing problem confronting any agency concerned with recovery management--the problem of estimating real costs and benefits involved in trade-off analysis of alternatives--runs throughout these studies as a major methodological obstacle to definitive quantitative recommendations. The lack of an established theory and body of knowledge concerning the formation of beliefs, attitudes, values, and opinions of segments of the population is an all-persuasive methodological obstacle to a full discussion of societal vulnerability. While the latter problem reduces confidence in predictions of the postattack evolution of familiar institutions, the pricing problem is likely to be of greater concern to harassed decision-makers in the aftermath of any nuclear attack.

ON REORGANIZING
AFTER NUCLEAR ATTACK

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A PERSPECTIVE FOR POSTATTACK RESEARCH

Spasm Wars and Civil Defense

It may be useful to examine some of the conceptual approaches to postattack research with the assistance of Figure 1. Part A of this figure shows a time-scale for contemplating civil defense problems broken into the three intervals: peace, war, and recovery. From 1945 to approximately 1960 most analysis of civil defense problems was pursued within this framework which assumes that a nuclear attack would be a strike out-of-the-blue and would allow only from minutes to possibly several hours before any region experienced hazards of the nuclear attack. This establishes a preconception that, for nearly any aspect of survival or recovery, any countermeasures must be taken during times of peace.

Even assuming the validity of Figure 1-A, practical difficulties arise. The large sums required (billions) have not been obtainable and probably will not soon be.

Deferred-Cost Civil Defense Programs

In the late 1950's some analysts began to examine cases in which a war was preceded by a period of international tension (Fig. 1-B). This possibility seemed to have a number of military consequences. As more studies began to consider this alternative, the notion became increasingly widespread that nuclear war preceded by crisis was not only not unreasonable but might be much more probable than a sudden war (Fig. 1-A). It has since been argued that if a choice is necessary, Figure 1-B should replace Figure 1-A as the standard basis for defense planning.[1] This perspective has persisted up to the present and has won wide acceptance among strategists, although in some studies not much more than lip service seems to be given to the concept, while the analysis mainly proceeds on the basis of Figure 1-A.

For civil defense, the acceptance of a crisis period as a basis for research and planning complicates the picture by introducing many

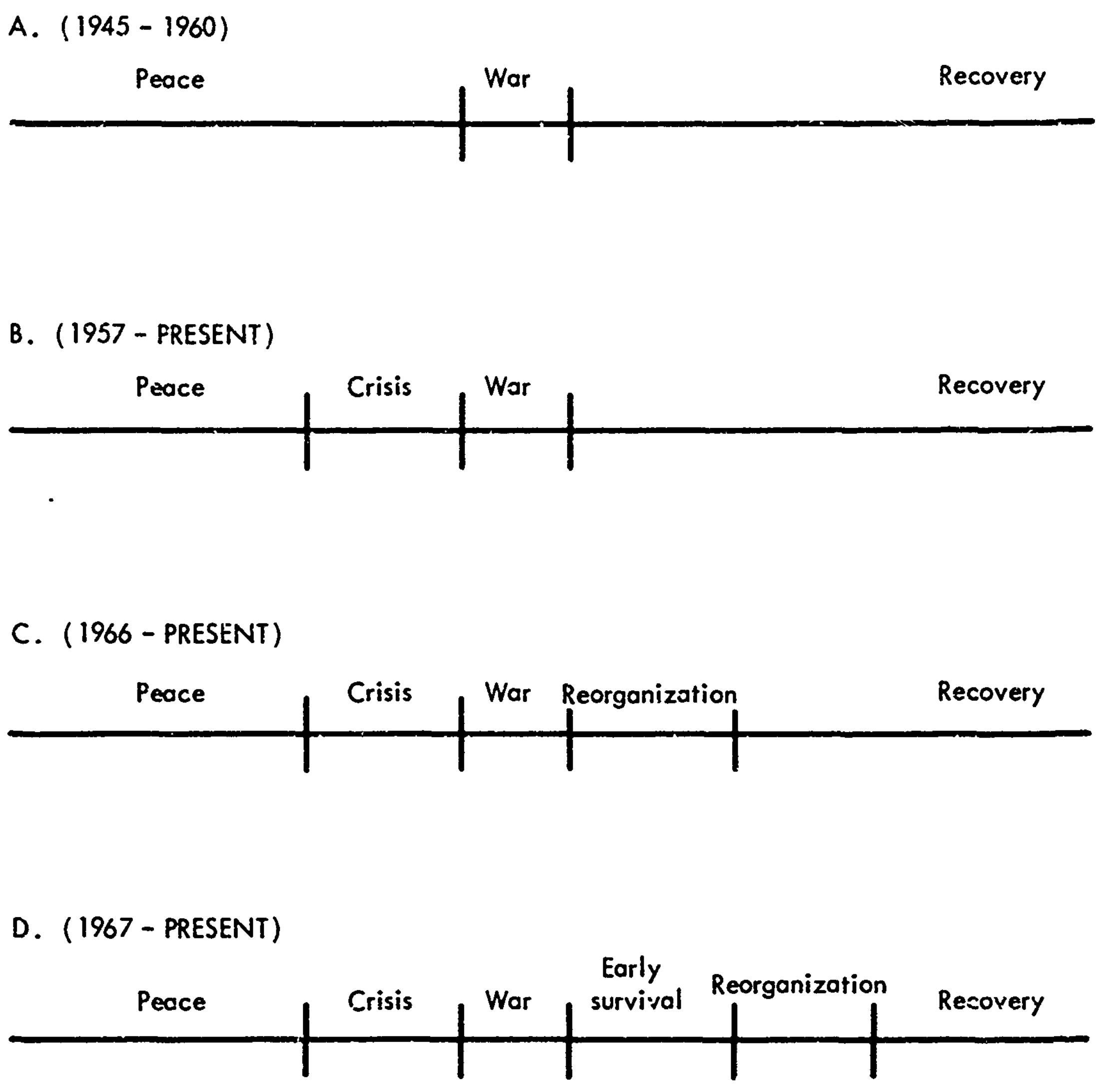

Figure 1. Bases for Defense Planning.

new response options. However, as a positive aspect, it enables analysts and planners to see a potential for designing low-cost systems which may enable nearly all the U. S. population to survive a nuclear attack.[2] Even survival in the 95-99 percent range does not now seem a ridiculous outcome for attacks in which a few thousand megatons are directed against urban centers. In addition, and of most importance for this conference, the visualization of Figure 1-B opens new ways to think about effective recovery planning.

The basic notion is that the systems for survival and recovery need not necessarily be built during peacetime. Figure 1-B implies that plans might be made in peacetime for a general emergency mobilization of the population which, during the crisis interval, could provide the labor and material resources to build rapidly the civil defense system. Presumably, a reasonable portion of effort during this interval would be allocated to phasing in measures which would improve our ability to recover.[3] A tantalizing aspect of this concept is that it introduces the possibility of deferring to the time of need -- when, presumably, funds would be readily available -- the major costs of systems which, if built in peacetime, might cost tens of billions of dollars.*

The argument is that at the present time civil defense seems to have little choice, if it is to obtain a highly effective defense, but to adopt a deferred-cost plan based upon rapid mobilization of the skills and physical resources of the nation. Thus, not unreasonably it would seem, a next logical step in the development of civil defense would be to add a capability, through preplanning, to phase in an emergency mobilization of the population in response to a future nuclear emergency.

<u>Postattack Reorganization Period</u>

Creeping into current postattack research is the orientation shown in Figure 1-C. The main point is the introduction of the reorganization period.

Some previous studies of recovery have concentrated on the reorganization required in a single institution, e.g., government, petroleum, steel. Generally it has been concluded that none of the problems

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* Of course the costs at the time of need may be greater than those involved in the construction of a peacetime system. Whether the system would be more or less effective than one constructed in peacetime would depend upon the factor of obsolescence and the specific war-outbreak scenario under which the system would be "tested."

are insurmountable, and that usually special preparations can be made which would speed up the recovery. However, what may be valid if problems are handled singly may be false if many problems must be solved simultaneously. For example, it is usually assumed, implicitly, in such studies that (a) the government is intact, (b) money and inflation problems are not important, (c) credit is available, (d) prices and wages have been settled, etc., etc.

Although going from Figure 1-A to Figure 1-B gave us a framework with a greater potential for solving some survival and recovery problems, the concept of Figure 1-C further complicates the postattack picture by introducing a need to worry about the reorganization phase. We find it conceptually distinct from any study of recovery which assumes that the surviving population can function without having to solve some basic organizational problems first. It will be argued that reorganization problems precede and may dominate the question of postattack economic viability. If this is correct it should follow that these problems deserve high priority in future postattack research.

It should be apparent that the effective functioning of long-term recovery plans would first require that the economic reorganization has been effectively accomplished, certainly to the extent that (a) certain elements of the federal government have been restored; (b) that a functioning money system exists; and (c) that the manpower can be obtained for the implementation of the emergency government functions. Subsequent discussion will point out that these conditions may be difficult to meet in some environments and that if they are not met a major postattack threat would exist.

POSTATTACK SOCIETAL PROBLEMS

One worry is that while there may not be sufficient survivors or capital for recovery to take place readily,[4] perhaps the social disorganization would prevent the effective use of the remaining assets and society would disintegrate by losing its "identity."

We will attempt to define this potential threat to postattack society by presenting a number of allegories or metaphors. Hopefully, this approach will add some clarity, improve our perspective, and thereby help decide whether this matter deserves increased emphasis in future research.

Environmental Shock and Personal Identity

The structure of human personality may be defined by the continual reinforcement of its identity through daily experiences. That is, by frequent interaction one comes to believe certain people to be friends, acquaintances, or enemies; one knows what work he can or does perform by his employment, hobbies, and chores; one knows humor by the events that amuse or entertain him and others. Without conscious thought one "knows" many of his functional rules, such as father, husband, gardener, accountant, commuter, skier, Catholic, Republican, neighbor, driver, voter.... Each of the major roles themselves break down into a set of functions. Thus, without having to think, it is important to know how to get breakfast, how to respond to routine questions, how to fill out forms, how to drive an automobile, how to go to work, how to react to a greeting, what a buzz on the intercom means, how to buy supplies for work and home, what to expect in a restaurant, or theater. There are thousands of daily functions by which an individual establishes his current identity. These functions are supplemented by the simple recognition, through the senses, of a house, lawn, mountain, tree, river, road, person, typewriter, violin, fire, perfume, etc. -- all of which help remind us of who we are. The point we are trying to illustrate is that in a major sense, a person's identity is established by a frequent sensory reinforcement of his past experiences.

Therefore, it is not surprising to find that many, if not most or all, persons who are subject to various degrees of unusual sensory experience-- for example, natural disaster, sensory deprivation, drugs-- will experience a partial, in some cases nearly total, change in personality which we may call loss of identity if it occurs suddenly. This effect in clinical or medical jargon is expressed as depersonalization, psychotic break, hallucinatory experiences, etc. Sensory deprivation experiements have shown that some people are strongly affected by such experiments; others are much more resistant.

This description of possible loss of identity through sensory deprivation, for our purpose, is meant to be allegorical and to express what we fear could be a parallel in postattack recovery. Thus, a sudden and somewhat massive extinction of functional identity may occur among most of the surviving population during or after a large nuclear attack. Individuals and families removed from familiar surroundings, employment and recreation would be deprived of their usual roles. One threat is that such a person may degenerate into a kind of listless behavior, for example, of the kind which has often been associated with occupants of camps for displaced persons. Another threat is that many individuals may revert to a more primitive, uncooperative, or aggressive behavior leading to riots, gangs, and general lawlessness, possibly leading to a breakdown of law enforcement in many areas -- if not the whole country.

Institutional Identity

The identity of an institution, like that of an individual, is generally slowly changing and therefore can usually be easily recognized over short periods of time - months or years. The identity is composed of such things as financial assets and liabilities, employees, buildings and location, products and services, management, internal procedures, and traditional relationships with other institutions. The expectation that change will not take place too suddenly or too massively for a reasonable adjustment to occur is important to the preservation of its identity. Thus, if employment changes very rapidly, shock waves travel through the institution and threaten injury. Also, an institution can be shocked by a sudden change in demand for its output as occurs when war or peace breaks out or an unexpected economic recession develops. If one large firm goes bankrupt, others related to it may fall like dominoes. Certainly, a single massive or sudden change can and often has killed an institution. Some are so fragile that they are not even adaptable to the ordinary slow changes of peacetime, e.g., in 1965 about 13,000 economic firms were bankrupted in the United States.

We are going to ask what may happen to institutional identity under the impact of a nuclear attack and what the implications are for postattack society. As the reader may suspect, under many conditions the answers may appear to be very grim. At least in the word picture to be presented the grimness will be deliberately emphasized in order to stimulate reflection on the threat.

The postattack institutional identity will be affected by what we may term its tangible and its intangible vulnerabilities. The tangible ones include (a) physical damage, (b) loss of personnel, (c) loss of demand for its product or services, (d) unbalance in supplies, fuel, or utilities. The intangible problems tend to be socio-economic or politico-economic and affect institutions whether damaged or not; they could have a much greater impact on the ability of the nation to recover. They may be composed of such matters as:

(1) Loss of credit or solvency.
(2) Confusion as to property rights among survivors.
(3) Legal problems of debts and unfulfilled contracts.
(4) Meaningless wage contracts or salaries.
(5) Temporary collapse of government or government authority.
(6) Temporary suspension of banking.
(7) Temporary suspension of the judicial systems.
(8) Wild fluctuations in prices, rents, expectations of future prices.
(9) Civil disorder arising out of spurious distribution of surviving supplies and surviving capital.
(10) Confusion in communication compounded by rumors often leading to local breakdown in law and order.

Postattack Scenario

This section offers a more specific image of the reorganization problem by presenting a brief postattack scenario. This scenario assumes that no special countermeasures were taken before the attack. It deliberately emphasizes many dire developments, which cannot logically be excluded, in order to attempt to "feel out" a few horrible, but not impossible, postattack outcomes.

We focus upon a small textile mill in "Parville," an undamaged Tennessee town: preattack population about 40,000; postattack population about 150,000. The attack against cities was about 2,000-MT. Most city people are assumed to have survived through an emergency evacuation and the use of improvised fallout shelters. Four weeks after the attack (late summer) the following situation prevails:

1. Uncertainty About Present and Future:

It is not clear whether the fighting will resume. The federal government is a shambles. Washington, D. C. is destroyed. Little provision had been made for emergency postattack operations for the federal agencies.

2. Radiation Threat:

The fallout threat is under control. Most people have left areas of intense radiation. There is confusion and some hysteria about radiation poisoning, but most people have learned to estimate the threat and are not frightened by low levels of radiation.

3. Presidential Rumors:

The President and Cabinet survived in an emergency shelter but his current location is not known. Various rumors claim he has been killed, murdered, imprisoned, committed, hospitalized, emigrated, etc. Actually, the President has been silent because he believes there is a high probability that knowledge of his whereabouts might bring another Soviet weapon on the United States, aimed at him, since the Soviet Premier was killed in Moscow.

4. Food:

There are severe food shortages in many localities and bartering of labor and supplies for food is becoming widespread. People are generally loath to accept money for goods, especially food, at almost any price. It is widely feared that money is and will be useless. Food hoarding is widespread. Surviving banks remain closed. People without food are forming into action groups. Rumors flood into every community about the location of food stockpiles, private or public, resulting in treks toward these areas.

5. Civil Servants:

It is difficult for the surviving remnants of the government agencies to get their personnel back since they have no current means for paying them except by checks -- in the old, now nearly worthless, currency. Most of their employees are out looking for food and supplies and would be difficult to find, even if someone tried. No solid information exists about when or whether a functioning federal government can be reconstituted.

6. Early Riots:

About 50,000 people arrive at Farville, between September 15 and September 30 looking for nonexisting food stockpiles. Friction develops between these people, many of whom now believe the residents have already hoarded the stockpiles in secret caches. Riots develop during October 1 and 2, in which a thousand people are injured and three hundred buildings and homes destroyed by fire. The rival groups improvise internal organizations for action and self-protection. Because of time pressure and hostility, effective communications between them is almost impossible. Appeals for state and federal intervention are unheeded because the remnants of government are already buried under a discouraging avalanche of other urgent tasks. The resolution of the local conflict finally comes through a dispersal of both groups to other areas in search of food.

7. Managerial Problems:

The owner of the mill contemplates his problems in trying to restart production He finds:

(a) many of his former employees cannot be located;
(b) there is much labor available but no one will work for money-- a gallon of gasoline trades for about $50.00 and a can of corn for $70.00;
(c) the banks are closed and no ones knows when or if they will open or even what the banks' business will be if they do open;
(d) he has no useful idea of what factory supplies can be obtained, or when, or how much they may cost, or even what "cost" means;
(e) he has no sales for his merchandise nor any reasonable way of getting any soon, at least that he is aware of. Besides

he would not know what to charge for any of the mill's products if he were asked;

(f) he does not know whether he will be solvent or bankrupt when a new balance sheet can be calculated, if it even can. Thus, he reasons, any firm that might attempt to deal with him may be similarly unreliable. Certainly credit cannot be extended -- nor could he expect to get any -- even if stable prices developed for which he sees little hope;

(g) to help resolve his dilemma, he looks to the local Chamber of Commerce, which in turn looks to the town government, which looks to the county, which looks to the state, which looks to the federal, which is not functioning effectively and some fear is threatened with imminent collapse.

8. Food Distribution:

Although there is no over-all food shortage in the country, the extreme problems in distribution, aggravated by a nearly universal tendency to hoard, have caused food stocks to disappear from usual wholesale and retail distributors. People flock to the farming districts to obtain whatever food they can, which is then either hoarded or bartered.

Because of a shortage of gasoline, there is a huge demand for bicycles, wagons, carts, and beasts of burden for which animal feed is locally available. The farmers are complaining that shortages of gasoline are threatening their capability to harvest, plant, and fertilize mechanically. Some are predicting that the next year's crop may be a disaster because of this threat and because of some shortages of pesticides and fertilizers. Also about half the cropland is considered too radioactive to farm for the next several months.

9. Some Federal Problems:

Economists agree on the need to reestablish confidence in federal money -- that is, to create an expectation of stable and reasonable prices for goods. But there is no agreement on how to bring this about in time. The federal government is losing its remaining authority rapidly. Rumors abound about currency reform, banks, damage compensation, welfare, starvation, renewed enemy attacks, epidemics, and bacteriological warfare. The government is blamed for the lack of preattack preparations, for getting into a nuclear war, for their current incapacitation, and for hoarding food.

10. Military Dilemmas:

The armed services are threatened with disintegration since their normal channels for supplies have been disrupted and it is not clear how these can be reconstituted. Factories producing munitions are closed, food suppliers are not operating, and teamsters will not work for their preattack contractual wage, if there were goods to transport. Also, there have been reports about extensive hijacking.

In addition, most servicemen are worried about their families and are requesting leave, even though transportation is uncertain. They are also grumbling because their pay has become meaningless. The armed services are afraid that if the men do leave, they won't get them back and if they don't leave that they won't be able to feed them.

11. Changing Values:

Law enforcement, preattack style, has become meaningless in most areas. Local police in food-rich communities help defend the status quo against outside mobs which in turn may have police assistance from evacuated or food-poor communities. Primary loyalties are to the local group and its leaders who are focusing first on the group's short-range needs. Violence is common when these groups meet. Pitched battles have occurred accentuating the nuclear disaster and inducing survivors to devote a substantial portion of their effort to the problems of local security.

Fear and rumors increase the instability of the accident-prone situations and frequently lead to unfortunate clashes triggered by misconstrued information. Suspicion of outsiders grows to include all of the nonlocal-government efforts -- especially those efforts which attempt to requisition supplies from the relatively undamaged regions without offering solid or acceptable compensation.

12. Prognosis:

The country is on the verge of a second major disaster -- a collapse of all but local community authority with little prospect of an early reestablishment of the preattack constitutional structure. The prevailing expectation among the pessimists is a total shattering of the country into numerous independent groups which over years -- perhaps decades -- would have to evolve a new federation into the "second U.S.A." The optimists are hoping that a federal authority can be reconstituted through the imposition of martial law -- an action which is made difficult by the magnitude of the problem, the inexperience of the army, the weakness of federal authority, and the widespread factionalism and loyalty conflicts within the military forces.

EMERGENCY ACTIONS FOR POSTATTACK RECOVERY

In the preceding sections the two prominent points were: (1) that reorganization after nuclear war could be very difficult; and (2) with small budgets for peacetime planning, much might be done during a crisis to enhance postattack recovery. The first point was illustrated through metaphors and by a stark postattack scenario. The second point suggests actions that can be taken in a crisis, e.g., stockpiles, training, policies,[3] may include countermeasures against the threats of the postattack reorganization period.

Stockpiling during Crises

If one visualizes a severe nuclear crisis of weeks or months in duration, during this period stockpiling could become a necessity, that is, a natural consequence of traditional prudential thinking. Thus, if plans did not exist which would facilitate stockpiling, efforts are likely to be improvised at the time.

There come to mind three major ways in which such stockpiling could be emphasized during a crisis period. They are:

(1) Increasing production.
(2) Reducing consumption.
(3) Increasing imports, and reducing exports.

Thus, production can be increased by a more intensive use of labor for the military mobilization and for survival and recovery. A substantial increase in this production may be possible by increasing (a) hours of work per shift, (b) number of shifts per day, and (c) days of work per week. This development might require a substantial shift in labor to the more critical industries and an increase in the total labor force.

For example, it may be desirable to greatly increase the production of pesticides and fertilizers. To anticipate this would be important both to the factories that produce these products and to their suppliers. Indeed, it may be important for many chemical plants to be able to shift some of their normal production into these raw materials. Thus, the rubber industry might find a decreasing demand for tires and, if it has the expectation soon enough, could shift some of this capacity to insecticides.

The second major way by which we may gain resources for emergency stockpiling is through reducing consumption. In part, some natural reduction should occur with the shift of manufacturing into new products. For example, we would expect that in industries which produce machinery whose value must be amortized over many years, sales would be diminished as the crisis became more severe. This could imply reduced production of standard producers of durables such as automobiles, trucks, railcars, ships, buildings, turbines, or office equipment.

Rationing may be advisable in order to obtain stockpiles rapidly and still maintain an equitable distribution. For example, if it were possible to store large quantities of petroleum products, e.g., by returning gasoline to formation through selected abandoned wells, then the government might wish to reduce consumption to, say, half-normal during the extreme portions of the crisis. Rationing might also apply to the control of food products if the government policy wished to discourage the development of individual hoards.

The third area in which stockpiling can be effective is that of imports and exports. In view of both the threatened vulnerability of stockpiles within the United States, and of transport limitations, it might be advisable to place orders with foreign countries for goods to be delivered to storage depots within those countries themselves. This could assist the rapid build-up of stockpiles of important materials which later could be shipped and distributed as transportation became available.

Although crisis stockpiling seems to be a useful concept, one which would appear even more important during a nuclear threat, the creation of stockpiles for recovery may be relatively less important than the creation of an organization which can effectively manage the stockpiling needs during and after the crisis period. This, we believe, is an important point. If accepted it should stimulate more detailed study to understand the potential to create rapidly a great organization which (1) would develop as required by the mobilization; (2) would be competent to carry out the measures needed to enhance survial and recovery prospects; and (3) would become an entity which, if needed, could take over the major management functions of the postattack reorganization period.

Emergency Supports for Postattack Currency

This section suggests that the feasibility of economic recovery may depend upon the existence of a new support for postattack currency. We argue that the major emergency support (or replacement of) the dollar could occur through a nationalization of the food industry.

The previous discussion has led us to worry about the danger of not being able to emerge intact from the reorganization phase. As we see it, this existence of an effective federal government simultaneously implies a functioning civil service, which in turn implies a reasonable short-range confidence in the value of a federal currency acceptable to the public. Thus, we argue, the federal government needs personnel, personnel require usable money, usable money demands that we have, or are confident we soon will have, an effective federal government. The argument thus seems to be a loop which, once broken, may not lend itself readily to reconstruction. It is somewhat analogous to the simpler chicken and egg story; to get one we need the other. If its personnel disappeared, the government and the money system would also vanish. If the government lost its authority, its personnel would leave and the dollar would collapse. If the dollar collapsed, the personnel could not be paid and would have to leave, and the government would then disappear or lose its authority.*

If this argument has merit, it is not at all clear that, once collapsed, the federal organization could be reconstructed in anything like months or even years. This postattack environment would probably witness independent, competing, and perhaps feuding regions. Civil war could follow -- civil war which could be either intra- or interregional. The problems of visualizing a functioning society developing out of this environment are so complex and at the moment seem to be so unrewarding that we turn instead to our purpose of examining the preparations needed to prevent the occurrence of such unpleasant possibilities.

It seems that we would need to take appropriate actions to assure the simultaneous continuing viability of the three factors in the government-personnel-money loop. Certainly formal government authority

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* This argument is based on a simplified model of interdependence and examines a pure case in order to make the stark point about the loop of interdependence. While any reality situation would be probably very much more complex involving partial losses of personnel, or severe inflations rather than total collapse, nevertheless, our deliberate purpose here for an initial orientation is to consider very extreme cases which may be nearly the same as the pure one. It is clear that in many historical cases, monetary systems have collapsed without the above consequences. However none of them have the massiveness and the suddenness of a large nuclear attack.

can, in principle, be maintained by simple procedures such as continuity-of-government legislation. Second, the desired personnel could probably be maintained or obtained if they are given both preattack and postattack assurances that their services are or will be needed, and if they believe that their renumeration will be either in good dollars or their equivalent.

Third, in attempting to either bolster confidence in the postattack dollar or supplant it (temporarily?) with an equivalent exchange medium, the federal government may wish to create, probably during the preattack crisis, a separate authority which would be prepared; if necessary, to take over, import, produce, and distribute all items of food. This may amount to creating a capability for the emergency nationalization and operation of the entire food industry. Of course it may not be advisable to implement a full nationalization; partial measures may be deemed sufficient.

If, in fact, the government also succeeded in creating large stockpiles of recovery supplies during the preattack crisis period, it would have real reserves which could be used to back up any new monetary policies which are required to enable the reorganization to occur and the recovery to proceed. Huge stockpiles of food, petroleum products, metals, lumber, paper, medicines, and chemicals would be a far superior underpinning for postattack money than a continuation of present monetary policy.

Growth of Civil Defense Mobilization Teams

A plausible outcome of a mobilization approach would be the early formation in peacetime of civil-defense teams in commercial and industrial establishments; teams which could develop plans for the best specific survival and recovery options. Presumably, these plans could be implemented later in accordance with international developments and national policy.

As a crisis developed, the growth of these teams and coordination with government groups having area and state responsibilities suggest a potential of millions of people with special training and education in survival and recovery tasks. Of course, a rapid development of this type would severely test our ability for emergency organization and coordination and in this manner suggests an important area for future studies. Such studies, if undertaken, could have two major purposes: (1) the development of plans for assisting the emergency civil-defense effort and (2) the creation of a temporary, paramilitary organization to help the government during the reorganization period.

Thus, we have visualized the growth during a nuclear emergency of a loose national organization of millions of trained citizens with previous talents in technology, management, maintenance, repair, production, distribution, and government, and with which the probability of an effective social and economic reorganization after an urban attack could be greatly enhanced. Also, remarkably enough, it seems not unreasonable to hazard the guess that to develop the research and planning which would facilitate this development would involve only a modest peacetime cost.

Food Distribution Problems in a Movement to Shelter (MTS) Program

As an application of the concept of emergency measures for post-attack recovery we would like to suppose that there exists an MTS program, one in which shelters either already exist in rings around, but outside of, the major urban areas or, it is assumed, can be built rapidly during the early stages of a crisis.[5] In this program, the shelters would be designed to provide very good protection for the occupants against any attack not deliberately aimed at the relocated people.

The food distribution problems for the MTS areas should be considerably alleviated if there were time to phase in the preparations gradually. Of course in this respect the war outbreak scenario can be crucial. With a surprise attack out-of-the-blue, little can be accomplished; civilians would be lucky to reach shelter in time. However, for scenarios which provide some strategic warning, the possibilities are very different. Even a scenario which gives as little as a few days of usable warning, which is relatively unlikely in our judgment, would permit a movement to existing shelters to be accompanied by the transport of a substantial amount of food from homes. Perhaps even more important would be the movement of food and other supplies by trucks and trains. The capacity of existing vehicles in the United States now permits the movement of over 100 million tons to dispersed locations if we assume only a single loading of each vehicle -- this comes to about 2,000 pounds for each urban citizen.[3]

However, for this last kind of operation to be effective, it would need to be well-organized and there is considerable doubt that the needed coordination could be effectively accomplished within a few days. In this connection it becomes important to emphasize the scenarios, perhaps the least unlikely ones, in which the available warning would be measured in weeks or months.

A relocation of a large fraction of urban citizens in the outlying shelter rings would require a massive change in the food distribution system including new routes for transportation and new outlets for distribution. The longer the crisis persists, obviously the greater the interval during which the economic adjustments can be made. However, we observe that those adjustments required for maintaining the population during a lengthy crisis should also have substantial utility for solving some of the postattack food problems. First, they could facilitate the establishment of large food stockpiles in or near the relatively safe MTS shelter rings, stockpiles that might be distributed roughly in accordance with immediate postattack needs. Secondly, some of the important aspects of a postattack food-distribution system would already have been learned and created preattack, thus eliminating much of the confusion which otherwise would be expected to occur at a much more inopportune time. Third, the lessons learned in developing the food-distribution system should have important carry-over into systems to produce and distribute other important consumer supplies. In this manner it is possible for a handle to be gained on many other important aspects of postattack requirements, for example, housing, banking, communications, transportation, etc.

In this last respect, a crisis-oriented MTS program, one which was designed to build the required shelters during a nuclear crisis, rather than simply to move people to existing shelters late in a crisis, would have two additional utilities. The first is that the large, rapid shelter-construction program would require a civil-defense mobilization that would develop both an experienced management for the organization of the construction effort, and a number of active auxiliary groups, in almost every locality, involved with the other civil-defense problems. The groups formed initially to aid the shelter program should provide an excellent basis from which to expand the mobilization into a more extensive national effort with principal emphasis on recovery measures and on managing the economic- and social-reorganization requirements.

A second advantage of the mobilization for shelter construction within an MTS program is that it can be expected to develop relatively early a major interest in survival and recovery problems among local and state governments -- as well as among agencies of the federal government. This interest should help to adapt the government organizations to the new functions which would be required of them during the mobilization and to develop contingent preparations for postattack recovery.

For the federal government to be able to give reasonable guidance to local recovery preparations during a civil-defense mobilization would require an extensive program based on prior research. If the research is reasonably funded, the formulation of the problem and perhaps the understanding of feasible countermeasures promises to take recognizable shape out of the murk and gloom which presently hovers about these problem areas. The initial research effort should soon be able to suggest the potential of further study; the payoff could be immense.

CONCLUSIONS

1. Even though a major fraction of the physical resources survive a nuclear attack, the economic viability of the country is not assured. For want of an effective understanding of the needs of the postattack reorganization period, the country could experience economic starvation "in the midst of plenty."

2. The purpose of preplanning for a civil-defense mobilization is to enable it to proceed rapidly and effectively at the time it is needed. Thus, if the preparations are satisfactory the efforts which would promote the subsequent postattack recovery could reasonably be balanced and thereby not only make the recovery more likely but more rapid.

3. The appropriate balancing of crisis activities includes the option to create a large emergency organization which could be indispensable if we wish to assure an effective postattack economic reorganization. It is argued that if a civil-defense mobilization does prove effective, that it should tend to produce just such an organization; that is, a paragovernmental agency of up to several millions of people who are already partially trained through their preattack emergency functions in the skills needed for managing postattack reorganization problems.

4. Another great threat to an effective reorganization following a nuclear attack is the collapse of federal currency -- that is, a nearly complete loss of confidence in the dollar. If this occurred, it could readily be followed by a collapse of the federal civil service and federal authority. It is suggested that preventive actions could include an option to seize the food industry, i.e., nationalize it, and, if needed, to operate it during the reorganization period as a temporary federal institution. Some ability to manage this new institution effectively might be provided by the paragovernmental organization mentioned in the preceding paragraph.

5. In addition to seizing the food industry, it is argued that during a crisis period the federal government could begin rapidly building up stockpiles of survival supplies other than food, e.g., petroleum, metals, chemicals, medical supplies. While these goods would undoubtedly have great postattack value, a major impact for the reorganization period would be to provide the federal government with additional currency to help assure that the government would survive and function in a way that would meet its major postattack responsibilities.

6. In order to provide a solid basis for an industrial role in a mobilization for postattack recovery, local studies are needed in selected industries to uncover their potential for emergency responses

within days, weeks, or months. These studies are needed to understand (a) the utility of protective measures to reduce vulnerability, (b) the utility of preattack emergency stockpiling of raw materials and finished products and (c) the potential of developing talented groups which, through the performance of these emergency functions during a crisis, would provide the large number of experienced personnel needed for a paragovernmental organization which would manage the postattack reorganization.

7. The MTS program options, as now conceived,[5] have some special advantages for postattack recovery. They (a) provide a better estimate of postattack population distribution; (b) encourage the creation of emergency protected stockpiles of food and recovery supplies; (c) provide, in crises of longer duration, an opportunity to solve many distribution problems which would crop up postattack; and (d) provide an unusual opportunity, especially if the shelters are constructed early in a crisis, for deeply involving local, state, and federal government agencies in preparations for reorganization and recovery.

8. The complex problems involved in researching and analyzing the requirements for planning a mobilization effort that would greatly enhance the viability of the U.S. economy by rapidly effecting a reasonable postattack reorganization may require substantial funding ($ millions, annually) for a decade. It is recommended that this aspect of postattack research should be strongly emphasized in forthcoming years.

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SUMMARY STATEMENTS BY SESSION CHAIRMEN

Lauriston S. Taylor, Chairman

THE SUSTENANCE SESSION

Bruce M. Easton
U. S. Department of Agriculture

Dr. Shinn spoke on Food Crops and Postattack Recovery. Briefly, he stated that the National Resource Analysis Center of the Office of Emergency Planning (OEP) announced in January 1967 that the need had not yet been established for a nationwide food-stockpiling program against the contingencies of nuclear war. In July 1967 the National Advisory Commission on Food and Fiber issued their report to the President, which recommended establishment of a national-security or strategic reserve, including emergency stocks for foreign food aid. Dr. Shinn's paper suggested that the size of our normal stocks and annual carryover stocks be set with consideration for the increased survival of population that would come about as a result of advanced civil-defense systems such as blast shelters and antiballistic-missile defense.

Inasmuch as the radiosensitivity of crops varies with stage of growth and with varieties within a species, we need studies on our major crops to specify their radiosensitivity at particular seasons.

The standard of 2,200 calories of daily food per person for immediate postattack consumption is doubtless adequate for a month or so, but experience in other countries suggests a change to a normal consumption of 3,000 calories as soon as possible.

Inasmuch as postattack transportation and distribution of food commodities appear to be potential problems, a documented state-by-state series of postattack exercises by the U. S. Department of Agriculture (USDA) state and county defense boards aimed specifically at solutions of these problems would be a valuable contribution.

Because livestock supplies may be seriously depleted for a number of reasons, including a biological warfare attack, several alternate sources of protein were investigated and appear feasible:

1. A mixture of ground cereal grain and full-fat soybean meal.
2. Lysine supplementation of cereal grains.
3. Harvest of freshwater fish to be used as a protein supplement (and not for caloric value).

Editor's Note: Some of the remarks on USDA policy and organization which Mr. Easton included in his summary statement have been deleted. They will be furnished on request.

Dr. Bell's paper, Livestock and Postattack Recovery, is summarized as follows:

After major disasters, food supplies and food production have played important roles in recovery. Livestock in the United States, valued at $19 billion, are a major food-reserve item of significance to postattack recovery. Our food reserve of cattle, valued at $16 billion, thrives on feeds not suited for man; cattle also help to screen out dietary undesirables such as radioactive fallout. Livestock-survival estimates for CIVLOG-65 are similar to human-survival estimates. These estimates of survival of livestock might be much lower if consideration is given to the interaction of gamma radiation with other insults such as blast and thermal effects, gastrointestinal and skin damage, and deprivation of feed and/or water.

The productive life of livestock surviving a thermonuclear attack would probably not be materially affected, provided the necessary production inputs were supplied.

Research for postattack-recovery evaluation is concerned with the availability of livestock products for human consumption. These needs can be summarized in terms of determining the following:

1. Shelters available for livestock.
2. Retention of simulated fallout on cattle and forages combined with livestock grazing.
3. Amount of unabsorbed radioactivity characteristic of early fallout consumed in 4 days or less to establish LD 50/30* to the gastrointestinal tract for cattle and sheep.
4. Interaction of combined insults which might be characteristic of insults to livestock in a fallout field. These include: blast and thermal effects; gastrointestinal, skin, and whole-body exposures; and deprivation of feed and/or water.
5. Wholesomeness of food products from lethally irradiated animals.
6. Guidelines to help establsih levels of radioactivity in livestock products which would be acceptable for human consumption in postattack recovery.

Dr. Park's paper, Limiting Factors in Postattack Recovery, in summary, stated that a general review of the disposition of the nine food groups and the related industries shows that there is a considerable imbalance in these industries because of their location in high-risk areas.

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* A dose lethal within 30 days to 50 percent of those receiving it.

There are disruptive elements that are related to the attack but are not direct weapon effects, which can have a serious impact on recovery of agriculture. Denial time is one of these and perhaps the most serious. The state of productivity of our dairy cattle and feeder cattle is highly dependent on man. Neglect by man during shelter time can have serious consequences, even death.

It is suggested that an epidemiological approach to these indirect effects will more clearly define the magnitude of the recovery problems.

In closing, let me state that agriculture and the food industry cannot be considered as separate units. Today they are too closely connected with the industrial complex of this nation. Our studies, including the papers given at this symposium, clearly indicate that should this nation ever be attacked by nuclear weapons, we will have land, livestock, and surviving farmers to continue to feed the surviving population. The problem will more likely be the availability of industrial products and services -- gasoline, fertilizer, pesticides, food containers, and transportation -- necessary to continue to produce, process, and distribute the needed food.

THE HEALTH SESSION

Palmer Dearing*
Group Health Association of America, Inc.

The speakers and discussants noted the understandable concentration on casualties and their care that has largely characterized postattack-health-services planning. Casualties are dramatic and public morale and morality require maximum effort for casualty care for humanitarian as well as recovery considerations, but their relative importance decreases with death or recovery, with or without residual impairment.

Planning and preparation for postattack recovery, therefore, require attention to noncasualty health services -- both for the normal load of disease in the surviving population and for the additional load that would result from added stresses of disruption of personal and environmental controls, crowding, nutrition, radiation, etc.

It is a basic premise that postattack authority will control health resources -- i.e., physicians and supporting personnel, their services, drugs, supplies, and facilities -- and apply them to meet priority needs. Additional knowledge and techniques, added to present knowledge, are needed to make both our planning and operations more precise and effective.

The first presentation, by Mr. Hallan, described a technique for studying and predicting, through computer analysis, the effect of various levels of services and supplies on survival or nonsurvival of casualties. The technique applied to a hypothetical attack on a specific city with assumed different levels of care, demonstrated the different survival rates to be expected with various levels of health services. It also demonstrated the law of diminishing returns in increases in survival rates as committed resources are increased.

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* In Dr. Dearing's absence, the summary was given by Dr. Robert Price, Public Health Service.

The discussion acknowledged the usefulness of the technique for analysis and planning. The discussion also noted the crudeness of "survival or no" as the sole index of success, and suggested development of other criteria such as productivity of survivors to increase the usefulness of the method.

The second presentation, by Dr. Sencer, dealt with changes in health-services demands during the recovery period, especially from communicable diseases, that would be anticipated from increased environmental and personal stresses.

Generally, major epidemics of known communicable diseases are not expected to result from postattack conditions. World pandemics of a new, presumably mutant disease such as the 1918 influenza occur from time to time now, and, even in peacetime, specific measures such as vaccination seldom catch up with the disease or greatly alter its attack rates. The availability of antibiotics for treatment of secondary pneumonia could have a significant effect on survival of individuals with such complications.

Two general conditions also would reduce the resistance of the postattack population to infection -- radiation exposure and malnutrition. The session on sustenance also noted the measurable effect of different levels of food intake on physical productivity. Elaboration of this type of information would provide valuable information for optimal management of the food supply during the recovery period.

With respect to specific diseases, recent experience, including World War II shelter experience, showed diphtheria as the only person-to-person-disease problem that arose from crowding. The U. S. population is estimated to be at least 75 percent immunized, and diphtheria should not be a major problem.

For the ubiquitous staphylococcus and streptoccus that complicate respiratory diseases, including pneumonia, and infect wounds and burns, the availability of antibiotics, as in an influenza pandemic, would be critical.

For tuberculosis, our rates of infection are greatly reduced, so that exposure even in crowded living conditions would be much less than 50 or even 25 years ago. Again, specific chemotherapy to render cases noncommunicable is the countermeasure, and depends upon the availability of isoniazid and PAS (para-amino salicylic acid).

Of the enteric disea. ·, polio has been essentially eliminated, and typhoid, which 50 years ago would have been a threat, is near the vanishing point today. The major problems with disrupted water supply:

food preparation and waste disposal, are the diarrheas -- Salmonell and Shigella -- and hepatitis. Sanitation, proper cooking, and boiling of water are the preventive measures, and would be important particularly to prevent the long disability that accompanies hepatitis.

Increased risk of rabies and tetanus as a result of moving from urban to rural environment were noted. Immunization of the population against tetanus preattack is the vastly preferable measure against tetanus. Plans to control the canine populations in areas where rabies is endemic in wild-animal populations, such as skunks and foxes, are essential to avoid the panic engendered by the frightful prospect of rabies.

Smallpox does not exist in the highly vaccinated U. S. population, and present world programs to eradicate its focus in West Africa can be extended in the near future to the other remaining world reservoirs.

Discussion, led by Drs. Huntley and Price, brought out additional points:

1. Knowledge of essential drug requirements -- insulin and digitalis, for example -- should be acquired and kept current.

2. Mental illness would not be expected to increase or be a major problem; neurotic behavior actually decreased under stress in the London blitz and in the Japanese experience.

3. The most effective health services during the recovery period will require assigning of priorities of procedures, personnel, and supplies to persons and conditions where they can make maximum contribution to recovery; the traditional one-to-one physician-patient relationship will be minimized.

THE LONG-RANGE EFFECTS SESSION

Charles L. Dunham
National Academy of Sciences

Dr. Osburn discussed in general terms the ecological effects to be expected from attacks such as CIVLOG and UNCLEX. He specifically discussed fire damage and indicated that it will depend very much on the season of the year, and on the weather in the preceding two or three weeks and on the day of the attack. He indicated that he did not expect massive erosion following the forest fires that might be kindled, but there might be heavy losses of timber in certain areas. He expressed a general uneasiness among the experts as to the actual extent of fires that might occur.

Dr. Osburn cited the general relationship between mass or volume of nuclei and radiation sensitivity in the plant kingdom, and highlighted the relative sensitivity of spruce. Attention was called to the extra forest-fire hazard to be expected in areas where fallout had killed off the conifers. Dr. Osburn concluded by urging that there be undertaken systematic studies of the relative sensitivities of plant and animal life in forests and grazing lands, and of cultivated crops in a number of specific regions of the country.

Dr. Auerbach discussed the possibility that insects might constitute a postattack problem because the adult forms are, in many instances, very radioresistant, some surviving in appreciable numbers as much as 100,000 rads. He pointed out, however, that the dose required to sterilize male insects was in the 2- to 5,000-rad range and that many insects would be expected to become heavily contaminated with the fallout itself, and hence would receive doses of radiation considerably above standard gamma-ray dose estimates based on measurements 3 feet above the ground. Adult birds have an LD $50/_{30}$* of about 1,000 rads. Killing of the insect-eating birds and sparing of the insects may not be too much of a threat postattack. Certainly more information is needed here.

Dr. Auerbach brought out the fact that pollinating insects are relatively radiosensitive and, specifically, that 5,000-rad exposure to

* Lethal dose in 30 days to 50 percent of those exposed.

a honey-bee colony in the hive had a devastating effect. Clearly more work on the beta dose from fission products, on sensitivity profiles of a variety of important insects, and on the sensitivity of complex insect communities is in order.

Dr. Reitemeier summarized our present understanding of factors concerned with soil-plant relationships. He indicated that much was known about the binding of cesium and strontium in the soil and about methods to reduce uptake of strontium from poor soils.

Dr. Tamura discussed the movement of fission products in and on the soil, pointing out how very slowly they move downward and how, in general, they move laterally in runoff only if there is enough rain, or if conditions are such that actual erosion of the soil surface occurs. Some further studies along the lines now being pursued are indicated.

Dr. Tompkins discussed how fission products enter the food chain via direct foliar uptake on the plant, as opposed to uptake via the soil. He pointed out the important time factors involved in these two modes of uptake as affecting their relative importance following fallout.

Dr. Straub summarized the rather considerable knowledge and know-how now available about the removal of fission products, especially strontium-90 and -89, cesium-137, and iodine-131 from milk. He also detailed the available methods for reducing the uptake of strontium from the intestinal tract and of methods for reducing radio-iodine uptake by the thyroid gland. He concluded that emergency methods for the removal of fission products from food are more effective than conventional treatment processes, but that in certain instances changes can be made in a conventional process that greatly improve its efficiency in this respect.

Dr. Dunham summarized the long-range radiation effects on man following a nuclear attack as follows:

1. 20,000 additional cases per year of leukemia during the first 15 to 20 years postattack followed by an equal number of cases of miscellaneous cancers, added to the normal incidence in the population for the next 30 to 50 years, constitute the upper limiting case. They would be an unimportant social, economic, and psychological burden on the surviving population.

2. The genetic effect would be lost, as at Hiroshima and Nagasaki, in all the other "background noise."

3. If there were an appropriate number of children and young adults surviving 1,000 rads or more of gamma-ray exposure, an unusual and, because of the age distribution, conspicuous incidence of clinically important cataracts would appear in the middle-age and younger population two to five years postattack.

4. In spite of precautions such as avoidance of iodine-131-contaminated food and water, or ingestion of stable iodine during the immediate postattack period, there may be many thousands of teen-age survivors developing more-or-less-benign thyroid tumors as a result of exposure to 150 rads or more whole-body radiation plus 700 or more rads of radiation received locally in the thyroid gland.

5. Radiation burns may occur but, in general, need not.

6. Cytogenetic effects may be expected in cultured lymphocytes of exposed persons. Their significance is uncertain.

Dr. Casarett indicated mathematical approaches to estimates of carcinogenesis in a surviving population following a nuclear attack based on the simple linearity-with-dose approach, and not attempting to take into account the greatly, but as yet not precisely quantitated, reduced effect that goes with lower dose rates and low doses.

Dr. LeRoy discussed equivalent residual dose (ERD) and stressed the need to be able to screen large numbers of persons using the total leukocyte count and the hematocrit to free the doctor to devote himself entirely to the sick and injured. He emphasized the need for guidelines for conserving hospital beds, medical supplies, and medical manpower for essential and effective care for the work force needed to maintain essential services and reconstruction.

Dr. Lushbaugh described a whole-body irradiation-therapy facility which delivers to the patient cobalt-60 gamma irradiation at an exposure rate of 1.5 R per hour. Patients receiving irradiation at this dose rate and accumulating 20 to 25 rads a day for several days have been symptom free.

There was discussion of the LD 50 for humans, and Dr. Lushbaugh stated that 300-to-325-rad (absorbed dose) high-dose-rate exposure was currently accepted by many people as the best estimate.

Dr. Dunham mentioned a recent experiment by Dr. Wright Langham at Los Alamos in rhesus monkeys, suggesting that only relatively few persons could survive more than 500 or 600 rads exposure received within a ten-day period. A movie of the experiment was shown.

THE PROSPECTS FOR RECOVERY SESSION

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The three speakers at the session on Prospects for Recovery were in close agreement in their answers to the basic question of whether relatively massive attacks against the United States would leave sufficient resources to support recovery. Although they used different input-output methodologies, all speakers concluded that surviving resources would be adequate for recovery from the attacks postulated -- given appropriate institutional arrangements.

The approach used by Mr. Laurino was to select several indirect indicators and to use them in evaluating what he called the "national entity." The indicators are of three classes: population, resources, and institutions. The emphasis in this discussion was on surviving resources and their relationship to surviving population. He found that, even in attacks directed primarily at population, industry would be lost in somewhat greater ratios than population and that some industries would suffer greater damage than others. Utilizing input-output techniques (while acknowledging the related data deficiencies) he found no major constraints on the input side to prevent maximum utilization of surviving capacity, and he found surviving capacity more than sufficient to meet the essential demands for personal consumption, with some margin remaining for recovery. Suggesting that a sizable portion of recovery efforts in the first year after attack would be directed toward provision of necessary food and water and the continuation of agricultural production, he concluded that there would be available the resource potential for continued survival and recovery, given proper management, including allocation of petroleum fuels necessary for food production.

Dr. Sobin examined the potential of surviving resources to meet the postattack requirements of the surviving population and stipulated nonmilitary-government programs. While stipulating rather austere nonfood requirements of the population, he gave special attention to the capability of the food industries to provide, by alternative means, balanced food nutrients for the surviving population. In this analysis he used an input-output model that incorporated unusual detail in the food sectors.

Dr. Sobin concluded that surviving resources would be sufficient to meet the requirements of stipulated, government, nonmilitary programs and civilian consumption.

Much of Dr. Sobin's discussion was devoted to the composition of his input-output model, to its relationship to other models, and to further applications contemplated for it.

Mr. Addington's approach was to appraise the situation with reference to various classes of resources following an attack sufficient in magnitude to kill 100 million out of a 230-million population in 1975. He concluded that an estimated 1975 preattack capacity to produce an annual gross national product of $905 billion would be reduced to a postattack potential of about $610 billion, and that this potential might appropriately be degraded to an annual rate of $490 billion to allow for the lower-than-normal efficiency of manpower, including abnormal additions to the labor force. He viewed this potential level of production as sufficient to meet personal-consumption requirements (based on World War II standards) as well as roughly estimated military and industrial recovery requirements.

Although the evaluations made by all the speakers employed input-output techniques, there were significant differences in the models used. The most aggregative of these was the roughly 10-sector model used by Mr. Laurino. The others used in different ways the Office of Business Economics' 86-sector interagency table. Dr. Sobin used, as previously noted, substantially increased detail in the food sectors.

It should be emphasized that all the estimates made by all the speakers at this session were estimates of potential capabilities, i.e., potentials that could be realized only in the context of a favorable institutional environment. All speakers recognized the criticality of institutional arrangements and the necessity for post-nuclear-attack reorganization on some basis that would support, or at least permit, recovery.

THE ECONOMICS SESSION

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The chairman's purpose in organizing this session was to summarize the potential for economic recovery from a nuclear attack and then to present a range of views on the problems and desirable government policies for managing the postattack recovery process. The papers presented in the previous evening session, Prospects for Economic Recovery, provided a valuable background for this session. The first paper of this session summarized the most recently completed study on the potential for economic recovery from a nuclear attack, given effective private and public management of the recovery process. The second paper summarized the considerations that led to the formulation of the present official National Plan for Emergency Preparedness and the major features of government policy outlined in this plan. The third paper presented some new ideas being developed for public policy concerning the management of the postattack-recovery process. And finally, the fourth paper presented a comprehensive evaluation of the problems and appropriate public policies for the management of the postattack recovery. A conscious attempt was made to present a range of viewpoints on these problems, to illuminate the differences of opinion, and to identify the major areas for further research on this problem. These papers indicated that there is a major difference in the evaluation of the problems of postattack recovery and the appropriate role for government and private action between the present National Plan and the evaluations developed during the last several years, but that there is a fairly general consensus, both within and outside government, among those evaluations conducted during the last several years.

The major conclusion of the paper, The Potential of the U. S. Economy Following a Nuclear Attack, given by Mr. Bickley and Dr. Pearsall and prepared by them and Mrs. Jane Crane, was that the physical resources surviving a nuclear attack would permit the realization of a high, post-attack economic level for the surviving population, possibly as high as a $3,500 a year gross national product (GNP) per capita, given effective management of the postattack-recovery process. This conclusion, surprisingly, did not appear to be strongly sensitive to a wide range of attack sizes or the focus of the attack. This conclusion was the result of a finding that a major nuclear attack would destroy a nearly commensurate proportion of economic capacity and population -- at least in the absence of a very large population-protection program -- and of the substantial redundancy of physical capital in the American economic system under normal circumstances. The level of population survival and, in turn, the level of the available labor force appeared to be the primary constraining resource on the achievable level of total postattack economic activity. Conversely, there appeared to be no general physical resource constraint on the level of achievable postattack economic activity. After a specific attack, some specific resource restraints might be effective, but these specific constraints would be very dependent upon the level and character of the attack.

The major policy implications that the chairman could draw from this study were the following: (1) U. S. strategic defense programs may be adequately designed and evaluated on the basis of population survival only, at least for moderate-to-large attack levels and strategic budgets. (2) No general economic-resource-protection measures appear appropriate. (3) Specific resource-protection measures such as hardening of certain industrial processes, stockpiling of intermediate and final goods, and/or dispersal of specific economic activities may be valuable, but the value of such measures is likely to be very dependent upon the detailed character of the attack; it has not been possible to identify which specific measures are likely to be valuable for a range of attacks. (4) This study leads to a general sense of optimism about the potential for economic recovery if adequate measures are taken to assure a high population survival, and the problems of reorganization and management of the postattack-recovery process can be resolved.

Dr. Livermore's paper on Resources Management summarized the background leading to the development of the National Plan for Emergency Preparedness and the considerations that led to the specific policy recommendations outlined in this plan. The set of public policies outlined in the National Plan were based on a recognition by the several authors of this plan that the major private institutions of property rights and markets that provide the incentives, information, and price expectations for our peacetime economy, and that permit private, decentralized, economic decision-making, would be enormously disrupted by a nuclear attack. The general assumption of the National Plan is that this disruption of private institutions would substantially increase the required role of the federal, state, and local governments in management of postattack recovery. These policies were developed specifically for a middle range of nuclear attacks similar to those being considered by other studies presented at this conference; this middle range of attack was considered primarily to present a postattack situation significantly different enough from the peacetime economy to require a fundamentally different set of policies, but not sufficiently large that the potential for economic recovery would be negligible. Finally, the paper identified ten major problems for further research:

1. Immediate damage assessment: Who should decide whether to abandon, cannibalize, or rebuild certain facilities?
2. Identification of long-lead-time physical resources important for recovery.
3. Identification of possible short cuts in production processes.
4. Identification of "bundle rations."
5. Specific policies for undamaged areas. For example, what should be government policy concerning movement of physical resources from undamaged areas to damaged areas and movement of population and labor from damaged areas to undamaged areas?
6. Identification of "broken chains in production processes."
7. Specific policies concerning the construction industry.
8. Potential utilization of cargoes in U. S. ports.
9. Efficient procedures for the collection and dissemination of important economic information.
10. Identification of measures to assure private responses are consistent with national goals.

In the chairman's view, the National Plan, prepared as it was by men who held responsible positions in the federal-economic-control system of World War II and Korea, strongly reflected their experience. As outlined in the present official National Plan, the federal government would provide the basic institutional framework for economic recovery plus an extensive set of specific actions to relieve bottlenecks and reorganize economic activity. The Plan reflected a general orientation to implement economic activity by government fiat rather than through reliance on private incentives. The Plan reflected a carefully developed division of responsibility among the federal, state, and local government agencies, based on the recognition of the value of the decentralized process, relying almost entirely, however, on government action. The Plan did not reflect apparent recognition of the problems of the enormous size and complexity of the necessary control system or of the potential vulnerability of the control system itself to the nuclear attack.

Dr. Peskin's paper, Areas of Research in Post-Nuclear Attack Recovery Planning, given by Mr. Vance, presented the results of some preliminary evaluations concerning substantially different approaches to the problems of postattack-recovery management. It was emphasized that this does not reflect an official position of the Office of Emergency Planning (OEP), but that it is indicative of one of several directions that research is taking.

The new direction of research outlined in this paper was based on an estimate that the federal government would have only a small part of the capability required to implement the policies outlined in the present official National Plan. The size and complexity of the federal-economic-control system implicit in this plan would be much greater than they were during World War II and enormously greater than those which exist at the present time. The federal control system would also be subject to attack and, most likely, would be relatively more damaged than the private institutions for which the National Plan proposes that it substitutes. This new direction of research also recognized that the federal government would have both major allocative and redistributive roles in the postattack-recovery process, and that substantially different policies may be appropriate in pursuit of these two roles. The paper suggested that the primary responsibility of the federal governm... its allocative role would be to recreate the institutions of the private market as soon as possible and with much greater emphasis than is implicit in the National Plan. The paper presented a specific proposal for meeting the redistributive role that had the following characteristics: (1) All physical resources would be nationalized immediately after the attack; (2) An equal amount of a new currency would be distributed to each surviving household; (3) All surviving resources would then be auctioned off to individual and collective purchasers. This final action would place economic resources back in private hands as soon as possible and would also provide revenues for a period of time to meet the initial expenditures of the federal government.

Commenting on this proposal, a member of the audience said that equal distribution of this new currency and surviving assets may lower the aggregate savings ratio and, in turn, lead to a lower growth path than could be achievable. Such an effect would occur if there is a substantially different savings pattern by income class.

The primary response to this paper by the audience was substantial surprise about this new direction of research, a direction that implies almost wholesale rejection of the approach to economic recovery outlined in the present National Plan.

Dr. Winter's paper, The Federal Role in Postattack Economic Organization, summarized and evaluated two major, different, federal responsibilities in the postattack-recovery process: (1) The recreation of private economic institutions; and (2) the direct, government control of economic activity. The paper concluded that one or the other of these approaches would be sufficient, and that an attempt to perform both roles would overwhelm the capability of the federal government. The paper recognized that the amount of federal capability for economic control outlined in the National Plan would have to be very much greater than existed in World War II and enormously greater than the capability of the present federal system; also, it recognized that the federal control system would be specifically vulnerable to attack. The requirement for federal controls outlined in the National Plan was based on a recognition of the enormous difficulties of recreating the private economic institutions, but a similar argument could be made that the requirement for private decision-making could be similarly based on recognition of the enormous difficulty of creating federal controls after a nuclear attack that damaged the nominal, existing, federal controls. This paper concluded that a comparison of the probable surviving capabilities for federal control and private economic decision-making indicated that much more economic decision-making, both private and public, should be decentralized than is implicit in the National Plan or, possibly, in our present peacetime economy.

On this basis, this paper suggested four major tasks for the federal government:

1. Reestablishment of private property rights as soon as possible.
2. Reestablishment of the use of money to prevent the inefficiencies of a barter economy.
3. Specific government actions to stabilize price expectations, possibly by operating on the futures markets and by a limited set of price supports.
4. Reestablishment of the traditional government operations in the provision of important public goods and services.

The paper also outlined four major areas for important further research:

1. Efficient procedures for rapid, equitable resolution of property rights.
2. Procedures to increase the decentralization of economic decision-making after the attack, for example, at the level of private local plants or utilities in a situation in which corporate headquarters are destroyed.
3. Development of efficient procedures for introducing a new currency, both for equity and to control inflation.
4. The effects of specific characteristics of a nuclear attack such as (a) the effect of the destruction of the District of Columbia, (b) the effect of follow-on resource demands by the U. S. military system, and (c) the opportunities for continued or possibly expanded foreign trade.

At the end of the session, the chairman observed that the primary impact of the papers presented was to illustrate the major difference in the evaluation of the postattack-recovery process reflected in the present National Plan and that of the group of analysts working on this problem, both within and outside government, in recent years. This major difference of opinion should cause a major rethinking of federal policies.

The chairman also offered an alternative to the specific redistributive proposal made in the Peskin Vance paper with the following characteristics:

> The government would assume property rights in all those resources for which there is an uncertainty or conflict of property rights. All surviving property, however, for which there were clear property rights by surviving owners, or for which the property rights could be resolved by private agreement, would be left in private hands.

Such a method would enormously reduce the amount of property the government would have to hold temporarily and auction. The proceeds from the auction of nationalized property would be used to finance the short-term operations of government, to finance transfer payments to those impoverished by the attack, and to reward the managers of those properties temporarily held by the government. For a period of time, this economic system could be best described as "free-market socialism."

The chairman concluded with the observation that the prospects for economic recovery following nuclear attack are restricted primarily by the failure of present government action to provide sufficient protection for the population, and by an inadequate set of government policies for reorganizing the economy.

SOCIAL AND PSYCHOLOGICAL EFFECTS OF NUCLEAR ATTACK

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INTRODUCTION

Considered as a target of a nuclear attack, a nation consists of more than the collection of individuals, their geophysical environment, and the man-made structures and facilities existing within given geographical boundaries. A nation is a complex, functioning system in which a population, organized in particular ways, accomplishes the basic functions of production, distribution, and consumption. Its people are bound together and interrelate through a variety of organizations, institutions, values, ideologies, and shared and patterned ways of behaving. These means for governing and influencing the behavior of individuals and groups with respect to each other and their environment have typically been omitted from consideration in studying the likely effects of an attack. But the vulnerability of the society to an attack, its ability to function in a postattack period, and its eventual recovery depend as much upon the effects of an attack on these elements of the total social system as it does upon the number of survivors and the physical damage to facilities. To assess the nation's vulnerability to attack, the social and psychological effects must be assessed and integrated with the physical effects.

Knowledge of the social and psychological effects of an attack, and their implications for the functioning of society in the postattack period and for eventual recovery, are prerequisite to the design of effective civil defense. Such knowledge is critical to the over-all mission of civil defense because: (1) it would permit more precise and meaningful definition of the goals civil-defense planning is intended

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Editors Note: In contrast to the summary statements of the other session chairmen, this paper is a resumé of the current state of knowledge rather than a discussion of the papers given in the session on societal vulnerabilities.

to achieve; (2) it is a source of countermeasure requirements that may not otherwise be established; (3) it is a source of information pertinent to increasing the effectiveness of countermeasure design; (4) it is a source of criteria for evaluating countermeasure effectiveness; (5) it would help fill a gap in the information needed to assess recovery capabilities; and (6) it would help in delineating critical research requirements and assessing their priorities.

The problem of planning socially valid civil-defense systems is not one of producing an array of myth-shattering, debate-scoring, comforting propositions that seem to show that, under definable social conditions which civil-defense systems can create, society or individuals or the American way of life will survive. Although answers to the real problem will have valuable side effects in allaying anxiety and chasing ghosts, the real problem is a different one. The problem of planning socially valid civil-defense systems is to show the social dimensions on which many different attack effects might occur, and then to show how systems can be defined to manage effects so expressed. It is necessary that the best possible information be obtained concerning the social, political, demographic, and psychological factors likely to be affected by a nuclear attack. Human reactions such as panic, apathy, aggressive behavior, lawlessness, or extremist political, social, or religious behavior must be assessed under an assumption of nuclear attack, and control measures, if necessary, must be devised. The possible upsets in occupational, education, and age compositions of the population resulting from nuclear attack should be studied and the results of probable unbalances assessed. The effect of nuclear attacks on community -- political, social, economic, and kinship -- organizations must be evaluated and a determination made regarding those most likely to survive and the part they would then play in accelerating, decelerating, reversing, or otherwise affecting social, economic, or technological changes going on before the attack, to what degree this would affect recovery capability, and how any adverse effects could be corrected.

Since attack effects on these various social dimensions are not clearly understood, and there does not exist an extensive body of knowledge about these phenomena, the technical requirements in this area are largely problem-defining in nature. They aim at developing sufficient comprehension of an attack-damaged social system to identify the key problems with which civil-defense planning must cope. From research in this area should come problem definitions and potential requirements for civil-defense policies and programs.

PAST RESEARCH

Much of the knowledge in the social and behavioral sciences is relevant to the task of describing attack effects in social and psychological dimensions. The problem, however, is in determining how to generalize that knowledge to the unprecedented postattack situation. This fact gives rise to the need for methodological and theoretical developments, which are equally as important as substantive propositions about postattack phenomena. The social and behavioral sciences, in general, have never considered the problem of massive damage and disturbance of the total social system of the kinds and magnitudes that would follow from a nuclear attack.

For this reason, the specific relevance of much past work in the field depends upon the development of sufficiently comprehensive theoretical structure to which it can be systematically related. The publication in 1966 of Vulnerabilities of Social Structure: Studies of the Social Dimensions of Nuclear Attack, S. D. Vestermark, Jr. (ed.), provides the most advanced development of a theoretical structure in terms of which the effects of an attack on a total social system can be understood. This is the first serious conceptual treatment of the social system considered as a target of a massive nuclear attack. The most relevant earlier works that tend to summarize the state of knowledge in this field include:

Barton, Allen H. Social Organization under Stress. National Academy of Sciences - National Research Council, Washington, D. C., 1963. (Disaster Study No. 17)

Janis, Irving L. Air War and Emotional Stress. McGraw-Hill, New York, 1951.

Nordlie, Peter G., and Robert D. Popper. Social Phenomena in a Post-Nuclear Attack Situation: Synopses of Likely Social Effects of the Physical Damage. Human Sciences Research, Inc., Arlington, Va., 1961.

Smelser, Neil J. Theories of Social Change and the Analysis of Nuclear Attack and Recovery. Human Sciences Research, Inc., McLean, Va., 1967.

Human Sciences Research, Inc. An Approach to the Study of Social and Psychological Effects of Nuclear Attack. McLean, Va., 1963.

Baker, George W. and D. W. Chapman (eds.). Man and Society in Disaster. Basic Books, New York, 1962.

Smelser, Neil J. Theory of Collective Behavior. The Free Press of Glencoe, New York, 1963.

In addition, the studies of natural and man-made disasters by the Disaster Research Group of the National Academy of Sciences - National Research Council should be noted. While of some value to predicting behavior in the postattack situation, all these disaster studies share the characteristic of being studies of events occurring in a limited geographic area and not affecting the total social system. This difference is a crucial one and limits the value of disaster studies per se for postattack planning.

Thus, a considerable amount of data is available on these assorted kinds of disasters, but there has been some question on the degree to which generalizations can be made from these disasters about the likely social and behavioral effects of a disaster of greatly increased scale like a nuclear attack.

What have the studies of expected social and behavioral effects of nuclear attack found to date? There are several kinds of findings -- methodological, substantive, and implications for actions. The methodology of postattack research has been seriously considered in a recent paper by Neil Smelser, Methodological Issues in the Social Analysis of Nuclear Attack and Recovery, in the publication edited by Vestermark referred to above. In this paper, the methodological problems in postattack research are analyzed; the limitations of such research delineated; and ways in which the scientific method can be applied to postattack research problems are described. This analysis should be highly useful to researchers investigating likely postattack phenomena.

In the area of substantive findings, while it is not feasible to provide a detailed summarization, a few examples may serve to illustrate the nature of the conclusions drawn from these studies.

1. The behavior of people in a postattack situation generally will be adaptive rather than maladaptive. Ignorance of what actions are appropriate will tend to reduce the amount of adaptive behavior actually displayed. The etiology of maladaptive behavior is more likely to be ignorance of appropriate action than the inability to function mentally in a relatively normal fashion.

2. Widespread mass panic will not occur. A qualification to this hypothesis is that, under conditions where a large part of the population of an urban area attempts a sudden evacuation, mass panic is a likely consequence.

3. The major psychological response to the attack will be extreme fear, which is likely to persist for relatively long periods of time.

4. The psychological state of most survivors directly affected by the attack will be quiet, passive, docile, and fairly responsive to direction and control exercised by persons of authority for a considerable period of time after the initial direct effects of the explosion have subsided. This will slowly give way to a more highly active energy state, probably characterized by the expression of some hostility and blame toward government authorities.

5. People directly affected by the attack will experience role conflict between the demands of their families and those of their normal jobs. In general, people will resolve the conflict in favor of their families and at the expense of other obligations and responsibilities. Exception to this general rule may be people who have no family, or for whom reunion with their family is inconceivable, and people whose normal jobs are in disaster-ready organizations.

6. Among survivors in contact with each other, there will be an increase in communication and a general lowering of barriers to personal intercommunication.

7. Survivors will seek to avoid social isolation.

8. An immediate effect of the attack will be to produce a sudden shift in the priority of values by which people govern their behavior. The highest and most salient value will become that of achieving the safety and survival of oneself and immediate family. Other values, such as private property, will have almost no significance for behavior. After the immediate effects subside, there will be a gradual return to the original ordering of priorities that existed before the attack.

9. Except for the shift in priority of values noted above, social norms that govern the normal relations between people will not be seriously altered, at least for a considerable period of time after the attack. This means that the survivors' behavior would not suddenly become amoral, lawless, and totally selfish, but rather, on the whole, conform to preattack behavioral norms.

10. The activities of survivors will be directed at obtaining the basic requirements for existence -- food, water, etc. -- for themselves and their families. For weeks and perhaps months after the attack, survivors in directly affected areas are likely to spend their entire time and energy on obtaining basic needs of living.

11. Under certain conditions of massive attack, there would be large-scale migrations to more livable areas of the country; this movement would be in contrast to the convergence behavior which is characteristic in small-scale disasters.

12. The distribution and allocation of food among the surviving population appears to be one of the most difficult immediate-postattack problems to solve.

13. Emergent leaders are likely to take over where constituted leadership is absent or ineffective.

14. After the attack, survivors would try to seek information about the fate of family members from whom they are separated, and information about the national and local situations. This behavior would continue until the information is obtained.

15. Preattack preparations and characteristics of the attack warning are important predictors of the effects of the attack and consequent societal recovery.

16. Societal recovery is related to the ability of the communication system to function at all levels of the social system. Recovery will be related to the extent to which effective communications at all levels in the social system are reestablished.

17. The normal division of labor will be severely disrupted, and recovery will be related to the ways in which the division of labor is reconstituted. The incidence of role conflict among survivors will retard effective establishment of a new division of labor. Prediction of the available labor force will be necessary to the prediction of recovery. Determination of the available labor force must take into account training activities and the convertibility and substitutability of skills.

18. The mobility of people and resources will be severely impaired and recovery will be related to the reestablishment of transportation capabilities.

19. The damage to and the capabilities for reestablishment of societal-control structures -- especially the national government -- will be significantly related to the form and rate of societal recovery.

20. The most general problem for recovery-management planning to solve is reduction of the discrepancy between what people will be inclined to do and what they must do if recovery is to occur.

In the most recent report* in this research program, a number of implications for civil-defense planning that were derived from past research in the program were described. In summary form, these were:

1. A society-wide frame of reference is required for meaningful definitions of civil-defense objectives and missions. Work should be continued and amplified and, where appropriate, initiated, in order to:

   (a) Identify and describe the dimensions and criteria of societal recovery.

   (b) Develop the conceptual apparatus to describe civil-defense problems and civil-defense systems in terms of dimensions of societal recovery. Among such conceptual developments should be: (1) capacities to describe postattack social processes as partial- or total-moving-equilibrium systems; (2) a total, socially valid definition of the civil-defense task: as that of managing a stepped progression of events to achieve specifiable, systemic recovery goals; and (3) specification of the technological and organizational bases of recovery.

2. There should be specific development of comprehensive methods for assessing the effectiveness and social costs of proposed civil-defense measures. To do this, three interrelated tasks should be initiated:

   (a) Definition of ultimate criteria for civil defense.

   (b) Development of methodology for defining intermediate criteria and for evaluating projected or actual performance against such criteria.

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* Nordlie, P.G., and S. D. Vestermark, Jr.: Civil Defense in Postattack Society: A Summary Report from a Research Program. Human Sciences Research, Inc., McLean, Va., February 1967. (HSR-RR-67/2-Me).

(c) Development of more adequate means for identifying and calculating the social costs associated with any proposed measure.

3. There is immediate need to extend existing damage-assessment capabilities to include counts on social variables not currently included in damage-assessment models; when fully developed, this social-damage-assessment capability could form a national social inventory for civil defense.

4. A national orphan-assignment plan should be studied to determine its design characteristics and feasibility.

5. Among the first longer-range applications of the national social inventory for civil defense should be the creation of an inventory of redundant social-system capacities, against which alternative forms of civil-defense systems could be projected.

6. Civil-defense research and planning should be based on a recovery-oriented approach. Work should be initiated to identify and define a set of recovery requisites that would form the basis of a recovery-oriented approach to postattack planning.

7. Civil defense will require both centralized and localized management. In attaining more precise definition of plans for the specific elements of the multi-tiered management process of civil defense, work should be initiated to:

   (a) Design a centralized recovery-management system designed to increase the probabilities of motivating survivors to engage in system-regenerative activities and of directing these activities in relation to the general requirements for the recovery of the whole social system.

   (b) Design a set of local-level capacities for guiding and/or managing individual responses to attack.

   (c) Determine which other elements of a comprehensive civil-defense system should be developed on a centralized basis; which ones should be developed on a localized basis; and which ones should be developed to meet requirements of intermediate level control.

8. From the study of social responses to nuclear attack has come the concept of "systemic disaster," which may turn out to be the most important civil-defense challenge of the future. Civil-defense planners should consider the results of the analytical study of societal recovery from nuclear attack as they may affect the potentially evolving future role of civil defense in American society.

EVALUATION OF PRESENT LEVEL OF KNOWLEDGE

With regard to an over-all evaluation of the present level of knowledge in this area in relation to the research questions to be answered, it may be said that the knowledge is moderately well-developed conceptually, methodologically, and substantively. Emerging from this work is the conceptual apparatus for conceiving of damage to and recovery of a functioning social system. This capability has not existed heretofore. It can be expected that from this work will continue to come new requirements for civil-defense planners to consider, new definitions of problems and factors civil-defense planning needs to take into account. Further work is needed to supply empirical data on how the institutional relationships that constitute the social system are distributed in various types of communities and population categories. Estimates of the extent and character of social-system linkages will be required to develop prediction of social-system vulnerability and to permit estimates of social-system damage from nuclear attack. Under way at present are studies concerned with the development and testing of methods for estimating social-system characteristics in relation to geographic areas and census-type data for such areas, to provide a basis for social-system-vulnerability estimates.

POSSIBLE DIRECTIONS FOR FUTURE RESEARCH

Research in this area was initially concerned with generating specific propositions about social effects and problems that attacks were likely to create. The effort in this direction has proceeded about as far as it is meaningful to go. Future research should recognize the need to move farther in the direction of assessing damage to the functioning social system and evaluating the effectiveness of alternative countermeasures in terms of their effects on total-system recovery. In short, a basis now exists for developing a fundamental approach to analyzing the cost-effectiveness of civil-defense systems, which takes into account the social costs of alternative systems and measures effectiveness in terms of effects on the ability of the total system to function.

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