Review

SUMMER 1967

OAK RIDGE NATIONAL LABORATORY

THE COVER: Artist's conception of a large coastal desert food factory envisaged by R. P. Hammond in an article beginning on page 3. The food factory consists of a large centrally managed farming area and a nuclear powered desalting station to supply the water needed for irrigation. An installation of this type could produce enough food for several million persons. In addition to supplying many millions of gallons of fresh irrigation water each day, it would also produce electricity and fertilizer and could be the nucleus of an industrial complex.

DAVID A. SUNDBERG, *Editor*

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Review

OAK RIDGE NATIONAL LABORATORY

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OAK RIDGE NATIONAL LABORATORY
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The problems of communication within a big research institution and their connection with the objectives of this new publication are discussed by the director of Oak Ridge National Laboratory.

INTRODUCING THE REVIEW

By ALVIN M. WEINBERG

COMMUNICATION within a big laboratory gives rise to an all but insoluble dilemma. Ideally, the activities of each of the laboratory's investigators bear upon those of every other investigator. But as the number of investigators grows, the mountain of information which each must digest about the others grows, until finally each investigator can be overwhelmed by his personal information explosion.

This phenomenon, which I have sometimes referred to as The Second Malthusian Dilemma, exists to some extent in any organization of interacting individuals, but it is particularly troublesome in a large research laboratory whose main objective is the generation of new information. Therefore laboratories generally respond to growth by fragmentation and subdivision. New small groups spring up whose members communicate strongly with other members of their own group but only weakly, or not at all, with other groups.

Though this trend is almost as much a law of nature as one of C. Northcote Parkinson's laws, its effect on the laboratory can be devastating. For the laboratory, which began as a coherent entity and dedicated to a single purpose, shatters into a multitude of separate units, each tending to go its own way, each seeing its own specific purpose through narrowly focused glasses.

Is anything really lost if a big laboratory becomes only a collection of weakly interacting little laboratories? To my mind, the laboratory's very essence is lost, both in applied research and basic research. In basic research the strength of laboratories like ORNL lies in the interdisciplinary composition of their staffs. Over and over again it has been demonstrated that the whole can be greater than the sum of its parts, that good people from diverse fields working together can make major scientific discoveries that are denied geniuses working in isolation.

Alvin M. Weinberg, Director of the Oak Ridge National Laboratory, has for many years been concerned with the complex problems associated with communication in science and technology. The White House report, "Science, Government and Information," which was prepared under his chairmanship in 1962, remains one of the most significant documents on the subject of scientific information.

Coherence is perhaps even more important in carrying out applied research. Many of the large jobs we are now undertaking at ORNL—the breeder reactor, civil defense, desalination and the agro-industrial complex as an instrument for development of the world's hungry nations—involve numerous technologies and viewpoints, some from the natural sciences, some from the social sciences, some even from the arena of public affairs. The key to successful attacks on these complex questions is the existence of coherent teams working aggressively and with enthusiasm.

This philosophic homily is, I believe, a proper introduction to the first issue of the Oak Ridge National Laboratory *Review*. The *Review's* purpose is to help stem this trend toward fragmentation that creeps up on us. The *Review* will seek to give each member of the Oak Ridge National Laboratory a better understanding of what ORNL is all about, to supplement his professional interest in what his colleagues in the same field but at other institutions are doing, with a comparable interest in what his colleagues in different fields here at ORNL are doing. In short, the *Review* will help maintain ORNL as a coherent, purposeful and interacting institution, one in which the successes and elations experienced by people in one field are transmitted to and shared by every member of the Oak Ridge National Laboratory.

Each article in the *Review* will be pitched at the level of scientists and engineers who are not specialists in the subject of the article. The authors will be chosen mainly from the staff of the Oak Ridge National Laboratory, but occasional articles by others will be included. We are very fortunate to have as the editor of the ORNL *Review*, David Sundberg, former editor of the American Nuclear Society publication, *Nuclear News*, and we wish him great success in this new venture.

All of us will look to the ORNL *Review* for much of the interdisciplinary interaction that has been such a precious characteristic of the Oak Ridge National Laboratory. The *Review*, in strengthening this spirit of cooperation, will surely enable our Laboratory to better discharge its responsibilities to the society that supports it so generously.

Tapping the oceans to farm the deserts is now possible and, under certain conditions, practical. Very soon, desalting sea water will be essential to meeting the world's rapidly increasing food requirements.

Desalted Water for Agriculture

By R. PHILIP HAMMOND

R. Philip Hammond is Director of the ORNL Nuclear Desalination Program which is sponsored jointly by the Atomic Energy Commission and the Interior Department's Office of Saline Water. He began investigating the possible application of nuclear energy to the desalting of sea water more than 12 years ago as a member of the Reactor Development Division of Los Alamos Scientific Laboratory. In the early 1960's publication of his preliminary studies indicating the promising economics for very large scale nuclear desalting plants gained international attention and an invitation to continue his work at Oak Ridge. Two years of additional preliminary studies at ORNL began in 1962 and led to the establishment of the Nuclear Desalination Program, with Hammond as its director. The author of numerous publications in several fields, Hammond was a member of the U.S. delegations to both the 1955 and 1964 Geneva Conferences on Peaceful Uses of Atomic Energy. He holds a Ph.D. in Physical Chemistry from the University of Chicago. The article on these pages is based on a paper which Hammond presented at the May 23–31 International Conference on Water for Peace in Washington, D.C.

MAKING the deserts bloom has been an age-old dream of mankind. Throughout our civilized history, wherever nature has provided a handy river, its diversion into the desert has usually been a fruitful and successful venture. The Nile, the Colorado, the Indus, and the Tigris-Euphrates are examples. There is at present no shortage of deserts in the world—nearly every country has at least a small one—but the supply of rivers to serve them is quite low. Many important studies have been concerned with what can be done with the rivers we have. I would like to discuss what we can do about the rivers we have not.

As the earth's population has grown, mankind has met the need for more food by putting more and more land into production. But now experts tell us that the supply of new productive agricultural land has been nearly exhausted at a time when the population is growing faster than ever before. The shortage is not one of land itself—only 11% of the land is used for agriculture—it is of well-watered arable land. Most of the world's land is too dry, too salty, too rocky, or too wet, or the rains come at the wrong time, etc. Figure 1 shows our use of the land.

It is impossible to overestimate the importance of improving food yields on good land and of improving the distribution of water on marginal land. But now a new and hopeful element has been added:

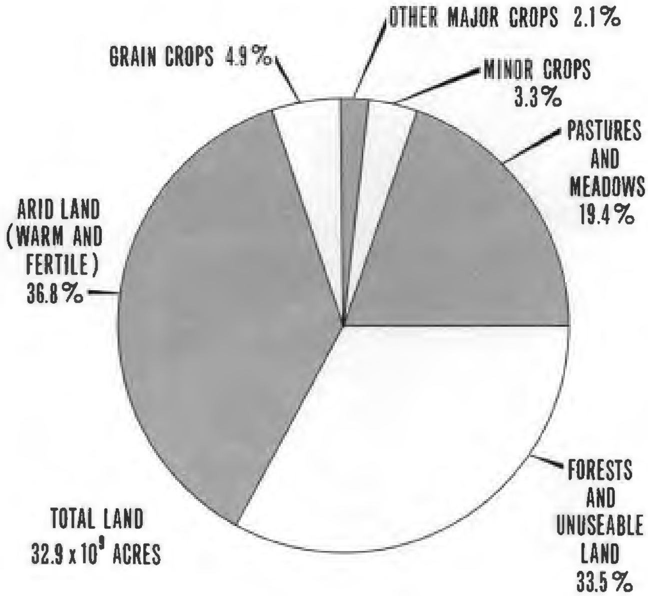


Fig. 1. Use of the World's Land.

the large-scale desalting of seawater has become a practical reality. The Metropolitan Water District (MWD) of Southern California has already undertaken to build a nuclear desalting plant to produce 150 million gallons of fresh water per day. Successors to this plant could be built on any scale to which we wish to commit our resources. If we wished, we could in the future create another Nile or another Colorado, flowing backward from the sea into the desert.

With this capability, a tremendous unused land resource—the arid lands—could be used for food production in the future. According to UNESCO, the supply of warm, fertile, accessible arid land exceeds several-fold the total land now used for our major food crops. Less than a fifth of our food crop land is presently irrigated. Yet this portion produces the majority of crops. More than a third of all arid land is close enough to the sea to be irrigated from that source.

Man's Future Land Bank

The desert has been called man's future land bank. But to put it to use we must be able to reap a benefit which will justify the cost. The purpose of this article is to review where we stand, to assess the costs, and to see what the future might hold for agriculture with desalted water from the sea.

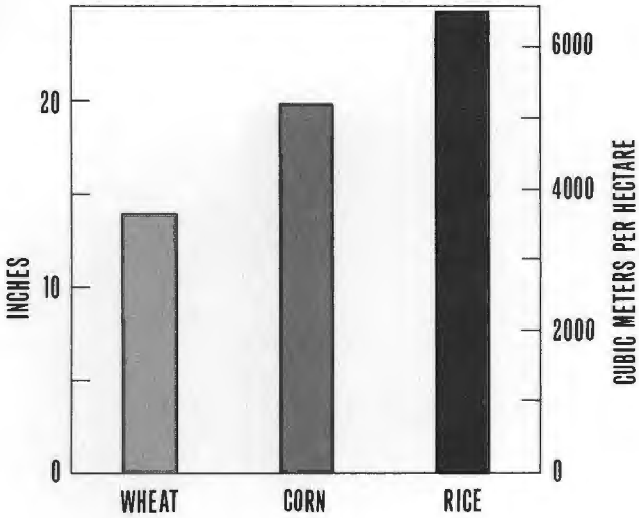
Only a few years ago it appeared that the cost of desalted water would always be more than 25¢ per cubic meter, or $1 per 1000 gallons, and that only small plants were possible. But now the MWD plant, if applied to food production, would sustain nearly a million persons, and the cost of the water is about 5¢ per cubic meter. So the question for the first time appears worth considering: For 5¢ worth of water, can we hope to raise 5¢ worth of food, or more?

The answer appears clearly negative if we consider the overall average yield of conventional agriculture. But some time ago I began to wonder if the answer might be different if we were to look at the yields of the *irrigated* land only. The basic food grains—wheat, corn, and rice—provide more than 70% of man's food supply. Although specialty food of higher market value would perhaps better support the cost of desalted water, it might have only a limited market. So let us examine the growing of grains only. If this appears even marginally feasible, then the addition of some high value crops would bring further economic and nutritional benefits.

I will first review the measurements which have been made by recognized authorities on the amount of water used by irrigated grain crops, and the yields obtained, in order to estimate how much water it takes to provide one person's food supply. I will then consider the special aspects of farming in a desert with desalted water, as compared with conventional agriculture.

The amount of water transpired and evaporated into the atmosphere from a growing crop has been the subject of intense investigation. Figure 2 is

Fig. 2. Water consumed by Crops.



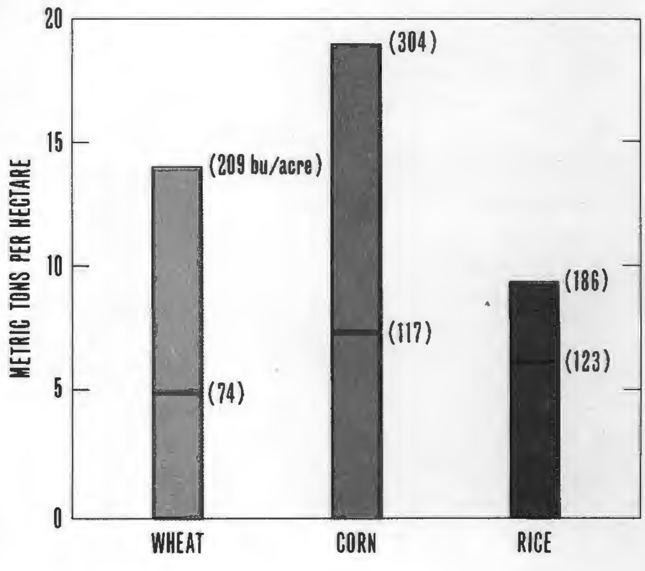
based on data provided by experts in the U.S. Department of Agriculture for the consumptive water use by the three major grains during the growing period. Thus, for rice, we see that about 25 inches of water per crop are required, or reading on the right of the figure, 60 centimeters, which is 6000 cubic meters per hectare. I am told that rice can be dry-farmed with a lower water consumption than this, but specific data are lacking so far.

The optimum growing procedure for maximum efficiency for the use of water has not been studied for conditions which would result from a desalted water supply. But there are a number of interesting indications from related work, such as those which refer to the timing of water application and the proper use of fertilizer. For example, it has been shown that making life too easy for the plant can have deleterious effects. At some stages of plant growth, too easily obtainable water and nutrients stimulate a lush growth of stalk without helping the grain yield and foster an under-developed root system. In later stages, then, water will be lost because it percolates too quickly beyond the shallow root zone, while the oversize foliage can increase the need for water and the tendency for stalk collapse. To find the best growing techniques would require extensive studies for each type of food. There are a few current experiments of this type, but much more work is needed.

Next we must consider the grain yield per unit of land area. Ordinary farming operations are attempted under a variety of conditions that affect the yield. Such variables as type of seed, type of soil, the latitude, the weather, the water supply and quality, the farming techniques, pest control, and fertilizer supply can all vary over wide ranges and produce major effects. The data show that farmers generally obtain far less than the optimum growing conditions, because there are frequent occurrences of record yields which are three, four, or even ten times the average yield. Just what the optimum consists of is still unknown, but we suspect that sunny, fertile desert land, irrigated with a controlled supply of pure water, would begin to approach it.

Figure 3 gives a few statistics about yields of wheat, corn, and rice under irrigation. The grid on the left gives yields in metric tons per hectare, and the numbers in parentheses are bushels per acre. The top of the bar is the record yield, and the line further down is the average yield over some substantial producing region. Naturally, some of the farmers in the region routinely obtained more than the average yield. For wheat, note that the representative yield I have chosen is about five tons per hectare, although since the figure was prepared I've visited an irrigated wheat region in Mexico where yields of eight tons per hectare are common.

Fig. 3. Grain Yields.



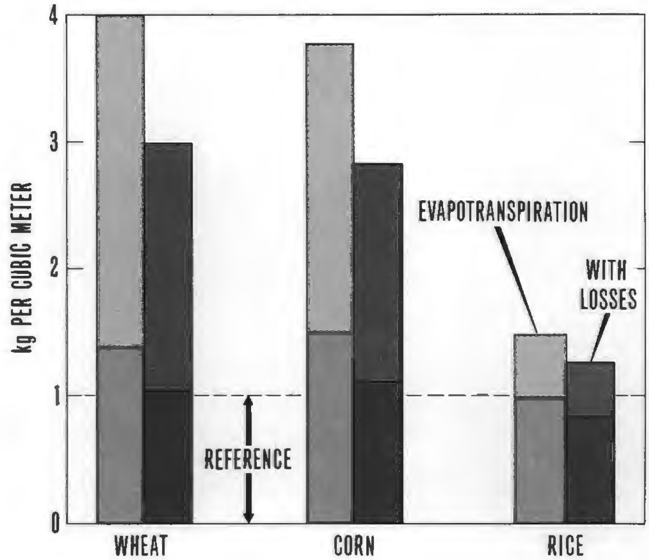


Fig. 4. Grain to Water Ratio.

Increasing Genetic Potential

The record yields might be taken as some measure of the genetic potential. But this too is changing. Plant geneticists are just entering a new level of understanding of plant breeding for yield and are rapidly producing new varieties of food plants of phenomenal productivity. Results with hybrid corn are an example. If everyone in the world liked to eat corn, and if everyone could produce 19 tons per hectare, we would not have any food problem—for a few years, at least.

From the data on water use and grain yield we can compute the grain output per unit of water consumed, or the grain-water ratio. These ratios are given in Fig. 4. Let us look at the results for wheat, on the left. The first bar shows that we can obtain 4 kg of wheat in consuming 1 cubic meter of water, with the record yield. If underground losses of 25% are included, this becomes 3 kg per cubic meter of water actually applied to the land, shown by the adjoining bar. The lower segments of each bar are similarly based on the lower reference yield of 5 tons per hectare which we noted was representative of a large area. Although the water consumption and yields for corn and rice were different from those of wheat, the ratios are very similar for the reference yields. Thus we can take the value of 1 kg per cubic meter as a general reference guide for a typical grain on irrigated land, using good present-day farming practice. We shall make use of this number later.

How much grain does it take to sustain one person in full vigor for one year? From data given by Dr. Roger Revelle, Director of the Harvard Center for Population Studies, we find that about 250 kg is required. His estimate includes an allowance for seed for the next crop, feed for animals to provide a small protein input, and an allowance for losses from waste and pests. This is more food than is received by millions of people today; yet it is almost a minimum for sustained human activity. If more animal-based foods were included, the grain requirement would rise rapidly.

Taking 250 kg per year per capita, and our previous number of 1 kg per cubic meter, we find that the water needed for production of one person's food is 250 cubic meters per year, or 180 gallons per day. When compared with the large water consumption per person on the average in conventional nonirrigated agriculture, this seems at first a surprisingly small amount; yet we have chosen yields and water use efficiencies that have been attained and surpassed many times in both conventional and irrigated agriculture.

I think this result makes it clear why we must examine in a very realistic way the prospects for putting deserts to work with desalted water. The MWD project would feed nearly a million persons. (World population increases by one million every $5\frac{1}{2}$ days.) The cost of the water from MWD would be 3–4¢ per day per person fed. The pioneering MWD plant will be followed by later generations of plants which will benefit from the rapidly advancing technology being developed by the USAEC, the Office of Saline Water, and by others both in the U.S. and abroad. This work has been described in official reports of these agencies and in those of the Oak Ridge National Laboratory. Even without the assumption that there will be any major new inventions, the advances already in course of development are expected to lead in 10 to 15 years to water costs

In addition to providing water for agriculture, a nuclear desalting plant could be the nucleus of a large industrial complex.

less than half those estimated for MWD. In the agricultural field, some agronomists assure me that the present rapid rate of advance in genetic and technique improvement is very likely to produce another factor of two in yield in the same period.

Although this would still be less than current record yields, I am less able to judge these agricultural prospects than the desalting ones, where I have some personal knowledge of what's involved. If the agronomists are right, however, then only 90 gallons per day per person are needed, and water costs of 2¢ per day per person would result from MWD, and only 1¢ for advanced plants. Remembering that there is a lot of work to be done before such costs are in hand, and that there are other costs than water to growing food, I think we should now take a look at what kind of farming we might expect in the desert.

Farming in an arid, desert land with desalted water from the sea must necessarily differ in many respects from ordinary farming. Most of the differences derive from the cost of the water. Whatever the advances in technology, distilled water will never be cheap in the same sense as are rainfall or diverted runoff. Thus, rational agriculture must conserve the most costly input, which in the desert is always the water.

The Food Factory

Other differences arise from the nature of the water supply itself. Instead of randomly distributed rainfall, or stored floods, the water comes from a nearby "water factory" at the seaside. It will be in reliable and constant supply year-round, as well as high in purity. These factors, and the other characteristics of the site, mean that most of the variables in the production of food can be precisely regulated. Therefore, a large agricultural enterprise of the type which I envision may appropriately be called a "food factory."

It should be recognized that the food factory will attract neighbors. In addition to water, the nuclear station can produce cheap electric power, fertilizer, and other products, and thus provide the nucleus for an industrial center. Such a water factory, food factory, and industrial complex may bring many indirect benefits in addition to the primary goal. We are just beginning to explore the synergistic possibilities of this multiuse kind of installation, and we are beginning to refer to the concept as an "agro-industrial complex." This summer at Oak Ridge dozens of experts from around the world have been visiting us to help explore the advantages of such complexes. I shall consider here, however, only the simpler case of a water- and food-producing installation, limiting attention as before to grain production alone, although some high-value crops would be present in any actual case.

A food factory consists of a large centrally managed farming area equipped for efficient use of water and a nuclear powered desalting station which supplies the water. The site of the food factory has three main requirements: soil, sunshine, and sea. The location will naturally be in an arid region, otherwise someone would already be farming there. The land should be fertile, well-drained, and more or less horizontal. The sun is the source of the food energy, so the more cloudless days the year-round, the better the yield. Dependable sunny weather is one of the few assets most deserts have.

An important characteristic of a food factory is its size. As many studies show, the cost of water from a nuclear desalting plant decreases as the size of the plant is increased. So the factory must be rather large to compete with other methods of raising food. Smaller sizes would be feasible, however, if high-value crops were produced. For illustration

I will describe a food factory to feed one million people at the assumed grain consumption, which would require 180 million gallons of water per day, after allowing for underground losses. This would require a reactor of about 2200 thermal megawatts and an irrigated area 10 miles square, or 25,000 hectares. The following table gives some further data about the food factory.

FOOD FACTORY STATISTICS

FOOD YIELD OF "TYPICAL" GRAIN	250,000 metric ton/yr
NUMBER OF PERSONS FED	1,000,000
AREA IRRIGATED	25,000 hectares
	62,500 acres
WATER APPLIED	10,000 cubic meters/hectare
SIZE OF WATER PLANT	180 Mgd
GRAIN YIELD (2 crops/yr)	10 metric ton/hectare
LAND DUTY (in rotation)	
PREPARATION AND HARVEST	20 days
IRRIGATION SEASON, CROP 1	90
IRRIGATION SEASON, CROP 2	90
STOCK FEEDING	90
IDLE	75

Another characteristic of a food factory is the degree of control exercised over every step in the food-producing process. A central laboratory analyzes soil from each block of land and determines the appropriate fertilizer mix. The fertilizer itself is probably produced on the site, using power from the reactor. Pest control is similarly centralized. The seed used is tested and controlled. Irrigation is monitored by moisture tests.

The distilled water is delivered under pressure in closed pipes so that none is lost. It is applied to the crops with sprinklers to obtain the maximum degree of control and uniformity. Main underground pipes bring water to the corner of each 200-hectare farm. From there portable pipes are used. Because the water has essentially no salinity and because the application rate and timing can be adjusted to fit the soil, the water lost by percolation can be held to the minimum required for leaching. The total cost of delivering the water to the land is shown in the next table. It requires a capital investment of about $22 per person fed, or 3¢ per thousand gallons of water.

WATER DELIVERY COST

PUMPING STATIONS	1.2 ($ millions)
MAIN PIPELINES	7.5
BRANCH LINES	2.5
FARM DISTRIBUTION	1.9
LATERALS, SPRINKLERS, AND CONTROLS (AT $140/acre)	8.8
TOTAL	21.9
(APPROXIMATELY 3¢/1000 gallons)	

Another essential feature of the food factory is continuous production. A favorably located enterprise would turn sunshine into food nearly every day in the year. At least two crops a year are grown on each block of land, and the various blocks are seeded in rotation, perhaps a week apart. Somewhere in the sequence, then, there are always some blocks being planted, others being fertilized, sev-

"Farming the desert will never substitute for conventional farming but it may become a desperately needed supplement."

eral being watered, and still others being harvested. In this way, the irrigation equipment and whatever machinery is necessary are used continuously. (In a developing country hand methods would be used wherever they were adequate.) Sprinkling continues day and night, although changing of sprinkler location is accomplished mostly in the daytime. Some animal feeding can be done on the one-third or so of the blocks which are "between" crops.

In summary, the food factory is not mechanized agriculture, but it is intensive, laboratory-controlled agriculture organized to produce the most food for the least water and to leave to chance as little as possible in the process.

FOOD FACTORY CAPITAL COSTS

	COST PER PERSON FED
1. WATER DISTRIBUTION	$21.90
2. LAND PREPARATION AND DRAINAGE AT $70/acre	4.40
3. FERTILIZER PLANT	4.00
4. INSECTICIDE PLANT	1.00
5. FARM MACHINERY	5.00
6. FARM IMPLEMENTS AND SHELTERS AT $25/acre	1.50
7. LABORATORY	8.20
8. DOCK AND SHIPPING FACILITIES	2.00
TOTAL	$48.00

The above table shows an estimate of the other capital investments required for a food factory. The first item, water distribution, we have already mentioned. This, with the other items, adds up to about $48 per person fed, which at 7% fixed charges is about 0.9¢ per day. To this amount must be added the water production costs we have discussed and the farm labor costs to obtain the cost of producing grain.

With MWD water cost, present yields, and present grain prices the outlook is certainly marginal for low-value crops. But if either the desalting people or the agronomists achieve their estimated gains, or if grain prices rise, the operation of a food factory could look attractive economically.

Farming the desert will never substitute for conventional farming, but it may become a desperately needed supplement. I do not want to leave the impression that attaining the technical goals involved will be easy. One could go on at length in outlining the extensive development of specialized reactors and evaporators and heat transfer surface which must be accomplished and listing the many tests of agricultural techniques, water control, fertilizer, and seed improvement which must be undertaken in many locations. Nearly every country has something to contribute to these agricultural experiments. However, the goal, once considered visionary, is becoming substantial and real.

I hope I can stimulate others to assist in defining the problems more clearly and in assessing the alternatives. There is not much time but with survival at stake the incentive is strong.

The Executive Director of the Oak Ridge Associated Universities views the responsibilities of ORAU to its members and to "the outstanding scientific center that is Oak Ridge."

Oak Ridge as an Educational Resource

By WILLIAM G. POLLARD

LAST OCTOBER, Oak Ridge Associated Universities celebrated the twentieth anniversary of its incorporation. We looked back over the post-war developments in southern universities and attempted to see to what extent our having banded together in ORAU may have stimulated these developments. More broadly, we tried to evaluate the influence of AEC's Oak Ridge installations and of the Atomic Energy Commission in general on our progress in science.

The Past Twenty Years

The result of this evaluation was published as a special twentieth anniversary report, *Atomic Energy and Southern Science*, which I prepared for the occasion. By a variety of tests, this report reveals the remarkable growth in the past two decades in physical facilities, staff competence, and research productivity which has taken place in science and technology among southern universities. In this

Physicist, priest, educator, administrator, author, editor—William G. Pollard's career encompasses a wide variety of experience and talent. A native of Batavia, N.Y., Pollard received his B.A. from the University of Tennessee and his Ph.D. from Rice University. During World War II, he left his post as physics professor at the University of Tennessee to work at Columbia University on the gaseous diffusion program for the Manhattan District, which operated the nation's top-secret atomic bomb project. On his return to Tennessee, Pollard became a prime mover in organizing the Oak Ridge Institute of Nuclear Studies—now Oak Ridge Associated Universities—and has been Executive Director of this educational and research corporation of Southern universities and colleges since its establishment in October 1946. In addition to his duties with ORAU, Pollard is an Episcopal priest; an outstanding lecturer on topics related to physics and metaphysics; a member of many scientific and educational organizations; author of "Chance and Providence" and "Physicist and Christian," and co-author of "The Hebrew Iliad"; and holder of eight honorary degrees. He is married, father of three sons, and resides in Oak Ridge.

period an impressive number of major scientific discoveries and achievements of world-wide interest have come from the region. In the large-scale apparatus required for nuclear research—accelerators and nuclear reactors—the region is well supplied at a number of its universities and government laboratories. The productivity of the region in research publication and doctorates in science and engineering has risen from a mere trickle in 1946 to a substantial level today. At the present time the South comes close to matching the Northeast, Midwest, and West Coast in capacity for graduate training at the doctoral level and in research productivity and accomplishment. This is a remarkable achievement.

Such programs as faculty participation and graduate fellowships at AEC laboratories have proved a great stimulus to the research developments at our sponsoring universities. These and other activities carried out by our University Participation Office are peculiarly suited for administration by a multiuniversity corporation. They continue to constitute the central mission and purpose of ORAU. These programs are used extensively by some of our strongest institutions and will remain valuable to them in the years ahead, no matter how extensive their own on-campus research programs may become. For many other institutions just beginning to develop research and doctoral programs in the sciences, these opportunities can be equally stimulating.

Apart from this primary mission of ORAU is the value to the nation which has accrued from the availability of ORAU as a means for effective management of a variety of important government programs. Some examples of this kind of management skill which ORAU provides are: the major clinical and research program of our Medical Division, the training in advanced radioisotope techniques for senior investigators and practitioners through the courses of our Special Training Division, the national and international programs of public education in atomic energy through exhibits and demonstrations of our Information and Exhibits Division, the administration of national fellowship programs by our Fellowship Office, and the important conferences and symposia arranged by our Special Projects Office.

The benefits of these programs do not accrue in any special way to our member universities. Yet they are of importance to the nation as a whole. The sponsoring universities of ORAU, in agreeing to assume management responsibility for them, have been rendering an important service to the nation

The Central Administration Building (at right) and Library Building of Oak Ridge Associated Universities. The nonprofit educational and research corporation is sponsored by 41 southern universities.

and to science, for which they can feel great satisfaction.

Oak Ridge Associated Universities was the first such university corporation established in the United States for the purpose of operating scientific and educational programs under government contract. Within six months, a similar corporation, Associated Universities Incorporated, was formed in the Northeast. Subsequently, a considerable number of such corporations, both regional and national, have been formed. The multiuniversity operating and management corporation has become an established element in the American academic scene and is extensively used by government agencies to carry out important national research and development programs.

The Immediate Future

With these considerations as a background, let us look now into the immediate future and to the immediate opportunities for expanded service to our sponsoring universities.

There are, I am convinced, many more ways in which universities can benefit by participation at AEC laboratories than those which we have developed in the past. We need the imaginative thinking of individual faculty members and of organized groups of university representatives in various special fields in order to identify such new opportunities. A recent example is the Engineering Practice School at ORNL which our Nuclear Engineering Education Committee is making plans to establish. A single department of Massachusetts Institute of Technology maintained a very successful practice school here for a number of years and this has recently been reactivated by MIT. Working through ORAU it appears feasible and appropriate for a national laboratory to establish such an engineering practice school on a broad basis serving a group of engineering schools rather than a single department in one of them.

We have set ourselves the objective for the next five years or so of exploring with university representatives other such avenues of university-laboratory participation and utilization. I am confident that in this period we shall be adding substantially to the long-established programs of faculty participation, graduate and postdoctoral laboratory fellowships, and traveling lectures. We will also add more and more new programs like the Engineering Practice School. The several AEC laboratories in the South are a great regional resource in all the basic and applied sciences as well as in engineering, medicine, and agriculture. ORAU's objective is to exploit this resource for the benefit of the universities of the region.

In the last few years the National Institutes of Health have added to the AEC program in biology at ORNL a substantial new program in carcinogenesis and bioengineering. This fact, combined with the growth in scope, scientific brilliance, and research productivity of the ORAU Medical Division, has resulted in the emergence of Oak Ridge as one of the foremost centers of biomedical science in the nation. The facilities and scientific staff of the Biology and Health Physics Divisions of Oak Ridge National Laboratory, the Medical Division of ORAU, the University of Tennessee–AEC Agricultural Research Laboratory, and the newly-established Graduate School of Biomedical Sciences of the University of Tennessee, represent a strong scientific establishment. In view of this development, we are particularly concerned to find ways to involve the biology departments and medical schools of our universities in this complex, and we are taking steps to explore this problem in depth.

Undoubtedly the most significant research opportunity with which southern universities are confronted at present is in the chemistry and physics of the transuranic elements. About ten per cent of all the chemical elements are heavier than uranium, and for the first time macroscopic quantities will be available in Oak Ridge for the same sort of research in chemistry and physics which has been done with elements below uranium. Such studies include thermodynamic properties, valence states, crystal structure of solid compounds, magnetic properties, atomic and molecular structure, optical, infrared, and ultraviolet spectroscopy, nuclear properties, alpha and beta ray spectra, and many others. Oak Ridge National Laboratory's newly-completed complex of High Flux Isotope Reactor, Transuranium Processing Facility, and Transuranium Research Laboratory is unique in the world. Chemists and physicists from southern universities have the opportunity to glean from this facility a rich harvest of research results of variety and diversity which cannot be obtained anywhere else in the world. It is indeed a golden opportunity which we in ORAU are determined should not be passed up by our universities at the expense of turning it over to investigators from universities outside the region.

A Longer View

Now I should like to share my thoughts on a longer range view of ORAU's responsibilities to its member universities. In seeking such a view, the tendency of all of us is to imagine during the next 20 years simply an extension and expansion of the major emphases and directions of the last 20 years. It is natural to do this, but at the same time very misleading to do so. Both in the university and in the future directions of science and technology I am persuaded that major changes lie ahead. I want to explain why I believe such changes are inevitable and what meaning I see in them for ORAU and its sponsoring institutions.

The dominating fact of the last third of the twentieth century is the explosive increase in world population. We are literally filling the earth—the entire planet—with human beings. As recently as 1930 there were only 2 billion humans on earth. By 1960 we had increased another billion, and right now we stand at 3.3 billion. By 1977 we will have reached 4 billion and early in the 1990's 5 billion. By the end of the century, just a short 33 years away, world population will be somewhere between 5 and 7 billion, and the earth will be about twice as crowded as it is now.

The sheer physical requirements for supporting such a world population, while keeping the earth viable as a habitation for man, are staggering. The central of these is the food and water requirement. We are already running out of water and arable land. In the next few years catastrophic famines will strike India, Pakistan, and China. Indeed, the beginning is already evident in India. By the mid-1970's such famine conditions involving deaths running into hundreds of millions will strike Indonesia, Iran, Turkey, and Egypt. By 1980 it will have engulfed most of the other countries of Asia, Africa, and Latin America. The only solution lies in engineering projects on a vast scale for the production of fresh water. We know how to do much of this already. But only in response to the urgency of what is soon coming upon us will the necessary manpower and capital be applied to the task. What is required is to add about 30 million acres of arid land to cultivation each year from now on by supplying it with at least 20 billion gallons of additional fresh water per day. This can be done by using immense sea water desalting plants and by mammoth projects diverting Arctic Ocean water southward into Canada, the United States, Russia, and China. But we have just begun to recognize the problem in the last year or two. Five years from now it will dominate our thinking and national objectives.

The brilliant series of major new discoveries which has marked the course of physical science over the past 40 years has led many to envision a continuing sequence of new wonders in the years ahead. I believe this to be a major error. The frontiers of physical science left to us, where the new and unexpected can be looked for, are in the nature of matter where we require very expensive high-energy accelerators; in astrophysics where further advance calls for a large telescope mounted on an artificial satellite; or in the high-temperature plasma state of matter requiring massive and expensive equipment for its investigation. The 200 BEV Accelerator is eight years and a half-billion dollars away from us. Yet it represents a much smaller step beyond what we now have than did the first proton synchrotrons at Brookhaven and Berkeley beyond their predecessors. For the rest of physics and chemistry we have good general knowledge of the structure of things. We shall continue to run onto new and interesting phenomena like the Mössbauer effect, but they will not change the general picture. Most of the research effort will be devoted to filling in the details and perfecting our knowledge. On the frontier we are not going to go much farther than we have now, simply because it will be too expensive to do so.

The primary exception to this general picture is in the field of molecular biology. Here the breakthroughs of the past decade in cracking the genetic code and recognizing the basic mechanism of information transmission and utilization responsible for life guarantees a succession of brilliant and exciting new insights and understandings over the next 20 or 30 years. For the period we are considering, the center of scientific interest will move rapidly into this field of research. Atomic Energy and Space will continue at something like their present level, but they will cease to be the focus of university and public interest.

I recognize that this picture is not the popular one of the state we have reached in science and technology. Yet it seems to me to be correct. As I try to visualize the state of things 10 or 15 years from now, I am convinced that the pressures which will be developing in that period and the dynamics of contemporary history ensure that the focus of interest will be much more on applied science than it is now. The desperate character of human need will concentrate our scientific interest on such basic problems as abundant and cheap energy, large-scale water diversion and sea desalination, food production on land or harvesting from the sea, the preservation of the earth's atmosphere and waterways from pollution, the control of human fertility, and a long list of others. Except in molecular biology, the traditional basic research emphasis in universities will no longer be dominant. Training at the doctoral level will show a trend toward preparing men and women to cope with the pressing and increasingly urgent problems which then will be besetting the whole human status on the planet. I do not see how it can turn out any other way.

If this evaluation is correct, it of course does have marked implications for our universities and for the Oak Ridge scientific center. For universities, the years ahead will generate more insistent demands for young people trained to cope effectively with the central problems of that world. I hope our universities will prove flexible enough to adjust to such demands.

The vision of the director of Oak Ridge National Laboratory, Alvin Weinberg, has resulted in this laboratory's becoming the primary research and development center in the nation for two of the most basic needs of the future of man: cheap and abundant energy and cheap and abundant supplies of fresh water. The first arises from the promise of the molten salt breeder reactor being developed at ORNL and the second from the major program in sea water desalination which ORNL is carrying out. These are guaranteed to be the two most important technological problems of the 1980's, and the role of ORNL in them assures the central importance and viability of that laboratory for the next 20 years.

Equally important is the strength of the developing biomedical complex in Oak Ridge. Since biological science is destined to be the center of basic scientific interest over the next several decades, this complex added to the central technological mission of ORNL assures that this major federal scientific center in the South will continue to occupy a central position in the mainstream of future developments.

With 20 years of successful management experience under its belt, ORAU is firmly established. As we face the changes and challenges of the next twenty years, there is every reason for confidence that we have the resources to rise to the demands of so great an age, both for our sponsoring universities and for the outstanding scientific complex which is Oak Ridge.

The Chief Librarian at ORNL since 1955, R. R. Dickison heads one of the nation's largest scientific libraries. A native of Colorado and a graduate of Colorado College, Dickison received his library training at Western Reserve University and his master's degree in Chemistry from the Pennsylvania State University. Prior to coming to Oak Ridge he was Head Librarian of the Colorado School of Mines. Dickison is active in the national Special Libraries Association and has written numerous papers on microfilm systems and on library mechanization. His main hobby is tennis in which he was the Tennessee state senior's doubles champion in 1965.

Our Man in Panama

A Librarian and Atoms in Action

By R.R. Dickison

THIS SPRING I had an opportunity to participate in the AEC's International Exhibits Program as librarian of the Nuclear Science Demonstration Center which was operated in Panama from May 4 to June 5. This is one of two such Centers the AEC has been operating twice a year since 1957 in a number of foreign countries.

The Latin American Center was in Managua, Nicaragua, last fall, in Panama City this spring, and is now on its way to Quito, Ecuador, where it is scheduled to operate from October 26 to November 26. The Center's European counterpart was in Ankara, Turkey this spring and is scheduled to open in Teheran in the fall.

In Panama, the least populated of all the Latin American republics, over 70,000 persons visited the "Atoms in Action" Center during the month it was open. The primary objectives of the Latin American Center are to acquaint the public with the principles and uses of atomic energy and to enable local scientists and students to do research with the aid of the Center's operating nuclear equipment.

Gamma Facility Included

For the Panamanian exhibit a team of scientists from the Puerto Rico Nuclear Center set up and operated a 5300-curie cobalt-60 gamma facility, which the Panamanian scientists and students were obviously eager to use. Their research was focused primarily on isthmian problems in control of insects, preservation of fruits and vegetables, and crop-improvement from irradiated seeds. The public part of the Exhibit was open only from 2 p.m. to 9 p.m. daily, but scientists and students conducted research from early morning until late at night.

The Latin American Center is housed in a specially-designed transportable structure with an octagonal shape. The white domed roof is formed of an inflated envelope of nylon which is kept rigid with air compressed to slightly above atmospheric pressure. During the approximately two months it takes to unpack and set up the pavilion and its equipment, the structure stimulates much public interest and curiosity. After the Exhibit opened there were attempts to circulate rumors that it was filled with an explosive gas or contained so much radiation that any visitor would become sterile. Perhaps these rumors had a slight effect during the first few days because the initial reception seemed somewhat reserved. But the longer the Exhibit was

The Atoms in Action Latin American Pavilion. The Dome of the portable building is inflatable.

open, the more enthusiasm and publicity it generated. Its popularity reached a point where the Center was requested to remain open longer than originally scheduled, but, unfortunately, it was too late to make the necessary arrangements to do so.

The octagonal floor plan of the Center lent itself ideally to eight exterior bays which contained the public displays. The public entered first a theater area where a wide-screen Cinemascope motion picture in color introduced some basic principles and typical applications of nuclear science. Visitors then circled through the remaining display areas where young Panamanian guides, recruited from among university science students, described and demonstrated how the many forms of atomic energy could be used for the benefit of mankind. During the approximately 45-minute tour the visitors saw presentations on nuclear techniques in agriculture, medicine, and industry, and on nuclear power plants, nuclear power in space, nuclear desalting, and the peaceful uses of nuclear explosives. One of the high spots for the scientific staff was the party given them by these young guides one night, which was complete with fireworks, native dances and costumes, and Panamanian food and drink.

Oak Ridge Well Represented

The scientific staff of the Exhibit included, in addition to the Puerto Rican scientists who operated the gamma facility, the Director and the Deputy Director from the AEC; eight scientists from Oak Ridge Associated Universities, who conducted the technical training program; a health physicist, also from ORAU, and me. A special entrance to the pavilion for the scientific staff led to the interior of the Center, where the laboratories for the technical training and the research programs were located, as well as the Technical Information Reference Room. The central area also contained a small theater for viewing technical films from the library's film collection and a private conference room which was used for an intensive program of lectures and seminars on subjects of primary interest to Panama's scientific, technical and industrial communities.

About 160 diplomas were awarded to Panamanian teachers, doctors, and industrialists who participated in one of the six four-week courses offered in the training program. I also presented diplomas to about 70 librarians and library students who attended a series of seminars on current methods in documentation. Librarians came from all over the country to attend these seminars, but I should mention that in Panama one can travel from coast to coast by rail in an hour and a half for a dollar and a half.

An oddity which struck me after a few days in Panama was that in some portions of this country the sun rises over the Pacific and sets over the Atlantic, so as I visted libraries all over Panama, I was never sure in what direction I was traveling to get to them.

Reading Table in the Technical Information Reference Room. Nuclear physics students from the University of Panama seldom left space at the table unoccupied for any length of time.

Library Busy Place

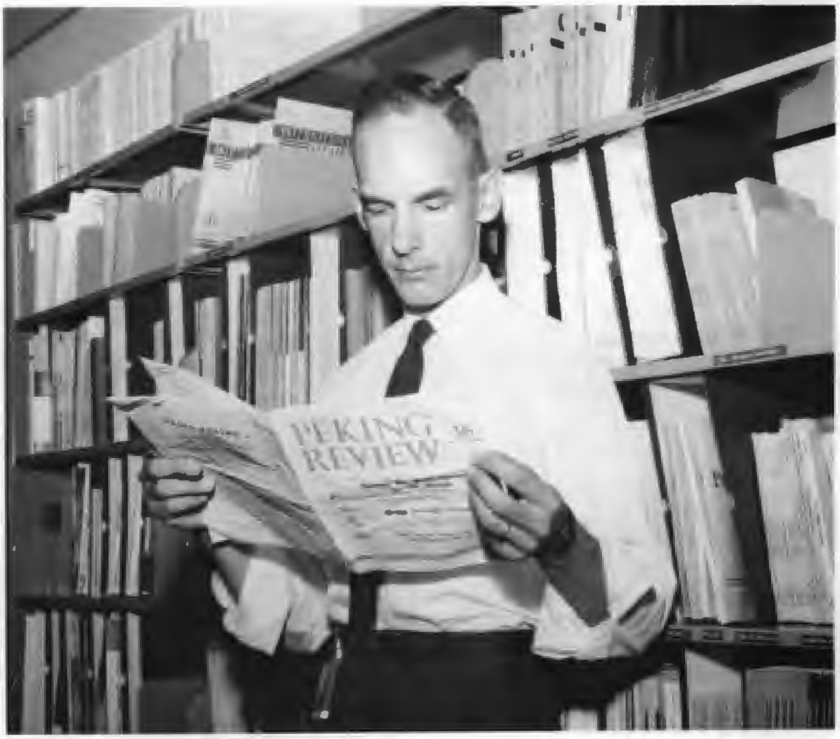
A librarian visiting Panama notices that there are no book publishers in Panama and very few book stores. As a consequence the libraries tend to be very busy, and the one at the Center was no exception. We could always depend on the nearly blind young man who came in every day with a new reference question and spent the rest of the day copying from books. Then there was the school teacher who came in regularly to borrow a film and returned it just as regularly three hours later. During the last week, when activity was at its peak, we were also kept busy by a toothless little old lady with a big handbag and kleptomaniac tendencies. The climate, with an average of 150 inches of rain a year and constant high humidity, introduced for the librarian additional problems of mold and mildew damage to the book collections.

While most visitors to this country are fascinated by the inexpensive but excellent fruits and fish available ("Panama" is an Indian word meaning "abundance of fish"), the Canal is certainly the single most impressive feature of Panama. In 1954 the American Association of Civil Engineers listed the Canal as one of the seven engineering wonders of the U.S., and it is all the more impressive when one considers that it is still being operated by the same system and practically the same equipment that was used when the first ship came through in 1914. It is indeed an engineering marvel.

The "Atoms in Action" Center had a considerable impact on the country. Thousands of school children and their teachers visited the Center and over 80,000 informational booklets in Spanish were distributed. A number of Spanish language films on nuclear energy were shown on the country's two television channels and there was almost daily publicity and pictures in the leading newspapers.

The Center cost approximately a quarter of a million dollars to operate in Panama, but one had the distinct impression that this was money very well spent. Panama appeared to be a very fertile area for atomic energy development, not only because industrial development is hindered by extremely high power costs, but because of the possibilities of a sea-level canal built with nuclear explosives. Since the Center was almost Panama's first introduction to nuclear energy, there will probably need to be further educational and training activities in spite of its considerable success.

Jim Bresee joined the technical staff of ORNL in 1954. He was Assistant Director of the Laboratory's Chemical Technology Division when he was chosen in 1964 to succeed Eugene Wigner as Director of the ORNL Civil Defense Research Project. Wigner, on a one-year leave of absence from Princeton, had established the project to continue the analysis of advanced civil defense problems begun by the National Academy of Sciences 1963 Project Harbor study. The ORNL project's initial staff of ten has doubled during the past three years and includes physicists, engineers, social scientists, economists, and agriculturists. Their work ranges from feasibility studies of various types of shelters having both peacetime and emergency use to examination of the psychological and sociological problems associated with large-scale defense systems. The project is sponsored by the AEC and Department of Defense. Bresee received his bachelor's and master's degrees from the University of Illinois and his Sc.D. degree in chemical engineering (1953) from MIT. For three years prior to joining the Laboratory staff, he was an assistant professor of chemical engineering at MIT.



Debate on Strategic Defense:

Will the Postattack Environment Problem Become the Key Issue?

By James C. Bresee

STRATEGIC DEFENSE, or "defensive defense," of the United States (that is, protection from attack by rockets or bombers armed with nuclear warheads), has been the subject of much public debate in magazines and newspapers in recent months. The debate was stimulated both by the official announcement last December of the start of construction of a Soviet ballistic missile defense (the anti-missile missile) near Moscow and by the successful test of a Red Chinese hydrogen bomb. So far the debate has dealt almost exclusively with the feasibility, cost, and political consequences of a U.S. decision to install its own BMD. Little has been said about how the BMD relates to the general strategic defense of the nation. Nor has there been much emphasis in the debate concerning some other important problems which our country must ultimately face if we adopt a consistent strategic defense program, particularly our incomplete knowledge of the postattack environment.

The Purpose of Defense: Reducing the Danger of War

Let us examine briefly the central strategic problem, the need to find effective ways to reduce the danger of World War III. In an attempt to put the various factors on a common basis, I will define first mathematically and then in words the *danger of World War III* in a special way:

$$\text{Danger} = f(A \cdot B \cdot C)$$

where
A = probability of war,
B = intensity of war,
C = vulnerability of participants.

That is, danger is related to the product of the likelihood that central war will occur (the probability of smaller wars unfortunately seems to be unity at present), the size of offensive forces used, and the degree to which populations (and resources) are unprotected from the consequences of a central war.

Much energy has gone into arguments that A is the most important if not the only factor – so important, in fact, that it should be the policy of the U.S. to maximize B and C in order to minimize A. Just how such a policy affects the product is not clear. Such arguments are complex and emotionally charged and I do not intend to pursue them here. Instead, I assume for this discussion that it is the legitimate business of the United States and other nations to attempt to minimize all three factors.

Table 1. Ways to Reduce Danger of World War III

1. World government (2000 AD?)
2. Stable deterrence (1950–1975?)
3. Arms control and disarmament
   a. limited test ban – 1963
   b. nonproliferation treaty
   c. complete test ban
   d. international control of nuclear weapons
4. Decentralization
5. Defensive defense

What policies may be most effective in reducing the danger of World War III? Table 1 lists five which may provide partial answers to this question. The first two entries are attempts to reduce factor A; the third, factor B; and the last two, factor C.

1. World Government

World government (with a consequent reduction in national sovereignty) has been so zealously advocated by some persons as a panacea for preventing war, that the term has to some extent fallen into disrepute. Yet, it appears obvious that the meaning of national sovereignty is changing. Consider the enormous gap between the furor of the U-2 incident in 1960 and the virtual acceptance now of almost daily launchings of satellites at least theoretically capable of carrying surveillance equipment over every point of the earth.

In spite of such changes, it seems doubtful that truly effective international peace-keeping operations will be possible by either a modified United Nations or some new world organization before the year 2000. I base this assumption on the recent decrease in the effectiveness of present UN peace-keeping techniques in, for example, the Middle East. It can be argued, however, that such operations are ultimately

This article is based on a presentation by the author at the Second National Symposium on Radioecology, sponsored by the AEC, the Ecological Society of America, and the University of Michigan, May 15–17, 1967, at Ann Arbor, Mich.

inevitable. I personally see no other way to guarantee that nuclear weapons will never be used and I do not expect the weapons to disappear.

2. Stable Deterrence

Stable deterrence, our present system for preventing war by guaranteeing that a nuclear attack would result in a retaliatory strike causing "unacceptable losses" to the attacker, may have many dangers associated with it, such as accidents, miscalculations, irrationality. Nevertheless, the present extremely low probability of central war can certainly be attributed to it. In short, deterrence *works* and it should continue to work for at least several more years. It may be assumed, however, that policy may lose effectiveness after about 1975. That this appears to be the case is based on the probability that China will achieve significant thermonuclear offensive power in the early seventies and that it may continue to reject peaceful coexistence with capitalist countries as a basis for its foreign policy.

3. Arms Control and Disarmament

Between 1975 and 2000 there may exist a period of instability and danger during which efforts to reduce the intensity and vulnerability factors will be particularly important. The U.S. Arms Control and Disarmament Agency (ACDA) has been working vigorously but, unfortunately, with only limited success to slow the world arms race. The U.S. government has taken several dramatic steps unilaterally—cutting production of plutonium and enriched uranium, announcing the end in 1964 of the Minuteman missile buildup and the elimination of its Titan missiles after 1970—to demonstrate its willingness to participate in international agreements to limit arms. The French and Chinese who did not sign the Limited Test Ban Treaty however, continue to conduct atmospheric tests of nuclear weapons. A nonproliferation treaty, strongly advocated by leaders in both the U.S. and the Soviet Union, is endangered by our simultaneous efforts to increase West German participation in joint NATO nuclear forces, as well as by French and Chinese independent nuclear weapons policies.

Many persons fear that a complete test ban might cripple a U.S. antimissile development program and there remain serious technical problems concerning detection of small underground nuclear tests. Also, complete international control of nuclear weapons (advocated by U.S. in the Baruch proposal to the UN in 1946) continues to raise the same serious problems of national sovereignty that advocates of world government face.

It seems clear that ACDA faces a difficult future in its efforts to decrease the danger of war.

4. Decentralization

Today 70% of the American people crowd into 1% of the nation's land area. Although nothing seems likely to stem the general trend toward urbanization in the next several decades, there is some hope for decreasing the average density of our big-city populations and manufacturing capability. If density decreases, physical vulnerability also decreases. Two trends are of special importance. First is the gradual completion of modern high-speed highways in and around cities which has encouraged central-core industries to relocate near belt highways and has provided workers with larger areas from which to commute in an acceptable time. The second trend is the continuing rise in per capita income at a higher rate than the average cost of suburban housing. More city families who wish to move to less crowded suburban neighborhoods can afford to do so. It is not clear, however, that these trends will counteract a growing total population and continuing urbanization. Consequently, the effectiveness of U.S. decentralization as a defense issue is at present unknown.

5. Defensive Defense

Defensive defense (or strategic defense), remains now to be examined. In Table 2 are listed the present and possible future components of our strategic defense system.

Table 2. U.S. Strategic Defensive Forces

- I. Traditional
  1. Air Defense—North American Air Defense (NORAD)
     a. Simulated Air Ground Environment (SAGE)
     b. "Century-Series" Fighters
     c. Ballistic Missile Early Warning System (BMEWS)
     d. Ground-to-Air Missiles (Nike-Hercules, BOMARC)
  2. Antisubmarine Warfare
  3. Civil Defense
     a. "Identify-Mark-Stock" Community Fallout Shelters
     b. Individual Basement Shelters (Census Survey)
     c. National Emergency Warning System (NEWAS)
     d. Emergency Broadcasting System (EBS)
- II. Advanced (Research and Development Stage)
  1. Ballistic Missile Defense—Nike-X
  2. Improved Early Warning
  3. Improved Submarine and Bomber Defense
  4. Advanced Civil Defense
     a. Shelter Development Criteria
     b. Postattack Environment

The use of the word "traditional" to describe our present strategic defensive forces is not intended to suggest either "old-fashioned" or "out-of-date," but is used to mean our present forces. Some components of these forces are extremely sophisticated military systems and should perform very well against the threat they are intended to counter. However, our strategic defense remains incomplete in the absence of active defenses against a ballistic missile attack. An enemy using a cost/effectiveness approach to the design of his offense would probably attack through the holes in our defense. Therefore, to some extent, the U.S. spends money on incomplete defense to decrease a potential enemy's options and to some extent because we have for many years spent money on those components.

If a decision were made to complete our defenses, the most important component of an advanced system would be a ballistic missile defense (BMD) or "antimissile missile." The Nike-X BMD is under development at present, and its production may be authorized this year.

But it must be emphasized that ballistic missile defense is just one component of what has been called by the Department of Defense a "damage-limiting system." The word "limiting," rather than "prevention," should be noted. Because damage would occur from a missile attack on the U.S., estimates of its magnitude at any level of investment in strategic defense should be the basis for the standard cost/effectiveness calculations used to optimize the investment. Two problems are immediately encountered by the strategic defense analyst: First, if human lives plus property and other possessions are protected by strategic defense, then how are common values calculated? Second, damage is often difficult to measure or estimate, especially when long-term biological damage is concerned. How much damage is done to a person by exposure to 100 roentgens of radiation? How does the damage change with rate of delivery, and how different are the values for a child, a young woman, and a middle-aged man?

In Congressional testimony, February 14, 1966, Secretary McNamara stressed that a decision to install a ballistic missile defense must be accompanied by investments in other advanced strategic defense systems. Three other types of systems are listed in Table 2. Improved early warning might add early signals from forward scattering radar or satellites to later information from our present BMEWS network to verify the launching of an ICBM attack. Improved submarine and bomber defenses could help reduce the nation's vulnerability to attack by shorter range missiles.

The final system, advanced civil defense, would be the most difficult of the four to install. Two particularly difficult problems are practical design criteria for new shelter construction and preattack preparations for postattack recovery.

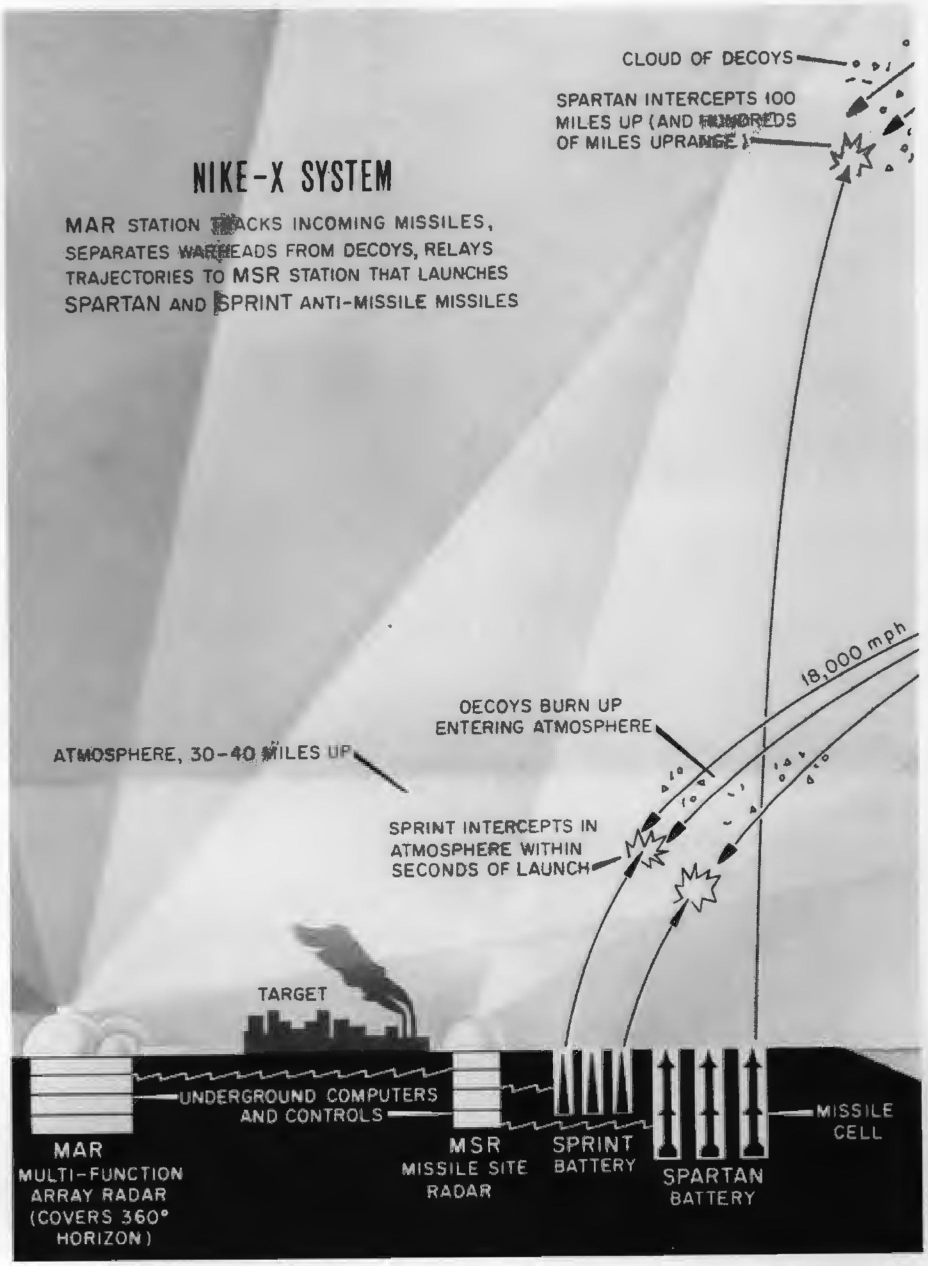
Providing shelters in areas inadequately protected under the "identify-mark-stock" community fallout shelter program, a shelter

"Our strategic defense remains incomplete in the absence of active defenses against a ballistic missile attack."

development program—probably heavily supported by federal funds and emphasizing dual (peacetime) use—would be required. Such a program could eventually provide protection against not only fallout but also blast and fire.

The final entry in Table 2, the postattack environment, is an extremely complex problem and requires more research. The mere existence of an enemy missile defense provides a strong incentive for an attacker to air-burst his weapons before they can be intercepted. Nuclear explosions high in the atmosphere increase the worldwide fallout to a much greater extent than would similar explosions nearer the ground. In the attempt to intercept the attacker's missiles, the detonation of defensive weapons would also increase the worldwide to local fallout ratio. This distribution of fallout decreases the local recovery problems but increases worldwide hazards, ironically shifting postattack problems from the attacked to the attacker.

This prospect of increasing worldwide problems associated with nuclear defense raise further the nuclear powers' already high level of responsibility to understand in detail long-term radioecology phenomena and to find ways to reduce their undesirable consequences.



Is Strategic Defense Dangerous?

Many thoughtful people have pointed out the analogy in international relations to the basic human problem in interpersonal relations: self-fulfilling prophesy leading to mutual distrust. If you are suspicious of someone, your behavior reflects it. He detects your feeling and reacts in a suspicious fashion, which confirms your original suspicion.

Improvement of our strategic defense is a behavior signal to the world that we suspect we might be attacked, in spite of our deterrent strength.

Because national objectives and motives are communicated by national investments as well as, and perhaps better than, public statements by leaders, the basic psychological aspects of the self-fulfilling prophesy must be taken into consideration in planning future defense programs. But I would plea for a sincere attempt to eliminate the "witchcraft effect" from the discussion of national defense. I refer to that part of human emotions which tells us that a trip to the doctor for a checkup in some way increases the probability of a suspected ailment, or that purchase of airplane trip insurance somehow causes the wings to fall off. It is not easy to eliminate this sort of fundamental uneasiness associated with planning for defense against nuclear weapons, but it is important to try.

I would plea also for a consistent defense policy to reduce the danger of World War III. I can imagine a "deterrence-only" policy, although I have grave doubts that it can continue indefinitely to be as effective as it has been. I can also imagine a "deterrence-plus-arms-control" policy. But here one might encounter a transition period when deterrence is physically weak (by reduction of ICBM's) but international control is not yet strong. It is to bridge this transition period that the Soviet delegates to the Eighteen Nation Disarmament Conference in Geneva have argued the need for nuclear powers to retain ballistic missile defense until the very end of the disarmament process.

I agree with their position. I favor all three programs: deterrence, arms control, and a balanced investment in damage-limiting systems. Any level of investment should provide an effective operating system at any degree of completion. It should provide also a broad research base upon which future systems can be built.

Expanded research is particularly required to better understand the word "damage" in "damage-limiting." Postattack economic and political recovery are so critically dependent on ecological recovery in general and radioecological recovery in particular that research in radioecology should be given high priority. Research on long-term radiation effects especially needs strengthening: first, because many long-term effects are unknown; second, because their interpretation is more difficult than for short-term effects; and, finally, because long-term effects, particularly genetic, continue to be surrounded with an aura of mystery that should be dispelled.

Postattack Environmental Research

The mutual distrust among nations that may lead the U.S. to install an expensive damage-limiting system might be reduced through increased international cooperation in scientific research. I would suggest that research on postattack environmental problems be included. This research would benefit from the close cooperation of scientists working in several countries. Not only would it help to allay this distrust but also the results would have real value for other conceivable nuclear emergencies, such as a large power reactor accident. Particularly at first, the research could take the form of basic radioecology research sponsored either by the International Atomic Energy Agency of the UN or jointly by the U.S. and the Soviet Union.

Perhaps the Ecological Society of America can take the lead in bringing about such an international cooperative research program.

With the goal of reducing international tensions and misunderstandings the program would certainly be worthwhile.