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NOTE ON ENCLOSURE

Enclosed is an up-to-date statement of our thinking about our study of the postattack environment. It extends and replaces earlier statements or outlines. Any comments you may have would be welcome.

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THE TAB STUDY OF THE BIOLOGICAL AND ENVIRONMENTAL CONSEQUENCES OF NUCLEAR WAR: A NOTE ON SCOPE AND APPROACH

September 13, 1963

U. S. ATOMIC ENERGY COMMISSION
Division of Biology and Medicine
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THE TAB STUDY OF THE BIOLOGICAL AND ENVIRONMENTAL CONSEQUENCES OF NUCLEAR WAR: A NOTE ON SCOPE AND APPROACH

Summary:

The underlying thesis of this program note is that one will get virtually nowhere toward the goal of an improved understanding of the biological and environmental consequences of nuclear war and the impact on national security policy unless he starts out with the point of view that the first step is a major improvement in the analysis of existing information. Sooner or later, he will expect to find himself at the limits of information. Appropriate theoretical or experimental research can be undertaken accordingly. In some instances, such research should be started as soon as possible because of long lead times. The success of the first step -- analysis -- will require a considerable effort toward the systematization of data, particularly in fields of research where progress has been rapid.

THE TAB STUDY OF THE BIOLOGICAL AND ENVIRONMENTAL CONSEQUENCES OF NUCLEAR WAR: A NOTE ON SCOPE AND APPROACH

1. Introduction

The Atomic Energy Commission, Division of Biology and Medicine, Technical Analysis Branch (TAB), is developing a program to study the biological and environmental consequences of nuclear war. The objective is to develop a better understanding of what nuclear war might do to mankind's health and his living environment so that the formulation of national security policy, for both military and non-military defense, can be guided. The purpose of the program is not to furnish technological detail in support of operating programs such as civil defense. A better understanding of the biological and environmental consequences of nuclear war should contribute to more enlightened decisions on strategy and foreign policy, military operations, weapons systems evaluation, nuclear stockpile composition, civil defense, arms control, and postattack recovery.

This note expresses our current viewpoint of what the problem is all about and of the scope of the program and an approach to its development.

2. The Present State of Affairs: Limitations of Studies of the Biological and Environmental Consequences of Nuclear War

Let us consider the present state of affairs first.

Strictly speaking, one cannot in clarity set forth to assess the consequences, biological or otherwise, of a nuclear war -- or to compare nuclear attacks for the use of clean versus normal nuclear attacks for the use of clean versus normal fission yield weapons -- without some advance specification of purpose. The purpose will affect the degree of attention to detail, to assumptions, and to error or sensitivity to assumptions.

For a full appraisal of the longer-term aftermath of a nuclear war, assumptions need to be made about what people will be doing to help themselves out of their predicament. If, for example, a nation's economy -- and, presumably therefore, the social and political system -- breaks down, the question will not merely be what the radiation or secondary fires might do to cropland, rangeland, or forest. There will be the further question of the fate of those normal activities of man that relate to his health and his biological environment and that may be discontinued for some time postattack: irrigation that ceases, pesticides and fertilizers not applied, land cultivation not carried out, forest fires not fought, etc. It should be clear that there is a close tie between the industrial or, narrowly, the economic aspects of agriculture or forestry and the biological aspects.

A similar argument applies to the protection of the public health, where the object often is the control (suppression) of certain biological populations; for example, disease organisms or insect carriers. If the nutritional status of the human survivors is depressed, if sanitary standards are lowered, and if specific public health measures such as immunization are curtailed or eliminated postattack -- if all of these things happen at once -- what will the biological consequences be? Some relevant information is available; for example, information on the effect of ionizing radiation on the immune response of certain laboratory animals.

It has become popular to cite the essence of the biological consequences of a nuclear attack as a reversion by the survivors to a more primitive method of living, meaning the life of 50 to 100 years ago. Such a statement is vague at best. We regard it an open question whether a mere reversion to the past is even possible, biologically speaking. Reversion should not be assumed uncritically.

Our biological environment is many things:

(1) plants and animals that are grown (cultured) under more or less controlled conditions for food or fibre: crops, livestock and poultry, etc., populations that man would presumably wish to re-establish postattack,

(2) plants and animals that are partially or near-totally controlled (suppressed) in numbers because they interfere with the production of food or fibre, or because they interfere with human health directly: "weeds" (plants), insects, bacteria, fungi, etc., populations that man would presumably wish to suppress postattack,

(3) plants and animals whose numbers are essentially uncontrolled by man but nonetheless harvested for food or fibre; fish from the sea, trees from the forest, etc.,

(4) plants and animals of no intrinsic importance to man but constituting key elements in the natural regulation of ecosystems of importance to man either because he regards them as useful or harmful.

A meaningful appraisal of the long-term biological consequences of a nuclear attack on health and the living environment would thus require:

(1) interpretation of nonbiological damage (industrial

damage or, more broadly, economic damage) in terms of implications on health and the living environment*.

(2) interpretation of biological damage in terms of impact on a nation, primarily in terms of health, agriculture, forestry, and similar activities, which are at least partly social or economic in character.

In short, biological and nonbiological factors are inseparable. The longer-term biological consequences follow from the initial biological and nonbiological damage and all the subsequent interactions, including what man does about the situation.

A meaningful study of the long-term biological or bioenvironmental consequences of a nuclear attack requires, furthermore, an appraisal of (1) the initial or prompt biological damage to people and their living environment from blast, thermal radiation, and ionizing radiation separately and combined, and (2) the consequences of multiple sources of damage to biological populations interacting with each other and with their physical environment. These appraisals have never been made to our knowledge.

We are presently unable, mostly for lack of information suitable for application, to appraise adequately the consequences of the residual injury to surviving people or livestock from blast. We are similarly unable to appraise non-urban firespread and its biological consequences, except to note somewhat superficially that an absolute upper limit is probably set by the fact that much of a Nation as large as the United States is not burnable by secondary firespread at any particular time. In the summer, much land is either in soil or young green crops, many areas are receiving much rainfall, and there are always the rocky areas, deserts, etc. We particularly need to pull together and examine the available information on the biological aftermath of non-urban fire.

The casualty estimates usually made available to us from the damage assessment calculations carried out by others are based upon oversimplified criteria that ignore thermal radiation and prompt ionizing radiation and that do not consider the combined injury from exposure to blast plus heat plus ionizing radiation. Such an approach not only raises doubt about the validity of the fatality estimates but also gives little information on the health status of the survivors.

We are unable to appraise the effect of large areas of high radiation levels on the wild and controlled-but-undomesticated biological populations: insects, weed plants, forests, mammals, birds, etc.

*This includes damage to a nation's ability to produce and transport and store food.

There are two problems, both difficult: (1) how to estimate effective radiation exposure, (2) how to predict the dynamics of these populations given their relative degree of depletion from radiation or fire. Exposure is hard to predict because, for example, many of the animals are partly below ground or close to the ground. Natural shielding against radiation may exist, but on the other hand insects close to the ground and plants may be subject to a beta dose because tissues are within the range of the beta particles.

By population dynamics, we simply mean the number-time variation, including reproduction, mortality, migration, etc., of a biological population for any given area. These quantities for any species will be determined by the interaction of the species with its physical environment and with other species. Data are hard to come by: prediction from studies of isolated populations (as in the laboratory or controlled field experiment) appears to be irrelevant; simulation by actually setting up realistic field experiments appears difficult. Certain generalizations about the number-time variations to be expected are offered not as doctrine but as incentive for speculation:

(1) an over-all limit to expansion of a biological population is food supply; populations can be thought of in terms of how far removed they are from direct feeding on plants; herbivores, carnivores, etc.,

(2) a population surge -- up or down -- by species A may be followed by one for species B which is parasitic on A,

(3) those environments having relatively few species (deserts, tundra, etc.) are in some sense "simpler" environments and as such are regarded as more susceptible to fluctuations of those populations that live there; the important point is that man's own historical influence on earth -- especially in civilized countries -- has been to simplify his biological environment so that agriculture could be established,

(4) radiation from a nuclear attack, or fire, will tend to still further simplify the environment; that is, these agents can only reduce numbers or species, not create them,

(5) but -- to repeat -- the great unknown is what man himself can be expected to do postattack; control measures, meaning a broad spectrum of activities including the ordinary practice of farming postattack (as opposed to stopping farming), would appear to make a great difference.

The major scientific obstacle to carrying out adequate appraisals is the lack of means for validation. The following biological problems are listed to explain this point; all of these problems are essentially unexplored:

(1) The status of communicable diseases (involving populations of biological organisms including bacteria and viruses and their hosts including animals and man) in a situation where people and livestock are injured, suffering from degrees of shock, subjected to substandard sanitary conditions, and living on an inadequate diet, with some degree of radiation exposure.

(2) The status of wild and controlled-but-undomesticated (free-living) populations of insects, plants, and mammals for which a population equilibrium (preattack) has been disturbed and may be further disturbed in the postattack period depending upon what man does with his environment.

(3) The extent of radiation exposure to plants and plant seeds not only from external gamma radiation but from beta radiation emitted by fallout deposited directly upon the plants, allowing for the fact that terrain and ground cover and other factors attenuate the radiation.

(4) The extent of radiation exposure to insects and other small creatures on or under the ground but close to the fallout particles (beta plus gamma radiation).

(5) The radiosensitivity of both plants and animals exposed to radiation under the natural circumstances of their life cycles.

We are presently unable to study effectively the economic geography or the plant geography or the regional pattern of agriculture of a nation except in a limited way. This means that relatively little regional detail is provided in our study reports beyond such things as a series of maps that show in a general way the portions of a country subjected to given consequences immediately after the attack (up to one year from accumulated dose).

Possibly the most significant omission from our study reports is an analysis or estimate of error. Based upon our knowledge of the assumptions used in damage assessment calculations (carried out by others) to make estimates of the immediate effects of weapons and the immediate consequences of an attack, we find it hard to believe that the casualty numbers have an associated error of less than ± 40%. In addition to errors in the technical assumptions now used in the computer-damage-assessment programs, and errors of fact in the data-base pertaining to the economic geography of a nation, additional error is introduced into the computer program itself by the grid-lumping procedure.

Considering the difficulties outlined in the preceding paragraphs, our approach has been to make the minimum number of numerical calculations sufficient to draw conclusions with due allowance for the errors carried in the estimates.

The net result of our current studies turns out to be as follows: (1) we are able to draw some inferences from the damage assessment estimates (by others) about the status of the survivors and their agriculture; (2) we are able to make a rough estimate of the internal emitter radiation exposure dose so as to enable comparison with the external gamma dose received by the survivors; (3) we make at least a qualitative assessment of the expected health of the survivors, for the short- and long-term, including the latent effects of radiation; (4) we make a general statement concerning the ecological situation postattack, including some preliminary remarks about the radiosensitivity of plants; and (5) we draw those conclusions that we think most clearly follow from the estimates in such a way as to be relatively insensitive to the many arbitrary assumptions*.

Thus, at present we do not purport to make full appraisals of the longer-term consequences of nuclear attacks on the health of people or on their living environment. In our opinion, such an appraisal needs to be made and to our knowledge has never been made in this country. The 1959 Congressional Hearings on the biological and environmental consequences of nuclear war, for example, emphasize the short-term direct damage and virtually ignore the interactions pointed out above.

3. General Approach

What do we do to change this state of affairs?

We start out by adopting the point of view that -- given our objectives -- the greatest significance of biological damage (to food and agriculture, public health, land, forests, etc) for national policy lies in its economic consequences. We insist here that "economic" be interpreted broadly to mean an important aspect of the social consequence and not to mean an antithesis of the social consequences. Analyses of the biological effects can start with assumptions about the immediate damage postattack; then it should be possible to characterize the subsequent biological damage and its significance for recovery. Ultimately, one would also "look backwards" to see which preattack and attack conditions can result in given levels of damage or prospects for recovery. These analyses should be addressed to a range of contextual war situations of general and sustained interest**. We believe that such an approach will aid in directing the focus of what is inherently a biological study to important problems and impose barriers against digressions into unnecessary detail.

* In comparative "case" studies, we find ourselves suggesting that only at the extremes can any two cases be told apart.

** See Annexes 1 and 2.

The biological study itself would emphasize (1) the health of the surviving people, including such directly related factors as nutrition, sanitation, and immunity, and (2) the economic prospects for the living environment as expressed by its ability to act, or to be restored to act, as a source of habitation, food, fibre, wood products, disposal of biological waste, etc. Both of these broad problems can be conveniently and usefully designated as problems in economic biology.

4. Approach to Problems in Economic Biology

Suppose for illustration we start off with the point of view borrowed from Winter* that the impact of a nuclear war on a nation can be assessed by making a comparison of human survival (interpreted as a set of requirements for consumption) with surviving inventories and means of production, particularly technological means. Requirements for consumption, compared with preattack, may be increased (medical care) or decreased (food) in particular circumstances. As pointed out by Winter, stable, sustained support of the survivors postattack implies the existence of a viable economic system. Or, practically speaking, that a stable solution has been found to the problem of using the surviving resources in such a way that adequate production rates are re-established before surviving inventories are exhausted. It would seem that our interest lies in knowing something about economic viability in association with various levels of attack damage, about the role that biological (and bioenvironmental) damage plays in affecting economic viability, and about the role that economic viability plays in affecting the later, deferred biological damage to health and environment.

Is, as has been suggested*, the dominant uncertainty to re-establishing a viable economy the re-establishment of agricultural production? And, is the re-establishment of agricultural production in turn primarily uncertain because of uncertainties in biological (ecological) factors? And, are such factors associated with the direct damage from such effects as fire and ionizing radiation, or more with the subsequent biological effects of a malfunctioning economy, such as lack of certain technological inputs to agriculture, or simply the cessation of farming?

In more detail, can we say that the availability of farm crops is more likely to depend upon radiosensitivity than upon radionuclide contributions to the human diet? Perhaps even more critical than either is the availability (as opposed to denial) of the land to the farmers who must work it. What, then, are the foundations for a relationship between the establishment of radiation exposure tolerances

*Winter, Sidney G. Economic Viability After Thermonuclear War: The Limites of Feasible Production. RM-3436-PR, September, 1963.

(land denial times) and postattack economic viability? Can we say that any land that can be worked within the first growing season postattack -- for a springtime attack, say -- (1) will produce crops undamaged by radiation to any significant extent, (2) will result in levels of radionuclides in the diet not considered intolerable provided the need for food is uppermost? Can we say that the internal emitter dose (except for iodine, perhaps) to people would be a small fraction of the external gamma dose already sustained, unless present conditions of shelter protection are greatly changed? Can we wrap all of this up by concluding that a nation attacked would be fortunate to be able to afford the luxury of making its decisions about the post-attack economic recovery -- including decisions as to which land to produce food on -- on the basis of minimizing radiation exposure from internal emitters? This would be because if the contamination levels are low (in association with relatively low levels of attack damage in general), then the nation will have and be able to exercise many options; whereas, if the contamination levels are high (in association with high damage levels), the nation will have few options to exercise and little ability to exercise them.

Turning to a health-disease problem as a second illustration, can we say that the long-term health hazards from the immediate and protracted exposure to radiation (the so-called latent effects and the genetic effects) are of little consequence in comparison with the immediate health hazards and their consequences associated with blast and fire and a malfunctioning economy, including lack of sanitation and medical care? Such consequences include effects on the mortality and morbidity of the surviving population, as well as genetic effects from nonequilibrium depletion of the preattack population. In short, even if radiation exposure is taken out of the problem, the problem remains.

We want somehow to ascertain the important biological limitations, if any, upon the ability of man to restore his environment, if not to preattack status, then to something familiar enough so he can manage it -- or at least to something vaguely recognizable. This objective suggests the need for studies of plants and animals (including insects, bacteria, and viruses) at the population level. What are the consequences of the selective depletion (or, of course, enrichment) of species?

5. Approach to Problems in Population Biology

We arrive at the suggestion that problems in population biology need to be understood if the broader study as a whole is to lead to useful results. For population biology, more than for any other biological subject matter applicable to the TAB study, limitations in basic knowledge hamper efforts to estimate the outcome of the attack as it affects health and the living environment. Section 1 gave a rough but useful classification scheme according to which populations can be regarded as to various degrees (1) free-living, (2) economically important, and (3) important for the internal regulation of an ecosystem. Ordinarily, agricultural land carries populations in all these categories, which are not mutually exclusive.

It is useful to regard the preattack populations as in approximate dynamic equilibrium. If trends exist, the rates of change would be slow compared with the sudden changes caused by the attack itself (if not, this is equivalent to suggesting that the attack had relatively little immediate effect and that there is time to counteract any long-term trends that might have set in). These changes would either be in the populations themselves (selective depletion, primarily) or in their associated physical environment. Given some more-or-less sudden, abrupt, and large changes in the population composition of the biosphere, and of the associated physical environment, what are the consequences?

Special aspects of the general question include the consequences to the gene pool. There is not only the effect of radiation, but of high nonrandom mortality in the population at the time of the attack. Another aspect is demographic. What will the life expectancy of the survivors be, if the preattack population is heavily depleted?

For a free-living population, we might assume that the biological end point of interest is the size of the population in time and space. Our interest would center in birth-death and growth and interaction processes. We would then assume that if we use data from observations of free-living populations under natural circumstances, the intraspecific and interspecific interactions are all accounted for in effect, though our observations may not be sufficient to let us sort these interactions out.

If population homeostasis is the rule, by action of negative feedback mechanisms of regulation, then outbreaks or depressions could occur transiently (because of nonequilibrium conditions) but there would be no divergence. Extinction or other irreversible phenomena would occur, if at all, because the populations were finite. A general problem is to discover how many equilibrium states there are for the systems studied and what the rules are by which a nonequilibrium state changes to a particular equilibrium state.

Energy flow concepts may also be relevant, and so, in the future, may be information flow concepts, a measure of complexity, or -- in ecology -- diversity. Some progress is being made toward viewing biological populations from the standpoint of statistical mechanics, that is, as ensembles in phase space. In this way, certain macropopulation relationships can be ascertained without reference to the overwhelming complexity of the microphenomena.

As an example, what does "simplicity" mean as a description of biomes? Is the desert, the tundra, or a climax forest more simple? Do we mean paucity of species? Does such simplicity correlate with the likelihood of severe fluctuations? Is diversity protective? Have man's historical activities served primarily to simplify his environment? Is an equilibrium community simpler or more complex than a successional-stage community? Are equilibrium communities better described as mosaics than continuums? What is the significance of mosaics from the standpoint of information content?

Some more specific problems include asking whether there is a correlation between the degree of control exerted by one species in an ecosystem with the fraction of the biomass comprised by the species. And finally, of course, we wonder how to use data from the laboratory or controlled field experiment in predictions for free-living populations in their environment.

6. <u>Tying Together: An Approach Through Systems Analysis</u>

With the background of Sections 1-4, we perceive a proliferation of questions and of subject matter that could easily get out of hand, lose form, and thus become hopeless to work with. It is necessary to have some scheme for weeding out irrelevant or trivial questions -- at least provisionally -- and for thus minimizing large accumulations of data of questionable utility. A central part of the study program might therefore take the form of a more rigorous, formal study such as the approach of so-called systems analysis. In particular, the appreciation of (good) systems analysts for the role, in problem solving, of (1) uncertainty, (2) error, and (3) sensitivity of results to assumptions can lead to more useful results and conclusions about the biological and environmental consequences of nuclear war. A further discussion of systems analysis and its possible usefulness appears in Annex 3.

Systems analysis is not the end of the matter, however. It will be necessary to collect and systematize* and interpret a great deal of information (data) now in the scientific literature, in many disciplines. One thinks of the past, but somewhat forgotten, practice of monograph-writing, wherein a broad view of subject matter is taken with as little loss of analytic insight as possible. The essence of such systematization is empirical data analysis and theory. In some

* in the classical sense of science, having little to do with "systems analysis"

instances, research aids such as computing and data processing would be needed. But we would emphasize that neither extensive computations, nor intricate mathematical manipulations, nor complex and extensive data processing should be regarded as necessary or sufficient activities for an adequate study. Since we can not show that these activities are unnecessary, we do not exclude them either. Various degrees and kinds of statistical data analysis and theoretical work will be essential.

For illustration, some fairly obvious needs for systematizing data -- and some lines of approach -- are suggested below; these illustrations apply primarily to subjects of interest to the Division of Biology and Medicine research program but other illustrations could equally well have been chosen:

(1) The available information on the radiosensitivity of plants and animals needs to be systematized. In mammals, for instance, one might start with acute lethality, then consider the acute syndrome leading to either death or recovery, then the latent effects including nonspecific lifespan shortening. Interest is in the quantitative prediction of response (or pattern of occurrence of response) for radiation exposures over a wide range of species, gamma doses, and biological endpoints. There would be less interest in such problems as the relative biological effectiveness of radiations of differing physical properties; at least such interest would be deferred.

For plants, we wonder how far the concept of a rank-order list of radiation effects can be related to increasing dose, and whether such a list is invariant by species versus a radiation dose parameter such as fraction of the 100% (of species) lethal dose.

Statistical processes like death need to be related to physiological processes as a basic approach to a major improvement in our understanding. Interspecies comparison techniques need to be developed so that we can use all of the relevant knowledge about mammalian dose-effect relationships to get the best estimates of radiosensitivity in man, in economically important animals such as livestock, and in animals that play an important part in the regulation of ecosystems. A possible approach to interspecies comparisons is through the use of dimensional analysis based upon arguments of biological homology.

(2) The available data on radionuclide transport in the atmosphere and biosphere needs to be systematized. One objective is to compare the relative contribution of the several nuclides to the total exposures. Another objective is the development of a scheme for systematically eliminating many of the nuclides from detailed consideration as a source of hazard -- because certain of their

properties lead directly to conclusive argument. At least we should be able to rise above ad hominem argument over which nuclides are "hazardous."

(3) The data on measured or calculated radiation exposures (for example, in r or rad units) resulting from previously specified internal or external radiation sources needs to be systematized. We need to know how to estimate the beta and gamma exposure to plants, for instance, allowing for the attenuation of terrain and ground cover. Likewise, we need to estimate the exposure to insects and other small creatures living on or under the ground but close to fallout particles and thus to beta as well as gamma radiation.

(4) We need a review and appraisal of knowledge (theory plus data) on the dynamics of biological populations, including populations of genes. Attention needs to be given to the question of scale. We want, for instance, to estimate the status of communicable diseases, involving populations of biological organisms such as bacteria and viruses and their hosts including animals and man. We also want to estimate the status of wild and controlled-but-undomesticated (free-living) populations of insects, plants, and animals for which a preattack equilibrium of sorts has been abruptly disturbed and may be further disturbed in the postattack period.

Properly systematized current knowledge in agriculture, forest and range management, soil conservation, wildlife management, water resource management, public health, and vital statistics can also help to provide an adequate background description of the preattack (undisturbed) environment and thus give a basis for estimating the effects of a nuclear attack. A study that is ecological, sociological, and anthropological in nature can draw some applicable information from historical processes behind the changing face of the earth, whether man-caused (and therefore most likely a long-term repeated insult) or natural (and therefore possibly abrupt or catastrophic).

Our hope is that the two aspects of the study -- formal, rigorous systems analysis and the general systematization of data in certain fields -- would proceed together, each contributing to the other. Flexibility of method, a willingness to explore problems, and ample provision for feedback of results and revision of ideas and method are important. Provisional ideas about requirements for new research will develop. Because of lead times, it will not always be reasonable to postpone starting new research projects until the need is well justified by the analysis. From the start, a part of the study should be the provisional listing of certain problems for which it is reasonably certain that new experimental work will be required before much progress can be made. New research work would be sponsored through the normal research programs of AEC and other agencies.

7. Conclusions

(See the Summary, p. ii.)

Annex 1.

OUTLINE FOR AN ANALYSIS OF THE IMPACT OF NUCLEAR WAR

I Prewar situation

A. Military

1. Strategic doctrines and war plans

2. Capabilities of weapon stockpiles and delivery systems

B. Civilian preparations

1. Warning time

2. Shelter

3. Evacuation

4. Recovery plans and preparations

a. Paper

b. Stockpiles of recovery items likely to be critical

C. Economic conditions

II Wartime situation

A. Precipitating force: five general possibilities

1. Inadvertence

2. Miscalculation

3. Escalation

4. Soviet first strike

5. United States retaliation

B. Attack pattern

1. Distribution by targets

a. Military

1. Strategic air forces and air defense forces

2. Other forces and installations

b. Civilian

1. People

2. Cities

3. Economic resources

4. Political authority

2. Size of attack

3. Yield of weapons and accuracy of delivery

4. Types of burst: air, land surface, sea, height of burst

5. Fission yield; fission to fusion ratios

6. Duration of attack

C. Attack environment

1. Weather, winds

2. Season or time of year

3. Ground cover

4. Shelter

D. Prompt effects of the weapons

1. Blast

2. Fire

3. Prompt ionizing radiation

4. Residual radiation

5. Indirect effects: e.g., fire

E. Termination of war: three general possibilities

1. Short-term defeat of one side

2. Mutual agreement to end devastation

3. Exhaustion of belligerants as a result of a spasm war

F. Short-term primary damage to biological and environmental resources

1. People and their health and vigor

2. Livestock and crops

3. Forests and ranges

4. Land and water

G. Short-term primary damage to the economy: technological conditions for production and potential for recovery

1. Agriculture

a. Viable farms

b. Food processing plants

c. Storage and distribution

2. Network industry

a. Transportation

b. Communications

c. Government

3. Energy industry

a. Petroleum

b. Electricity

4. Other industry

a. Machine tool

b. Etc.

5. Population

a. Labor force

b. Skills

c. Health

III Postwar situation

A. Survival and reorganization

1. People

2. Preservation and restoration of essential economic assets and medical facilities

3. Maintenance of civic order

B. Secondary damage to people and their living environment as a sequel to the short-term primary damage to biological and environmental resources and a malfunctioning economy

1. Medical and health problems

a. Radiation hazards

b. Communicable diseases

c. Malnutrition

d. Physical exposure

e. Psychological trauma

f. Life shortening

g. Cancer

h. Synergistic effects

2. Genetic problems

3. Ecological changes

a. Life forms affected

b. Inter-species relations

c. Population changes: depressions and eruptions

1. Infestations

2. Epidemics

3. Extinctions

4. Combined biological stresses

IV The long-time aftermath: problems of recovery and reconstruction; re-establishment of a viable economy

A. Agriculture: Some specific examples

1. Animal husbandry

2. Soil management

3. Crop ecology

4. Irrigation

5. Fertilization

6. Disease control

7. Pest control

8. Food processing and distribution

9. Nutrition

B. Land and water resources: Some specific examples

1. Range management

2. Forest management

3. River basin management

4. Wild lands management

5. Reservoir management

C. Ecological engineering

D. Medical and public health

E. Genetic

F. Other recovery problems

1. Economic

2. Social and psychological

3. Political

Annex 2.

ILLUSTRATIVE DEVELOPMENT OF CONTEXTUAL SITUATIONS IN RELATION TO QUESTIONS

QUESTIONS

1. To what extent are the biological and environmental consequences of nuclear war primarily the sequelae of a malfunctioning economy?
2. How important a factor, economically and otherwise, is man's response to the immediate damage of an attack?
3. To what extent would the consequences be less severe if the attack was made with nuclear weapons producing no radiation exposure whatever?
4. To what extent is agriculture limiting in postattack recovery?
5. To what extent do uncertainties in biological information limit ability to predict the consequences to agriculture?
6. etc.

CONTEXTS

1. Geographical areas
   a. USSR-USA exchange
   b. War in Western Europe
   c. War in the Mediterranean
   d. War in the Far East
   e. War in the Caribbean
2. Targets
   a. Strategic bombers and missiles
   b. Air defense forces
   c. Other military objectives
   d. A nation's population
   e. A nation's economy
   f. Aspects of a nation's vulnerability that are biological in nature
3. etc.

Annex 3.

A note on present concepts of operations research and systems analysis with applications to the study of the biological and environmental consequences of nuclear war.

I

What is a "system?" No specific answer will be suggested here. Much philosophical argument is devoted to deciding such qeustions. One related view is that systems analysis is a broader development of operations analysis (of the practical World War II sort, I presume), bearing the relationship to its predecessor that strategy does to tactics[1/]. Some of the World War II operations being analyzed could, of course, be regarded as instances of systems. Both operations analysis and systems analysis are currently viable, irrespective of whether they can be defined.

The notion of a system is not, of course, new even to science. Perhaps the most useful conceptual treatments have been those developed by the thermodynamicists. They seem to appreciate and stress that a "system" is a product of mankind's need for thinking in terms of categories and therefore can be anything we say it is so long as we are definitive and explicit.

At any rate, the system may simply be matter in multicomponent, multiphase equilibrium; an atomic nucleus; a metal conducting heat; an electronic network; a cafeteria waiting line; a group of children with a teacher; or the money and credit flow. And systems analysis and operations research clearly relate to such diverse subjects as mathematics and statistics, thermodynamics and statistical mechanics, ecometrics, behavioral sciences, information theory and cybernetics, general semantics, and the management sciences.

One point of view[2/] that may be fruitful is to note the particularly close relationship between systems analysis and (a) practical decision-making and (b) those aspects of mathematics, statistics, and economic theory having to do with a formal theory of decision-making. Operations analysis in particular is often revered for its down-to-earth associations in World War II; there was less concern then about the role of the analyst vis-a-vis the guy doing the shooting.

A system (and systems analysis) is also regarded as a concept designed to overcome traditional approaches to analysis where

1/ RM-1829-1
2/ RM-1678

isolation was readily possible; the system implies overlapping of many elements ordinarily studied separately. In thermodynamics, however, perhaps a better perspective is put on matters: the system involves the notion of isolation, but the isolation need not be complete provided the terms of the interactions with the environment are specified. It then makes sense to think of a system as something to which definable properties can be attributed in a formal sense (e.g., conservatism, determinism, etc.). A system would, furthermore, then bear analogy with mathematical sets: there may be subsets, or the set itself may be a subset of some other set; in brief, the elaborateness or complexity of one's system is likely to be arbitrary and the choice to depend upon the purpose of studying it. Ideally, the purpose defines the system. For our study of the biological and environmental consequences of nuclear war, we suspect that practically speaking we have yet to define the system(s) to be studied, and this may mean we haven't defined our purposes well enough either.

The question is bound to be raised whether a system can be effectively analyzed by using information about subsystems. If the system can be regarded deterministically, and if the complexities are not too great, the answer is that it can and, in fact, this is the common approach to the analysis of most problems in science and technology. If, however, the system possesses random components (or, better, exhibits random behavior), or if the complexity is so great that the interactions are not understood, then the answer is probably no.

Statistical mechanics describes certain macrophenomena involving mass and energy transport without recourse to an exhaustive description of the microphenomena, and such an approach also leads us to an appraisal of the limits of deterministic statement.

Now, what of this is or could be useful for the study of the biological and environmental consequences of nuclear war? Certain problems, such as the macroscale dynamics of single and multiple biological populations, with strong or weak interactions, including interactions with the physical environment (boundaries) may be amenable to an analogous approach. We would be especially interested in the formulation of negative exclusion laws whose role is so fundamental in the physical sciences. These laws would be satisfactory for our purposes even if applicable only over restricted domains.

II

Damage assessments or vulnerability analyses might properly be viewed[1/] as studies of the effects of severe disturbances (as from

1/ That is, they ought to be done, ideally -- not as done currently.

nuclear war) to the works of man (or, his social and economic systems), to his health, and to his environment, including his living environment (or, on certain biological systems). As a problem in systems analysis, each estimate of the effects of a disturbance on some one major system would in realism need to be made with due regard for interactions with other systems. Most of the existing approaches to damage assessment or vulnerability analysis developed thus far under the military or civil defense agencies center in elaborate data processing schemes and stop at the point of enumerating damage to physically existing objects (people, oil refineries, acres of land, etc.).

Most of the current data processing schemes have been developed without consideration of what modeling of social, economic, or biological phenomena might be appropriate for the underlying problem being studied, whatever that might be. It is assumed that enumeration of physical objects is the first and only approach. The end product of the data processing is a tally of damaged objects. This approach leads to the accumulation of a large "data base," not an adequate substitute for needed modeling in the field of economic geography. The end product is commonly inapplicable for studies of the major problems in agriculture, forestry, public health, etc.

A proper analysis of the consequences of nuclear war, including the biological consequences and their relationship to the total, requires, we conclude, an integrative, "system" approach whether or not formal data processing schemes are utilized. A distinction should be made between meaningful complexity to be taken into account in describing the dynamics of these systems as opposed to the complexity of the elaborate data base associated with current data processing schemes. The latter represents complexity without compensating added information.

An important point in the approach is to reject at the start the idea that a quantitative time-space description of "all" the consequences is to be developed. More likely, we will be interested in limiting cases, including reverse cases of showing that certain consequences are <u>not</u> likely to happen.

The approach also assumes that there is a limit, practical and conceptual in character, to the degree to which equivocation can be eliminated from statements about the biological consequences of nuclear war, and even to the freedom to arbitrarily designate the points where equivocation will be tolerated. Both of these points are difficult to understand or accept.

A key factor in determining what the ultimate consequences of a nuclear attack will be appears to be the role that man himself plays postattack. This factor is in turn related to the state of the environment. We want to learn the conditions under which these factors interact to a destructive or constructive end.

It may be useful to ask abstractly which is more vulnerable, the social and economic systems of man or the biological systems of his environment. A measure of vulnerability may be the capacity for information processing.

BACKGROUND READING[1/]

Literature on systems analysis, including P-699, RM-1678, RM-1829-1, RM-1937, books, ORSA journal, etc.

Literature of earlier RAND civil defense studies including R-322-RC, RM-2206-RC, RM-3436-PR, etc. (and the P-series for the 1961 Congressional Hearings)

Hardin, Garret(t), Nature and Man's Fate. Mentor Books. A book developing cybernetic notions of biological populations, tying to theory of evolution, the role of isolation in speciation, genetic drift, etc.

Thomas, W. L. (ed.), Man's Role in Changing the Face of the Earth. An international symposium of the Wenner-Gren Foundation. University of Chicago Press, 1956. A social, anthropological, biological view of our world and how it got that way.

Mathematical Theories of Biological Phenomena. Annals of the New York Academy of Science, Vol. 96, Art. 4, pp 895-1116, March 2, 1962. Includes discussion of analogy between Gibbs ensemble and biological ensemble, and discussion of mortality as an inherently stochastic process.

Neyman, Jerzy (ed.), Proceedings of the 4th Berkeley Symposium of Mathematical Statistics and Probability, Vol. IV, Contributions to Biology and Problems of Medicine. University of California Press, 1961. Many provocative articles on problems of populations, transport, physiology, etc.

Bartlett, M. S., Stochastic Population Models in Ecology and Epidemiology. Methuen, 1960.

Boulding, Kenneth E., Conflict and Defense: A General Theory. Harper Torchbooks, 1963. Includes discussion of "ecological" and "epidemiological" models.

The Yearbooks of the U. S. Department of Agriculture, from 1938 to now offer as good a way as any of ensuring that one gets back down to earth. Topics include soils, weather, forests, animal diseases, agricultural economics and marketing, land management, and soil conservation.

1/ This list almost certainly should be expanded.

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