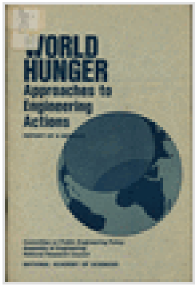

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WORLD HUNGER
Approaches to Engineering Actions

REPORT OF A SEMINAR

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CONTRIBUTORS

Robert C. Seamans, Jr., was President of the National Academy of Engineering (NAE) at the time of the COPEP seminar. In December 1974, he was appointed Administrator of the newly created Energy Research and Development Administration. Dr. Seamans was Deputy Administrator of the National Aeronautics and Space Administration from 1965 to 1968. Between 1969 and 1973, he served as Secretary of the Air Force.

Edward Wenk, Jr., is Professor of Engineering and Public Affairs and Director of the Program in Social Management of Technology at the University of Washington. He is Vice-Chairman of the Advisory Council to the Technology Assessment Board of the U.S. Congress. Between 1966 and 1970, Dr. Wenk served as Executive Secretary of the White House National Council on Marine Resources and Engineering Development.

Hubert H. Humphrey was re-elected to the U.S. Senate from Minnesota in 1971. He is Chairman of the Joint Economic Committee and a member of three other Senate Committees and of the Technology Assessment Board of Congress. He served as Senator between 1949 and 1965 and as Vice-President of the United States from 1965 to 1968.

John Mellor is Professor of Agricultural Economics at Cornell University. Dr. Mellor has written extensively on problems of agricultural development in Third World countries, including the books entitled _The Economics of Agricultural Development_ (1966), and (as co-author) _Developing Rural India: Plan and Practice_ (1968).

Don Paarlberg is Director of Agricultural Economics of the U.S. Department of Agriculture. Between 1961 and 1969, he was Hillenbrand Professor of Economics at Purdue University. He served as Special Assistant to the President and Food for Peace Coordinator from 1958 to 1961, and as U.S. Assistant Secretary of Agriculture from 1957 to 1958. Dr. Paarlberg is the author of several books and articles, among them Great Myths of Economics (1968).

Charles S. Dennison has had extensive experience as an executive in international business. He was a Vice-President of the International Minerals and Chemical Corporation from 1958 to 1970. Mr. Dennison served as a member of the President's Science Advisory Committee Panel on World Food Supply in 1967.

Peter Cott is Executive Director of the Population Institute. He was Executive Director of the National Academy of Television Arts and Sciences from 1956 to 1964.

Charles Cargille, a physician, is Assistant Dean of the School of Medicine, University of North Dakota. He is the President and a founding member of the World Population Society in affiliation with The American University.

Foreword

Robert C. Seamans, Jr.

Hunger is the persistent enemy of mankind. The Old Testament chronicles a succession of terrible famines. Every generation in the cities of ancient and medieval Europe suffered severe food shortages. Into the 20th century, wars, plagues, and such natural disasters as droughts, earthquakes, and floods have resulted in millions of deaths from starvation and malnutrition.

After World War II, however, it seemed at last that man was winning the age-old battle against hunger. From 1954 to 1972, world food production surged by 69 percent, exceeding by far the growth in population. As more land was opened to intensive farming, with the introduction of such crop-improvement techniques as high-yielding "miracle" varieties of grain, heavy doses of chemical fertilizers, irrigation, mechanization, and skilled management, it appeared that the nightmares of famine and chronic malnutrition could be avoided.

Optimism, then, was the keynote in 1970 when the National Academy of Engineering conducted its Sixth Annual Meeting on "The Food-People Balance" and concluded that equilibrium could be achieved through technological innovation and resource conservation in combination with population control. In a foreword to the published proceedings of that symposium, Richard D. DeLauer observed that achieving the food-people balance first requires understanding of the total system--ecological, sociological, biological, financial, cultural, and political, as well as technological.

By the time the Committee on Public Engineering Policy (COPEP) held its seminar in 1974, designated by the United Nations as "World Population Year," events had so altered the balance--with food in short supply, energy enormously expensive, and populations expanding nearly everywhere--that the plight of some one-fourth of the world's people was desperate. In the course of only two years, poor harvests had reduced world food reserves to a 22-year low.

Not surprisingly, at the World Food Conference held in November 1974 in Rome by the United Nations, many voices called for stepping up humanitarian relief activities and raising yields through approaches like the Green Revolution. The trouble is that, except for meeting emergencies, relief missions can never solve the world's food problems and that agricultural strategies based on new seeds, irrigation, fertilizers, machines, fuels, and warehouses involve large capital outlays and critical cultural dynamics.

Many engineers only dimly perceive the opportunities and limitations for feeding a hungry, crowded world. This is why COPEP undertook the seminar in the first place--to create a greater awareness of the technological options for coming to grips with this important issue. The participants recognized the vital interconnection between farm production and social organization, between resource requirements and trade balances, between the rational use of the ecosystem and the wellbeing of all people.

What they advocate, it turns out, is a coordinated strategy of actions for achieving worldwide food security. Until such actions--specifically requiring massive infusions of scientific and technological knowhow--are adopted and practiced, much of the Earth's population will be living on borrowed time.

Introduction

Edward Wenk Jr.

The purpose of this report is to bring to a wider audience the issues covered in a seminar of the Committee on Public Engineering Policy (COPEP) of the Assembly of Engineering. The seminar was attended by the Committee members and a small group of experts. They discussed ways in which engineering resources and techniques could be applied to improve food production, processing, storage, and distribution. The one-day seminar was held on July 10, 1974, at the National Academy of Sciences building in Washington, D.C.

A combination of unfortunate circumstances--bad weather, poor harvests, sharply rising prices for energy and fertilizer--precipitated a world food crisis in the last two years. Hardest hit were the people in the poorest and some of the most populous Third World countries. Because of large grain purchases by the Soviet Union and an earlier U.S. policy to reduce its agricultural surpluses to manageable levels, food supplies in the world market became insufficient and too costly for the needy countries.

Looking beyond the need for short-term relief for the hungry, it is clear that Third World countries must build a better margin of food security. They must increase their agricultural production and potential to be better prepared to feed their people. How can they do this quickly? What resources, skills, and cooperative measures will it require? These were some of the questions raised in this seminar.

The discussion of solutions ranged from raising crop yields through better agricultural and irrigation practices, to improving food technology, and building more efficient transport and management systems for the delivery of inputs to farmers and food to market. It became clear that engineers have a contribution to make and that opportunities for engineering innovation and talent are manifold. Some of these opportunities lie in discovering new agricultural practices and techniques, in delivering necessary quantities of vital inputs to farmers on time, in designing storage and transport systems to handle increased output, in enriching and preserving food, in developing new foods, and in packaging and marketing food products. At the same time, the demand side of the food problem--increased appetites resulting from high growth rates in both affluence and population--need attention and consideration. The ideas and solutions we explored were by no means exhaustive. We hope that this report will stimulate additional thought on how various skills and approaches can be applied to increase food production and assure its distribution to those most in need.

Senator Humphrey opened the discussion by calling attention to the public policy aspects of food production and trade. He urged us to seek a better definition of the limits of the ecosystem in order to help determine how and where to make the best use of the world's natural resources. He suggested that while continuing the search for new energy sources, we look for new ways to produce food with less energy in the developed countries as well as in the developing. For the United States, which supplies 60 percent of the international trade in feed grains, Senator Humphrey proposed two key measures: a coherent national food policy that includes building food reserves and initiating a worldwide information and data network on crop production and reserves--both promising safeguards in a food security system.

Following this, John Mellor assessed the potential for agricultural growth in developing countries through the appropriate application of research and technology. Particular conditions of soil and climate in different countries, he observed, demand special methods of cultivation, strains of seeds, and other specific inputs and practices. Moreover, the abundance or scarcity of labor and capital will often determine the methods, the machinery, and the markets. The organizational and institutional network required to support all this needs to be created where none now exists and strengthened where it does.

Practical lessons based on the experience of United States agricultural research and extension services could benefit the developing countries, said Professor Mellor. He favored greater integration of regional and national food research into an international system as a significant way for disseminating knowledge about more efficient techniques to increase output and for encouraging nations to adopt such practices.

Care must be taken, Don Paarlberg observed, to consider local customs and infrastructures. In developing new foods, designing new machines, and introducing new technologies, the efforts of scientists and engineers must be "socially acceptable." New methods of food processing, storage, transport, handling, and marketing bulk quantities have resulted in substantial savings in developed countries. However, the introduction of similar technologies in developing countries frequently requires better warehousing, roads, and machinery, for a start, before significant benefits can be realized. Dr. Paarlberg urged engineers to accept the challenge of improving the food system of the Third World and designing solutions appropriate to their particular economic and social conditions.

As part of this effort, Charles Dennison pointed out, engineering know-how is critical in overcoming the present world shortage of fertilizers. He selected the fertilizer problem as an example of the way that technology could increase crop yields and, at the same time, contribute to making developing countries self-sufficient. Building fertilizer plants in developing areas, he pointed out, would strengthen the local industrial infrastructure, create jobs, stimulate marketing and distribution channels, and improve foreign trade balances.

The presentations by Charles Cargille and Peter Cott are included as special advocacy positions on the subject.

The array of issues explored at the seminar confirmed COPEP's expectation that systems engineering inputs are important in attacking the age-old problem of world hunger. COPEP, for its part, is prepared to apply the problem-solving capabilities of engineers to selected issues. Until June 30, 1974, just 10 days before the seminar, COPEP was part of the National Academy of Engineering, and since then it is a constituent of the Assembly of Engineering, National Research Council. It is able, therefore, to call upon a community of distinguished engineers, as well as other concerned scientists and experts, to meet this critical challenge.

On behalf of the Committee, I want to thank the speakers and guests at the seminar for their valuable contributions. COPEP staff, particularly Barry Barrington and Micah H. Naftalin, who organized the seminar, and Pushpa Nand Schwartz who prepared this document, are commended for their fine efforts.

A National Food Policy — Why We Need One

U.S. Senator **Hubert H. Humphrey**

It is fortunate that the National Academy of Engineering is addressing this very important problem--one we all ought to have been working on years and years ago.

Our government today is without a national food policy. We have been operating within what we call free market forces, regardless of what these market forces may do to the population, to hunger, to satisfying human needs. We have tended to ignore the basic needs of millions of people on this planet. I do not believe that this policy can be pursued for long.

It is no problem at all for this government to support massive programs of military aid and justify them in the name of national security, but we quibble over whether we can afford a billion dollars a year to provide the needed supplies for an international food program. We fail to understand that there is no security in hunger and want, and there is no security for a country that has no national food policy.

We depend on good luck most of the time. A massive crop failure in the United States is highly unrealistic--that is, on a total basis--but we can have sharp drops in production in certain years. If we should have this happen now in the absence of food reserves, we will face serious conditions.

We have not really planned a policy for food, a policy that includes basic nutrition, adequate supplies, incentives for producers, reasonable systems of distribution, processing, and storage. These elements are all interrelated. There is no use talking about increased production if we cannot move it to market, or about production and opening up millions of additional acres if farmers cannot get the needed finance. American farmers today cannot afford additional production at prime interest rates of 12 percent.

We have ignored most of the basic inputs that go into making possible a national food policy. Our rural transportation system is outmoded and inadequate. The railroads have one way of solving their problems--that is to quit railroading. We built interstate highway systems for huge trucks, but we forgot to build the feeder roads for the 10-ton trucks. In my part of the country we now have 8-ton and 10-ton dairy trucks. That is the only way that the dairy cooperatives can keep in business, and make any money, because transportation is part of the production cost. Unfortunately, we use mainly 4-ton roads. In certain parts of Wright County, Minnesota, it takes miles of circuitous travel to find the right kind of concrete and blacktop highways to handle the big trucks.

Most people planning these things in Washington are urbanized specialists who have forgotten their heritage and do not know what is happening in rural America. We constantly hear about the urban problem. The other side of the coin is the real problem: rural decay and rural obsolescence. These are the major contributing factors to the urban problem of today. The answer is to modernize rural America in terms of all the technology available in a modern society.

A national food policy is not possible without considering international implications--the impact of our food policy on other people and countries. We now have to think about commodities in international terms, and this applies also to transportation and other aspects of food production.

At present there are only four food reserve countries in the world: the United States, Canada, Australia, and New Zealand. Eastern Europe is a food deficit area, as are Western Europe, Latin America, and, of course, Asia. We have in our hands, in the Anglo-Saxon world, the greatest single source of power--namely, food. It is more important than oil because people can get by without oil, at least in part, but they must have food to stay alive. The major food reserve and producing countries must have a concerted, coordinated policy and not work at odds with each other. It is very important that we set the world an example on trading, and on the social, political patterns in the use of food.

It is only in the last two years that the media, which is the great educational arm of the American people, has at last begun to acquaint the public with some of the dimensions of world food and population problems. Many citizens are raising their voices, and it is out of this concern that new ideas come forth and that national policy is made.

WHAT CAN NAE DO?

How does this Academy fit into some of these concerns? You can offer your judgments, particularly on a number of technical questions which relate to the whole cluster of issues in the food area. Two related problems need be considered.

1. Define Ecological Limits

What are the present limits of our ecological system in terms of supporting a population constantly expanding in size and in the scope of its demands? We have seen the impact of affluence on food supply just in the last four or five years, even though there were some bad weather conditions and poor crop yields. The people of both Western and Eastern Europe began to want more animal protein. They wanted to get away from just eating grains and to add dairy, poultry, and animal products to their daily diets.

Interestingly enough, even in the communist-socialist societies, public opinion has forced central governments to make decisions to feed people increasingly better rather than cut back consumption levels. This is one of the most significant political developments of our times, for never before have these governments bowed to domestic public opinion. When Mr. Brezhnev promised the Communist Party Congress his new program of more consumer goods and food supplies, he had to keep his word. This also happened in Poland after Mr. Gomulka was ousted. Everywhere food production and market outlook depend today upon political decisions. Even our market conditions are heavily influenced by decisions in the controlled economies.

2. Expand the Limits

Can the limits of the ecological system be expanded? What steps should we take to expand these limits? These questions put the problem in a universal perspective--the interdependence of our world society and our role in it. In looking for the answers we cannot ignore other people in the world.

I am reminded here of the words of Adlai Stevenson: "We travel together, passengers on board a small space ship, dependent upon its vulnerable reserves of air and soil, all committed for our safety to its security and peace; preserved from annihilation only by the care, the work, and, I will say the love we give our fragile craft. We cannot maintain it, half-fortunate, half-miserable, half-despairing, half-slave--to the ancient enemies of man--half-free in this day. No craft, no crew can travel safely with such vast contradictions. On their resolution depends the survival of all."

While teaching at the University of Minnesota and Macalester College, I used the perilous Apollo 13 experience as a way of describing the interrelationship between people and the different sources of supply in the world. You may recall that there were three men aboard the spacecraft. Had there been five, they would have perished because their system did not have sufficient food, oxygen, or water, to support five. I also pointed out to the young student group the importance of experience from down on the ground. Veteran astronauts on the ground shared their experience with those in space who were learning while in danger.

The space program has taught us as much about the relationship between resource supply and people demand, or, to put it in the terminology of this discussion, between food and population, because we created, in reality, little worlds inside these space capsules. Just so much supply was there, and it could only take care of just so many people. Some stretching is perhaps possible, as was done during the emergency in Apollo 13.

My first question concerning the limitations of our system is a relatively new one for all of us. Malthus tried to bring it to our attention years ago, but we ignored him and only recently has he become popular.

Until recently we assumed an unending supply of minerals, petroleum, soil, and water. Americans now are becoming aware of the limited supply of petroleum and the future scarcity of many important minerals.

Engineers can play a very critical role in answering my second question about stretching the present limits of our resources. Are we using what we have for maximum benefit and are we doing it in a way that does not destroy the resource? One of the most important areas of concern in food production is energy supply. Energy is critical to producing fertilizer and powering machinery. We must find new sources of energy to enable the developing countries to increase their food production.

Our agricultural methods require great amounts of energy and are not always appropriate for the developing countries. We must find ways to produce food with less energy for ourselves and also for the developing countries. We have operated too long on the assumption of an unlimited supply of cheap energy.

Another area where engineers can play an important role is to improve soil and water management, nationally and internationally. This is a vital concern to countries such as India and Pakistan that need to increase output from dry land farming and existing irrigation systems. Improved management of soil and water resources could lead to a several-fold increase in the food output of these countries. The United States alone cannot feed the world. But we can help others feed themselves. We can help them by providing assistance to improve their technology. But they must make a strong effort to increase their own agricultural production.

Engineers can make other important contributions too--from developing improved techniques of food processing to designing new approaches to food storage and planning new and better methods of transportation. If we are creative, we can stretch the benefits of our resources. For example, research must continue for developing new seed varieties. We have had breakthroughs in corn production, but our soybean productivity has changed very little in 25 years. Soybeans fix their own fertilizer and it is a wonderful crop. I have already proposed a U.S.-Sino soybean research project. This is one way to secure a breakthrough in soybean production.

BUILDING FOOD SUPPLY AND RESERVES

Some people have noted that most of the world's best land is now in production. In the last two years the United States has returned most of its usable land to production. That was the basic reserve we had. Even though we had reserve supplies in granaries, our biggest reserve was this usable land. We have returned about 65 million acres to production. We have a little available beyond that, but it is not very productive land. In addition, water supplies are severely limited.

The late Robert Kerr, when he was chairman of the Senate Public Works Committee, did a study on the water supply situation. We have paid no attention to it at all, just as we paid no attention to a study in the 50s on energy supply. We are intellectual squirrels. We accumulate these reports and we file them away. Little is done to translate the findings into public policy. I was always amazed that so little was done about the White House Conferences that were held while I served as Vice-President. I tried to get action in Congress, to create an *ad hoc* committee to follow-up the recommendations of these conferences. Nobody wanted to pay any attention to that. We conducted the studies, and people who participated were excited about what they were doing. We had a week's publicity and printed a lot of copies that nobody used. This has been basically true of issues of land use, water supply, and mineral resources.

We have depleted another important resource which Americans have taken for granted for many years--i.e., ample food reserves, which have meant plentiful supplies of food at very low prices for a long period of time. These reserves of food gave the international community some degree of security and, from an economic point of view, some degree of stability. We need to remember that in most countries of the world the major cost item for a family is food, not a night club, country club, or an automobile, not even a home, but food.

It will be difficult to rebuild reserves in face of a growing population and sharply increased demand from developed and developing countries. Fortunately, however, food reserves, as contrasted with the nonrenewable minerals, can be rebuilt if we plan properly and have the will.

There is a big argument going on in this government about food reserves. I am on one side of it and a lot of other people are on the other side. I hear people say that we cannot build a food reserve program without depressing the market. I disagree. I have never understood why we demand that the Federal Reserve System have reserve requirements for our monetary system, while we ignore reserves for our food system. How can we ask other nations to build food reserves and leave the matter to the food trading companies? Why should they maintain a food reserve system to provide some degree of price stability?

I believe we need a national agricultural policy that relates not only to domestic consumption and commercial exports, but also to international humanitarian needs. We ought to plan for it and figure humanitarian needs into our crop projections. The government ought to set aside a certain amount every year just as individuals set a certain amount away to buy bonds.

The United States recently discovered that it was a little short of plutonium, but that did not stop the Atomic Energy Commission and the Department of Defense from wanting to upgrade nuclear weapons. There was never a word of objection that we were short of plutonium and we ought to cut back on weapons. I understand something about the world in which we live and the need for weapons. But when we get to other critical areas, such as food, we say we cannot establish even a modest program because we are a little short.

To obtain sufficient food for reserves, we must have an incentive system for the American farmer so that he will feel secure in producing abundance. He has been burned in the past by excessive supplies. Some way must be devised to seal off reserves from the market. There must also be willingness to share the risk with the farmer. To allow a reasonable return, we must have some basic floor that farm prices do not fall below.

We face difficult choices on the issue of limited resources in the face of increasing demands. We face a great moral choice this fall: Will we use scarce energy to produce food or to power our automobiles? Are we prepared to cut back somewhat on available supplies of food for ourselves so that other people may survive? If the American people were really asked these questions, they would respond affirmatively. They would say that we ought to share. We did it before under the Food for Peace Program, and the American people still support international food assistance.

Many people are pessimistic about the future, but I am not without hope. We are not going to be the victims necessarily of an international crash or crisis, because of the relationships of food and population. Engineers can play an important role in resolving this present crisis.

THE NEED FOR NATIONAL PLANNING

We are our own worst enemy because of our failure to look ahead and plan. We are the only industrialized country in the world with absolutely no national planning at the governmental level. A country with a national budget of more than $300 billion a year can hardly afford not to plan for the future. What our government does in the money markets and how we spend our money is critical. The Office of Management and Budget is not a planning office; it is a bookkeeping office. It has no sense of vision, and it is not equipped for long-range planning.

We must have a program of national planning for development and growth. This also fits into the most important issue of planning our food production and its distribution and use. If the Department of Agriculture has a three, five, seven, or ten year projection, it is one of the best kept secrets in the world. Only two agencies in the government have any plans and they get the money: the Defense Department and the Highway Administration. When I was Vice-President, I saw the Pentagon people come in with those long lead time items and their long-term plans. The Highway Trust Fund and the Highway Administration have long-term plans and they know how to use the money. But there are no plans for health, education, or food.

FOOD INFORMATION SYSTEM

I would hope that engineers will respond to the challenge of developing an improved food information system. With the threat of scarcity before us, we will need the best possible and most timely information on the world's food supply and demand. I am confident that if we had had more timely information about the Soviet food situation, we would have handled the wheat purchases differently. The information that we were getting was reaching the Department of Agriculture two or three weeks late, because there did not seem to be any hurry or any great need. We must have a better system than that. On two occasions during the time that Orville Freeman was Secretary of Agriculture, he called on American farmers to produce more and they did. But, then we ended up with a huge market surplus because the Russians decided not to buy some of our increased production.

When we had ample reserves, we could be casual about crop and food information. But with world food reserves down to between three and four weeks, we do not have that luxury. The World Food Conference undoubtedly will direct itself to this problem. I am pleased that our government is taking an active role in the World Food Conference. We must, in fact, play a major role.

This concern over sharing information is why I recently urged President Nixon to take up the subject with the Soviet leaders during his trip to Moscow. I know we signed an agreement with them, but I want to be sure that it is being implemented properly. It is hardly unfair to ask the Soviet Union to warn us if they expect a poor harvest and plan to buy heavily on the world market. We have a right to know. I would suggest giving priority in our exports to long-time reliable customers. That should encourage other countries that they too should show some reliability and share food information with us.

LONG-TERM APPROACH

In the long run we need to bring population increase in line with food and other resources. We can hardly expect parents in developing countries to accept Western notions of family planning when surviving sons represent the only available form of social security. We have to look at the population problem in developing countries as an economic development problem. It is somewhat like the early days of the American frontier when large families were a needed source of labor. We need to emphasize the total development for these countries in whatever area we work, whether it is through the World Bank or Asian Development Bank or through our own foreign assistance programs. We must shift from building cement or steel plants as the first item of business and do what needs to be done first--i.e., develop the essentials of an economy --food, employment, health care, housing and education.

We have tried to emphasize this in the new Foreign Assistance Program, but it is hard to get people to do things to which they are not accustomed. When these basic conditions are established, population growth will begin to decline, as it has in other countries. We cannot expect success or an appreciable impact on the population with the new contraceptive devices in developing countries where there are high rates of illiteracy and inadequate medical and professional personnel. In countries where manpower or childpower is critical to economic survival, I doubt that we can do much about population growth until we have total development.

We must not expect miracles or shortcuts. My suggestions are modest proposals that you can and should be interested in tackling. Beyond your professional interests, you are, above all, citizens with the accompanying rights and responsibilities. We, Americans, have begun to realize that a chaotic world with one-half affluent and well fed will not long survive while the other half faces starvation and malnutrition. I hope we are beginning to realize this, but I worry that we are beginning to turn our back on it. Whether we call it isolationism or selfishness or self-protection, our interests have changed a great deal in the last 10 or 15 years. We have expected too much to be done in too short a time. We built up people's hopes and dreams beyond what was realizable or achievable. This turns people off. That is why planning both domestically and internationally is so vital--to place goals within a time-frame, to allocate resources, and to set achievable goals and benchmarks so that people know what has yet to be achieved.

Technology to Increase Food Supply

John W. Mellor

Growth strategies of the last two decades have done little to increase employment and participation of the poor. However, when increased employment and participation of the poor in growth is achieved, it greatly increases pressure on food resources. As the poor gain employment and higher incomes, they spend a high proportion of additional income on foodgrains and other agricultural commodities. In India, the lowest two decile income groups spend about 60 percent of added income on foodgrains and 85 percent on agricultural commodities in total. In contrast, the income group in the top 5 percent spends only 2 percent of income increments on foodgrains. Efforts to include the poor in growth may be quickly stifled unless there is a rapid increase in food production. Without commensurate increases in supply, rising demand for food will raise food prices and thereby directly reduce incomes of the poor, and it will mobilize the politically potent urban middle classes to take measures to reduce those inflationary pressures--measures that will be effective only if they reduce income and employment of the poor.

TECHNICAL CHANGE TO INCREASE AGRICULTURAL YIELDS

In the classical view, agriculture, dependent on a limited land area, encounters rapidly diminishing returns with additional production inputs, including labor and even fertilizer. The consequent increasing costs of production necessitate higher agricultural prices to provide incentives for increased production. But higher prices discourage labor-intensive production and economic growth. The economist Ricardo, in the early 19th century, recognized these forces as retardants to industrial growth and advocated food imports from the New World to relieve Britain's problem of limited land. The "new world" of the 20th century is technological change that increases yield per acre. New technologies of the Green Revolution break the diminishing returns bottleneck by developing new plants that produce much greater yields by using vastly greater quantities of inputs, such as labor and fertilizer.

To overcome the diminishing returns of traditional agriculture and to support employment-oriented growth strategies, science and technology have a key role in agriculture. To play this role, complex science and technology systems must be built.

SCIENCE AND TECHNOLOGY SYSTEMS FOR AGRICULTURE

Three key characteristics of agriculture influence the nature of an optimal science and technology system.

First, agriculture is comprised of myriad small-scale units. The individual farm cannot economically support or justify a large-scale science and technology system. An effective system usually requires a large-scale private sector (which either does not exist in low-income countries or lacks means to pay for science and technology services) or a public sector system of science and technology to aid small farmers. Most countries, including the United States, have developed large public sector research systems to service agriculture. Without such systems to reduce production costs, agriculture remains inefficient or is forced to organize in large units to the detriment of employment.

Second, agriculture varies greatly under different conditions of production--i.e., physical, economic and cultural--so that the transferability of research results from high-income to low-income countries is greatly limited. Also, an intricate system of research stations is required to service a wide range of conditions within low-income countries. Wheat production has increased much more than rice under the Green Revolution. This is due substantially to the markedly greater heterogeneity of production conditions for rice in Asia, and the rice research system's inadequacy to fill this larger and more complex requirement.

The close relationship between rural development programs and income distribution means that areas which do not have vigorous science and technology based rural development will remain or become areas of intense and entrenched poverty.

Third, because of its size, dominance as an employer, and potential for intensification through technological change, agriculture itself must provide a major portion of future employment growth in low-income countries. Technological change must be tailored to this employment need. Because of the larger labor force in low-income nations, the research effort may need to be directed, staffed, and organized differently to meet employment needs.

THE TECHNOLOGICAL NEEDS

The Biological Sciences

The potential for improving agriculture is immense and varied. It includes plant breeding to develop appropriate new varieties with greater yield, shorter growing-seasons, and more resistance to disease and pests. With increasing concern over the environmental effects of chemical pesticides and their very high cost in the humid tropics, pressure mounts to find biological means of pest control. The peculiarities of tropical soils and the long concentration of soil research in temperate latitudes now calls for a wide-ranging agronomic research effort.

Under appropriate conditions, new high-yielding varieties produce double or triple the normal yield. Manipulation of crop-growing season lengths has enabled double and triple cropping. Where the right technologies are combined under favorable conditions of sunlight, temperatures, water control, and fertility, vast production increases--even as much as four-to six-fold--are possible.

Bangladesh, which suffers intense population pressure, has half the population per cultivated hectare as Taiwan, and yet Taiwan supports a much higher per capita food consumption and income from agriculture. The difference lies largely in the adaptation of science and technology to the respective conditions.

The Mechanical Sciences

Biological breakthroughs create a demand for sharply increased research in the mechanical sciences. Increased marketable outputs and inputs such as fertilizer to farmers need to be transported. They require improved roads, and rural development being a nationwide process, the road requirements are massive. New ways to reduce building costs, improving low-load capacity roads, and doing both efficiently, must be found. Similarly, increasing demand for rural electrification creates demand for low-cost transmission. As food storage requirements rise, particularly in rural areas, the scope for devising low-cost, efficient, small-scale storage increases.

The yield increases from new seed varieties increase labor requirements for harvesting and threshing, and justify more intensive weeding, seed bed preparation, and insect control--all likely to produce seasonal labor bottlenecks, even in regions of large total labor surplus. New seed varieties increase the returns to water and justify new irrigation systems. Change to double and triple cropping greatly exacerbates these tendencies to create labor bottlenecks. The high cost and limited availability of capital demand that such mechanization be low-cost. The general labor surplus requires that mechanization be keyed specifically to periods of labor shortage. Engineering research must be appropriate to these specific local needs, and it will inevitably include systems to raise water, provide insect protection, improve threshing and tillage, and so forth.

Finally, vast increases in the use of such purchased inputs as fertilizer--a necessary part of the Green Revolution--mean that these must be produced in large quantity without increasing the relative cost. Currently the optimal means of producing these inputs are highly capital intensive. Can engineering research develop lower cost production methods, including smaller scale, less complex plants, more suited to the conditions of low-income countries?

THE ORGANIZATIONAL NEEDS

Increasing food supplies through technological change requires (1) complex interrelated systems of research, education, input supply, and marketing, and (2) an institutional base for recognizing and handling important issues of prices, land use, and resource allocations. Since agriculture requires an accelerated rate of growth over time, a system is needed that constantly generates new technology and implements it, not just a "once and for all time" boost in production to a new plateau.

A blueprint for a complex system is not enough. The scarcity of trained manpower requires a careful setting of priorities phasing the building of the system to maximize short-run returns, as well as building the various sub-systems for the long run.

BUILDING A RESEARCH SYSTEM THAT WORKS

The research system is most fundamental, and in developing countries especially, it must come to terms with particularly severe problems of communication between user and scientist, variability in conditions, and interactions of social and growth policy.

Small-scale production units have an immense advantage in tapping entrepreneurial sources not appropriate to large units or government bureaucracies. Small entrepreneurs often have substantial business acumen, but little formal education, and this can result in a communications problem between the research establishment and the productive user. Communication is crucial to the success of research in agriculture and industry; most important is a channel that takes problem-definition from the user to the researcher and provides feedback from the initial research efforts. In agricultural research this feedback occurs by close contact between research institutions and extension organizations. In Japan and Taiwan, farmer organizations have been predominantly used in this context.

The common complaint in low-income countries is that agricultural research is irrelevant to local needs, that foreign-trained researchers work on problems irrelevant to local conditions. The problem is basically one of communication and clientele, and the institutional structure is the key to this problem. The foreign-trained researcher may well have a clientele in foreign journals, an orientation to international conferences, and he may work under an incentive system that encourages cultivation of an international clientele. What is needed are incentives that make the researcher service a domestic-productivity-oriented clientele, and that compensate him as he benefits those users.

The variability in agricultural conditions requires a widely dispersed system of research. Individual research stations serving specific adaptive needs must be tied to sources of more basic research. The one requires many small stations, the latter large integrated units. The solution lies in coordination between central stations and field stations, a complex institution building problem.

Small-scale industries based on natural or agricultural raw materials, such as gems, forest products, fibres, vegetables and fruits probably require similar research support. Without such support the ability of small-scale firms to compete against large-scale firms as well as in foreign markets will be lessened. This, in turn, will hurt the efforts to move to higher employment strategies of growth.

The impact of science and technology on social policy is particularly great in agriculture because of the large absolute number of people and the very large proportion of total population in this sector. A technology which changes income distribution between laboring classes in rural areas and peasant farming classes, or between small and large farms, has major impact on the social objectives of society. Hence, society must be very much concerned with the nature of the technologies being created and their impact--i.e., the choice of technology and the way it is applied. It should also determine the institutional organization of science and technology that largely determines the options. The choice between working on yield increases through biologically-oriented innovations as opposed to labor-saving and mechanically-oriented innovations is a simplistic example because some mechanical innovations can break seasonal labor bottlenecks that, in turn, may allow major yield increases.

The problem is even more complicated when we deal with regional allocation of science and technology resources. For example, to what extent should one take a particularly high risk on the rate of return from research resources by allocating them to backward sub-regions that seem to have poor development prospects but where social problems are particularly serious? Such problems also occur in the development of a research structure to service the small-scale industrial sector. Decisions must be made about which products to emphasize, about the location of stations, and about the labor intensity of particular units. Agriculture also illustrates the complexity of the problem of setting research objectives. Where social and economic conditions have determined the research thrust, in isolation from technical scientific considerations, the result has often been an insoluble problem definition. What is necessary is the interaction between the social objectives and physical realities--an exercise in the art of the possible.

Public Sector Organization

Organization of a science and technology system largely in the public sector raises difficult problems of setting and enforcing priorities. The public sector objectives are likely to be diverse, the political process may inhibit an explicit statement of objectives, and the bureaucratic procedures may make it difficult to allocate resources consistent with unstated objectives. This raises questions about the extent to which research should be organized in institutions largely autonomous of political processes so that objectives may be dealt with more explicitly, while risking less contact with and responsiveness to societal needs.

In science and technology systems the key allocative decisions are: personnel and incentives. These are important to the total size and effectiveness of the research effort. Particularly in ex-colonial, low-income countries, the administrative and salary structures in the public sector often favor a stable administration and the generalist administrator. Change may be needed to give emphasis to technically trained persons for research through a shift in relative salaries and prestige. Such change is difficult to achieve. The problem is exacerbated in mixed economies, where the private sector is likely to adjust more rapidly by drawing on the best technical manpower to the detriment of work best done in the public sector. This has been particularly detrimental to agriculture, small industries, and public welfare programs.

Integrated Interdisciplinary Approach

Applied problems in agriculture have been solved best by integrated research and institutions that cut across disciplinary lines. For example, crop yields reduced by apparent disease or insect pests may really be due to a trace element deficiency dealt with by agronomy, rather than entomology, plant pathology, or plant breeding. Unless the problem is examined by persons from several fields, the optimal solution may not be found.

Coordination across several fields may be more difficult in public research institutions because of close relationships with academic institutions and strong ties to disciplinary organizations. The problem is how to maintain a strong tie with the efficiency-increasing logic and methodology of the academic discipline and also develop a capacity to constantly regroup along problem-oriented lines in the face of constantly changing problems. The closer the tie with the clientele, the greater the pressure to find productive patterns of institutional organization.

Integration of Basic and Applied Research

It is not clear how and at what level basic research needs to be integrated to applied research. Nor is it clear the extent to which the return to such integration occurs by increasing the efficiency of research through the direct utilization of basic research or by providing greater upward mobility of research staff to potential national and international institutions. It seems that national research systems have all too often erred on the side of inadequate support in basic science. Efficiency can be increased by selective applications of basic theory and sophisticated methodology. Much of the criticism of basic research is, in fact, based on examples of poorly defined and irrelevant applied research. In general, research results have been sparse where research is done in highly applied stations with little integration within a larger system and when it is conducted entirely by people with only applied training.

Interregional and International Research Grids

The need for complex mixes of disciplines--and of basic and applied science--poses problems of scale in small countries that necessitate integration into a larger research system. In recent years international research systems in agriculture have been created that provide a prototype for other research systems. These international institutes provide: (a) major centers for interdisciplinary interaction to which less fully staffed stations can relate; (b) the communication and institutional base for developing a core of basic research; (c) a quality level that sets a desirable standard of problem definition; (d) an apex to integrate country research stations. Through these institutes complex problems have come to the attention of the international agricultural research system. Initially, support funds came largely from private U.S. foundations; recently, international and bilateral aid agencies have played a growing role; in the future low-income nations themselves may provide financial as well as intellectual support. Nevertheless, it is still not clear how they will be financed in the long term. This question relates to the role of these institutes, whether they should exist as separate operations to provide complete solutions or as part of a total research complex fully integrated with national systems.

FUTURE NEEDS

There are clearly visible potentials for increasing food production that can provide breathing room for a pattern of economic and political development, which in turn can bring birth rates and population growth under control. To realize these potentials there must be a major reallocation of resources toward rural development and the building of a complex institutional structure with an international research system as a key component.

The American science and technology establishment can play a major role. Integrating this research establishment into the international system can contribute directly to knowledge, strengthen the institutions of the international research system, and orient American research more toward certain aspects of food production problems faced by poor countries. Financial assistance to the international system can be massive and effective if given with the backing of U.S. knowledge and experience in building such systems. A flow of American researchers and technicians to field stations in low-income countries can significantly add to the volume of research output as well as assist institutional development and the training of people in developing countries for productive effort.

Technology to Improve and Deliver Food

Don Paarlberg

A report assessing the world food situation was prepared by the Food and Agricultural Organization (FAO) of the United Nations as a background paper for the November 1974 World Food Conference in Rome. The assessment covers three time periods: the near term related to the 1974 crop, the next decade or so, and the long term.

In the short term, covering the crop year 1974, the picture is a mixed one. In the food exporting countries, food production is increasing markedly. In the U.S. this year we will harvest an all time record crop of wheat and very likely of corn also. Canada and Australia are expanding their output. In the food importing countries, however, particularly in South Asia and also to some extent in Africa, the situation is precarious. Their reserves are depleted and, in view of the current high price of food, their capacity to import food is limited. They are short of fuel and fertilizers. They are more than ordinarily dependent on a good crop this year. If the monsoon is good, and if a good crop comes along, they will be all right. If not, they will be in serious difficulty.

In the next decade or so FAO anticipates that food production in the exporting countries will grow rapidly and supplies per capita will continue to increase at a rate of about 1.5 percent a year, which has been the growth rate for some time. In the less developed countries the projection is that aggregate production will be a little ahead of the rate of population increase and per capita supplies will rise about 0.5 percent per year. This average will cover some very grave difficulties in distribution; there will be large population sectors that will experience no improvement and perhaps a worsened situation. On the whole some improvement is expected even in the less developed countries, but there will be a widening of the gap between the developed and the less developed countries in per capita food supply. Substantial problems in the transfer of food supplies both from the developed to the less developed countries and within the latter can also be expected.

In the long run, projecting into the 21st century, unless there is some check on the rate of population growth there will be no solution to the world food problem. If present rates of population growth are projected into distant periods, they simply run off the chart. Not only problems of food supply, but others--depleted natural resources, excessive crowding, congestion, political and social disturbance--are likely to be encountered.

We have estimated the United States' capacity to produce food by the year 1985. Making certain assumptions--(1) reasonable weather, (2) farmers will have access to their land and will not be limited on the amount of land they can cultivate, and (3) reasonably attractive prices for farm produce--we anticipate that production of feed grains could increase about 50 percent, wheat about 40 percent, and soybeans about 30 percent over present levels. There appears to be considerable latent capacity for increased food production here and also abroad.

TECHNOLOGICAL OPPORTUNITIES IN FOOD AND NUTRITION

Turning now to technological opportunities for maintenance and distribution of foodstuffs, this is the area of food technology that is greatly influenced by engineering. One important topic here is food fortification to supply the nutrient elements lacking in food in its natural state. One of these often lacking, particularly in grain, is amino acid lysine that can be added at a moderate cost. Lysine addition greatly improves the nutritious quality of cereal grains for humans, and adds 2 to 10 percent to the cost, depending on how much, and which kind of amino acid is added. We know how to do this. We know that the effect is to greatly improve nutrition. However, some people have reservations about food additives, or about any kind of food engineering, and so we have the very human problem of food acceptance.

Another promising development is textured soy protein. After oil is extracted from soybeans the meal that is left is very high in protein. With the application of food technology it can be made into textured soy protein and fashioned into a great variety of flavors, shapes and colors. Soy protein costs from 12 to 14 cents per pound, a fraction of what animal protein costs. There are some problems here again of taste and aesthetics, but the acceptance of this product is advancing, and it is one of the most promising areas in the whole food field.

The case of soybeans illustrates the interrelatedness of engineering, economics, aesthetics, food habits, and tradition. Soybeans have been a food product in Asia for thousands of years. The soybean plant was imported into the U.S. about 100 years ago on an experimental basis. We were reluctant, at that time, to consider it a food crop, because we did not want to eat what the Chinese were eating! Initially we used it as green manure and plowed it under. It was rather expensive though to grow it and then plow it down, so we decided to plant it as a hay crop. We noticed that cattle would eat it; but all the leaves would fall off before it could be brought into the barn, so we soon gave up its use as cattle feed. Then Henry Ford recognized its potential for industrial use; the soybean could be utilized as an industrial raw material. We discovered, however, that petroleum was a much more economic source of industrial plastics. Next we found the oil in the soybean. We squeezed the oil and used it for human food. We called it an oil crop and still do. We discovered later that the meal left after oil extraction was a very valuable livestock feed and worth more than the oil. So it became a food crop. Finally, we have discovered that the meal is an excellent human food. One hundred years later, we are back to where the Chinese were 1,000 years ago!

There are other very promising food products that require engineering. However, they also encounter problems of aesthetics and acceptance. One is fish protein concentrate (FPC). Fish is processed and made into a highly nutritious fish meal. It is an excellent human food additive. It can be made very bland so that the fish taste is not noticeable. But people have an aversion to it and will not use it as a human food. As a matter of fact, we have some rules that outlaw this as a human food. We feed it to chickens. We know technically now how to get animal feed from algae grown on sewage wastes. Indeed, we might in time get human food that way. The extraction of protein from green leaves, and single-celled protein are other possibilities. We have come a long way in engineering food products, but our efforts will not be enough unless we can overcome the human problems of aesthetics and acceptance, and the problems of economics.

INSTITUTIONAL IMPACT AND ACCEPTANCE

I am convinced that engineers are far ahead of the social science disciplines when it comes to the capability of solving the world food problem. There is a long, continuing argument between engineers and social scientists. The engineers believe that technical change is good, that more technical change is better, and the best thing would be the most rapid technical change that is possible. For them the relationship between the public good and the rate of technical advance is positive, linear and steep. The social scientists, on the other hand, believe there is an optimum rate of technical change that the institutional arrangement can assimilate and accept without tearing itself apart. They have doubts about generating technical changes faster than the society can comfortably accept. For example, if agriculture were mechanized in some less developed countries, the resultant unemployment of a great number of people might bring about social unrest and, indeed, disaster. We did it in this country when we mechanized our cotton production at a very rapid rate and caused the unemployment of millions. We had not anticipated this fact and had made no plans to accommodate the new situation that came about. The unemployed people went to the cities in great numbers and had difficulty being accepted there.

Therefore, as we deal with engineering solutions to world food production, we need to keep in mind that social institutions must keep pace with them, and that there is a maximum rate of acceptance of which these institutions are capable. To push beyond that rate may perhaps be an engineering triumph, but it could be a social disaster.

TRANSFER OF FOOD SUPPLIES: COST AND EFFICIENCY

When we speak about moving our increasing abundance of food to the poorer countries an overriding factor to be considered is the cost. The technology we now have or will develop cannot always be transferred easily to the less developed world. However, people like you are in a position to help the poorer countries better feed themselves and become better customers of the U.S. farmer. This effort will require substantial investment of know-how and money. It will take foreign investment in modernizing overseas port facilities and building roads in the interior to get the food to the people who face the greatest danger of starvation. But perhaps as important as money is the availability of technicians. This is where engineers and other specialists are vitally needed.

The development of larger bulk containers for shipping farm goods in this country has significantly lowered the cost per unit of product. This applies to ocean transport as well. Shipping in bulk reduces the handling time at the port and streamlines the whole distribution system.

Containerization has been one of the greatest innovations in our marketing system in years. The benefits, however, have been largely reaped by the industrialized countries. Container ships are heavily plying the ocean lanes between Europe and the east coast of the U.S.

But what about Indonesia, for example? It has few ports for such vessels. Container ships require a big investment. Each crane needed to remove the cargo from the ship costs a million dollars or more. Trucks are needed to transport the cargo to destination points, and highways are needed for the trucks. The coastal regions usually have the roadways for food transport, yet the interior regions are often more in need of food. Without the right equipment to handle the commodities dispatched from the modern ships, one ends up with the old scoop shovel, and thereby loses all the efficiency that could be gained from using the larger bulk carriers.

Part of the problem of sending vast supplies of grains to foreign countries is that it takes these countries a long time to build the port capacity to handle what is landed on their shores. Besides, they do not have the facilities for shipping food inland. At present, we are sending sorghum to Africa under P.L. 480. Except for Dakar, most of the African ports cannot take cargo from our newer ships. After leaving the ports, the situation becomes even more dismal. Railroads cannot handle the load. As for trucks, they travel on what we would consider trails which become loblollies of mud when it rains. It is fortunate that most of our donated grains arrived in Africa soon enough to be moved to the Sahel before the rainy season, but much of the grain from other countries could deteriorate.

Even if the food does get in, storage presents a problem--not just in Africa but in many parts of the developing world. India, for example, has had severe problems in storing food. As much as 20 percent of the food supply is lost to rodents. In parts of Africa, the storage facilities are so bad that the ships often have to fumigate the grain--at a cost of around $25,000--before it is taken ashore. On the brighter side, the introduction of lash vessels will lower the cost of fumigation, since the ship will be able to leave the vessels and retrieve them later.

The condition of the waterways in many developing nations hinders food shipment to them. In Bangladesh, the ship Manhattan--one of the biggest ships then afloat--was used as a warehouse. This proved expensive because the ship remained in Bangladesh for more than 6 months. It was unable to leave due to the low water level. Bangladesh is just one example of a needy country to which food cannot be delivered economically.

Marketing of food costs money, but the cost may be sharply reduced by increasing volume. The unit train, for example, goes from production point to consuming point carrying a commodity, but it cannot make money unless it moves all the time. And that means somebody on the other end has to unload a lot of grain. Because they lack transport facilities, the developing countries often have no one available to move the grain. What we consider progress in marketing is not necessarily viewed that way in the developing countries, because the end result is a higher price for the product. By that I mean packaging and quality maintenance--plastics, and wrappings that protect the products. These savings are resisted by many countries because of the cost. We spend 8 cents of each marketing dollar in the U.S. just for packaging to protect the product; but in the less developed countries, it is sometimes cheaper to lose the product than to package it.

The picture is not as bleak as I have painted it. The U.S. has a tremendous capacity to produce food to avert world shortages. It is true that many of the nations most in need of food are ill-equipped to receive it at the ports, to store it, and to transport it to the hungry. But people like you have the know-how to help correct the conditions that make it impossible for some of the world's needy to get the food that we can provide them. This will take money, but without expertise that money will be wasted.

The crux of the problem is expertise, in growing the farm commodities the rest of the world requires, and in getting this food into the mouths of those who need it. This means designing ships that can sail into ports that are now inadequate by our standards, helping foreign countries to design ports that can handle the ships, and designing storage facilities and inland roads to move our great agricultural abundance.

Planning Implications for Increasing Food Supplies

Charles S. Dennison

The world society today is very different from what we have known in the past. Conservation of materials, and a totally new conception of waste and of consumption, as a linear increase must figure in all our thinking. We must also face the question of how we are going to divide up and use the resources of this finite planet. These are questions in which the engineer, along with his science and social science colleagues must be deeply involved.

On the subject of increasing food production in developing countries, one crucial area we could focus on is fertilizers. The complexity of this subject--the need for management and feedback--will require skills that lie substantially but not exclusively in the engineering sector.

FERTILIZER NEEDS OF DEVELOPING COUNTRIES

Approximately 85% of world fertilizer production is concentrated in the developed world. Fertilizer consumption in the developing countries is expected to increase from 5.8 million metric tons of nitrogen nutrients (N) in 1971-72 to 15.5 million metric tons by 1980-81, and phosphate nutrients (P) from 2.7 to 7.1 million metric tons over the same period. In aggregate terms, N&P nutrient consumption is expected to grow from 8.5 to 22.6 million metric tons.

This rate of increase in fertilizer use is consistent with an average annual growth rate of 3.3%-3.5% in food and total agricultural production. Much of this increased fertilizer consumption can and should come from increased indigenous production in developing countries. This course, despite certain economic disadvantages, will contribute to overall economic development, employment, technological and management advance and insure a stable and secure supply of a vital element in food production.

World fertilizer production grew sharply during the first half of the 1960s geared largely to expected demand increase in the developing world. Failure of this market to materialize caused sharp price drops in the second half of the 1960s and a marked drop in new fertilizer investment. This restriction of fertilizer supply had a marked effect on the price and availability of fertilizers now urgently needed by food-deficit developing countries. Pre-1973 urea cost averaged $90-$100 per metric ton, C&F at Asian ports; by mid-1974 this cost had risen to $270 and, in the future could go up to $350. Higher prices and increased demand should encourage substantial investment in fertilizer production capacity. However, it is most unlikely that this will occur quickly enough to meet the needs of the poorer countries.

Estimates of the investment required for fertilizer production in developing countries range from $6 to $10 billion between now and 1980-81. Some of this may come from private enterprise, but not enough, because private investment flows to stable, assured markets chiefly in the developed world. It does not readily enter high-risk, low-margin operations in the developing countries that most need the fertilizer.

AN ACTION STRATEGY: A FOUR-POINT PROPOSAL

What can be done to alleviate this situation? I have a four-point action proposal to suggest, but first I would like to mention some of the assumptions basic to the proposal.

1. Population control on a national and global scale is a vital and necessary consideration in any food production strategy. Unless mankind grapples with its growing numbers, all strategies, programs and projects will be reduced to futile palliatives.

2. The food problem is global, and its solution will require cooperation among industrial, socialist, and developing economies. Yet effective action requires a

competent, neutral, central authority--one that can measure, manage and execute policy, exercise objective but positive leverage on individual countries, follow up programs and evaluate their results. The engineering profession has an important role to play in creating and operating such an authority.

3. The private fertilizer industry with its supporting and outreaching auxiliaries has demonstrated excellent technical and managerial capability for producing and marketing its product. Therefore, it should be involved whenever possible, and all fertilizer supply programs should be coordinated with its normal market processes. However, private industry is responsible for earning a return on investment and for maintaining a competitive share of the market. These pressures serve the developed countries well but usually do not serve the poorer, less developed nations' farm populations well. Hence there is a need for a stable, continuing supply system for the poorer nations--one that will compensate for the drastic rises in energy and fertilizer costs.

4. Food production must be considered within the context of balanced, overall development. Fertilizer has been selected as the "critical path" item in the following proposal, but it is essential that other inputs in the "agro-industry" complex--seeds, chemicals, implements and pesticides--be brought together at the country and farm level.

The four-point proposal that is suggested here is based on a new concept of the role and responsibility of the engineer in international development. It outlines very broadly the design of an international action program to deal with a critical element in the present world food situation. In this field, several studies, analyses and computer-model building exercises have been done, and others are in process under the direction of international or national agencies in developed and developing countries, universities, and private foundations. However, they are largely concerned with defining and measuring the food-population-growth "problematique." My proposal, on the other hand, suggests a systematic, urgent, engineering management action system to deal with the food production problem. This will require mobilizing investment and technology for fertilizer production, transport and distribution for on-farm use in developing countries. The approach constitutes a "critical path" effort to mobilize fertilizer supply and production where and when it is most needed.

The four points of my proposal for COPEP and other appropriate organizations are:

1. COPEP should begin to make an immediate appraisal of the role that engineering and engineering-based management can play in devising and executing strategies and action programs in the world food-population situation at the international macro-level, and at the complementary national or micro-level. Such an appraisal should use, but not rely entirely on systematic approaches and techniques.

2. Select a concrete and urgent element for action in food production, and formulate and recommend, for example, a trial effort to provide adequate supplies of chemical fertilizers, in sufficient time and over time, at costs developing nations can afford. Such a fertilizer supply effort should be international, be tied to a program of emergency and reserve food supplies, and be aimed at the poorest 40% in the developing world.

3. Collaborate in this fertilizer supply study program with other disciplines--agricultural scientists, development economists, financial and transportation specialists--to develop a systematic management approach that could be applied to other equally important aspects of the food and population situations such as population control, food stocking and distribution, water use and conservation, energy, chemicals, and other inputs, waste control, environmental protection and improvement, etc.

4. Explore with other professional organizations such as ICSU, FAO, IBRD, IIASA,* and the fertilizer industry, the specific arrangements for implementing a food-population strategy.

COPEP action should be given impetus by the impact of the energy crisis, the sharp inflation of fertilizer prices, disruption of world fertilizer supplies, and resulting hardship for the poorest countries and farmers.

Elaborating further on point 2, my suggestion is that we start with national food-fertilizer needs and work back to the requirements for raw material inputs, technology, transportation and investment. Such food and fertilizer needs will have to be calculated for now to the end of the decade, and to 1985-86, with concentration on the most needy countries (estimated to number 26-30 with a probable

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*ICSU (International Council of Scientific Unions)
FAO (Food and Agricultural Organization of the United Nations)
IBRD (World Bank)
IIASA (International Institute for Applied Systems Analysis)

population of 350-400 million by 1985). These countries are to be listed in priority according to: (1) need; (2) government receptivity and will to act; (3) agricultural, logistical, and environmental absorptive capacity; (4) water availability; and, (5) population control policy.

An international managing and financing authority should be created with the support of international organizations in the food and economic development field. Such an authority would respond to the systems-defined priority needs at the country level with a four-phase synchronized program:

1. Provide emergency food supplies and build better food stocks as already proposed by FAO.

2. In close coordination with this world food reserve system, create a complementary pool and supply system for fertilizer and other food production inputs. The fertilizers and inputs would be purchased on the open market in large quantities and at competitive world market prices thus providing a quick and substantial demand to encourage increased fertilizer production in developed and certain developing countries. The pool fertilizer would be supplied to priority-need countries at concessional prices to offset the inflationary impact of sharply increased petroleum costs. Countries receiving such supplies would meet the criteria listed above, thus providing a measure of international leverage to ensure improved agricultural policy and practice in recipient countries. The supply of pool fertilizers and other inputs would work as a "seeding program" intended to create and test a fertilizer logistics system, including shipping, harbor unloading, storage, railroad, road and barge movement to farm areas, provision of credit to cultivators, extension services for cultivation and post-harvesting processing, storage and distribution to market.

3. Concurrently with the operation of the emergency food-cum-fertilizer and requisites supply system outlined above the international authority would devise a program with governments for indigenous fertilizer production in certain suitable priority countries that would be hospitable to such operation. This would entail expansion, modernization, and full capacity use of existing fertilizer facilities as well as construction of new facilities appropriate for the market. The following would be assessed in planning production facilities--indigenous resource availability, energy and fossil fuels or substitutes, phosphate, potash, and sulfur as raw materials, transport and logistical facilities, environmental carrying capacity and constraints, and water availability.

4. Finally the authority would create an international support base for the planned indigenous plant network. This would consist of locating, mobilizing and channelling the raw material supplies--petroleum or gas (with particular emphasis on using flared gas in the Middle East and elsewhere), as well as the phosphate, potash, sulfur required--at the most favorable terms possible. Much of this supply operation could be handled by the world market but the authority would have to intervene to supplement the market, to adjust prices to ensure continuity of supply and to compete effectively with the usually favored industrial country users.

The authority would expedite and collaborate in the provision of the required technology and management drawing upon private industry, consulting engineers, government and international agencies. It would also assist in providing ocean transport, including specially designed carriers for ammonia, phosphoric acid, etc.

The financing of a fertilizer supply program would have to be considered as an integral part of the financing of a food supply and buffer stock program. The purchase of fertilizers at competitive world market prices would come from funds that might be added to those provided for food supplies. Financing of the long-term indigenous fertilizer facilities would have to come from a vast new reservoir of development funds, including OPEC. Core funding of about a billion dollars could start the indigenous fertilizer production program with additional funding being supplied as viable projects begin to develop both at the country and materials supply level.

A Call to Engineers

Peter Cott,

The problem we have explored is immense and complex, and the need for responses and solutions is greater than ever before. Two essential things must happen if what we have been discussing is to have any policy impact. One of them is a recognition of the need for structures both within the NAE and outside, in organizations to which those present here belong. The other is a larger role for engineers as societal leaders. We have spoken of engineers in two capacities--as professionals, and as societal leaders. It is in the latter role that more action is needed.

Engineers have a capacity for much greater influence over policy than they are aware of or have chosen to exercise historically. They must intrude themselves actively in structures, in macro-and micro-systems throughout the world, and contribute to policy formulation in the areas of population, food, and resources. They should be on the boards of every organization addressing these problems. My organization, like some others in the population field, has good people who are concerned, but we do not have a great deal of authoritative knowledge or posture. Engineers could provide that element of authority and perception. It is unfortunate that engineers are not usually members of the U.S. delegations at world conferences. Perhaps it is because they do not make their presence adequately felt so that they have the opportunity to be a part of these delegations.

I want to make some suggestions for your serious consideration. First, there are areas where engineers must play a role--in public policy, the private sector, and funding. In a speech before the World Population Society in February 1974, President Seamans identified the Congressional Office of Technology Assessment as a major mechanism wherein the knowledge and perceptions of engineers might be heard and be useful. It is equally obvious that such an office must be established at the Executive level and that engineers should be in the forefront demanding it. Second, there is a real need for the NAE to amplify and energize its own structure to deal with the urgent problem of population and food imbalance. It should be the priority concern today for this organization and its sister organization, the National Academy of Sciences. Unless that structure is developed, this urgent issue will not be addressed as it should be and as it has been expressed here. Instead, it will be business as usual, starvation as usual, toppling governments as usual, and so on.

Another matter needs emphasis. While engineers can identify the possibilities, probabilities, and the pragmatics of the technology of population and food balance, they must also identify its limitations. Here again, I speak to engineers as members and leaders of society, and not as professionals. Without their authoritative definition of the limits, societal changes that are imperative to save spaceship earth will not be facilitated. Without new perceptions Americans will not feel compelled to reduce their consumption of food, energy or anything else. There is an obvious want of leadership in political circles today. It will take other circles that society has historically relied upon--academic and professional circles--to provide the leadership, and to provide this outcry. And, finally, to build bridges between the professional and societal roles, engineers must function fully committed in both roles.

Charles M. Cargille*

Excessive population growth--along with its many deleterious consequences--is the world's most critical long-term problem. Putting a man on the moon was simple compared to the problem of world population growth. Its solution will require more people, more computer support, more institutional strength, and more money and resources than were needed for the NASA space program.

If COPEP wants to take a long-term view about potential food shortage beyond the next six to sixty years, then it must ask whether engineers can help to limit excessive population growth and how this ought to be done. The present annual world population growth rate of 2 percent means that more than 76 million people are added to our planet each year. Each new person requires the basic necessities for life support, such as food and housing, from the earth's dwindling resources.

The population problem is a far more complex issue than any other your profession has faced before. Medicine has failed to respond adequately to the population problem. Physicians and biomedical research scientists have failed not only to provide new, suitable, and safe contraceptives, but have failed to provide leadership.

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*The views expressed here are Dr. Cargille's personal views and not those of his organizations.

The public health profession should have recognized long ago that population size is a principal determinant of the future state of the public health. So-called population research is behind the times, and it seldom deals with critical issues of population dynamics. Little attention is paid to non-demographic variables.

In recommending what engineers and the NAE should do, I express hope in engineering as a problem-solving discipline. I offer three recommendations as part of a systems and engineering analysis approach to the population problem.

First, the NAE should document the fact, and convince the public, that population size is a major determinant of the quality of our future existence. Second, the NAE should document that the present population research and administrative establishments are inadequate, and it should propose specific and sufficient changes to make these institutions adequate to solve population-related problems. Third, the NAE should devise a strategy to obtain large and sufficient resources for new talent, new institutions, new funding, and new objectives to deal with the population problem.

More specifically, the above will require: (1) New definitions of population science and population research that are broader than those currently used in federal population research programs; (2) A technological assessment of the tools and adequacy of methods used in the population field. A systems analysis of the population establishment, its funding, and its deficiencies, could definitively document the reasons for its present ineffectiveness; (3) A multi-disciplinary approach to population research and programming; (4) An adequate population and environmental information gathering, retrieval, analysis, and dissemination system; (5) New curricula in population education, multi-disciplinary in scope and management-oriented in context; (6) Multi-billion dollar funding for the population field in all of its aspects; (7) The selection of new and internationally acceptable goals. For example, one might consider that food, shelter, and other basic human needs should be provided at a sufficient level to each person to ensure his well-being and dignity. Another goal might be that man ought to survive, and in order to minimize the risk of extinction, he should take special steps to preserve the genetic pool which assures the well-being of future generations; and (8) An ethic of unity between all peoples to reduce and replace cut-throat competition that threatens famine and death for millions while the affluent become ever more rich.

While recommending an active and principal leadership role for engineers and the NAE in the population field, I must caution that population is a sensitive science policy issue and that vested interests will oppose new initiatives. Engineers, both as individuals and through active participation in NAE, can provide new leadership, but they should prepare for a long and difficult effort in the search for solutions--rational and humane solutions that will ensure the survival and dignity of man.

Discussion

QUESTION: Senator, how can you get the American farmer in the Midwest interested in the realities of what is happening to people in far away places, in the districts of India or Africa? When he is preoccupied with his own problems, how can he be persuaded to show compassion or a willingness to help people he does not know?

SENATOR HUMPHREY: If the U.S. Government announces it will buy $3 billion worth of foodgrains, the farmers will produce them, exactly as tanks are produced when the government says it wants to purchase 1,000 of them for security purposes. The problem is one of leadership. We have a presidential system and it requires strong leadership--moral leadership, political leadership, a design and programs. If you have this, people will respond. If the government says we must produce 2.5 billion bushels of wheat next year, and we will put 500 million bushels in an international emergency program, and we are going to buy it from you, Mr. Farmer, he will produce it. The American people are perfectly willing to see that people in India or Ethiopia have food, and those who produce it want to sell it. If they cannot sell it commercially, they would like to sell it to their government. Then the government can make concessional arrangements with somebody else.

The American farmer is still concerned about surpluses, depressed prices, and overabundance. That is why the government has to design a program with target prices. These must be raised above $2 a bushel for wheat. We are still dealing with our farmers as if diesel fuel costs 12 cents a gallon and they can get all the barbed wire they want!

QUESTION: Senator Humphrey mentioned the need for a food information system to help predict the supply of food crops. Is there any ready and easily understandable information available that shows for each country and population the amount they raise domestically, the amount they usually import, and how this has varied over time?

DR. MELLOR: The answer is yes, but there are some difficulties in this, and they are of two types: First, the demand for food is very much a policy variable that is related to the distribution of income, which is a function of national policy. In order to project the demand for food we must know what some of the national policies will be. These policies in turn have to be framed in terms of what the supply will be. It is a very complex interaction. On the supply side, the basic means of increasing agricultural production beyond the minimal amount to keep up with population growth is new technology, which is a very opportunistic issue.

Second, and the greatest problem for countries that today are pressing on world food reserves, particularly India, is simple unwillingness to face reality as to where they are going. They face a "political" problem because the government does not want to admit that it will be dependent on food imports for a considerable period of time. This makes it very difficult for them to frame a sensible long-run import policy which will mesh in with policies of other countries. This difficult political problem, in some respects, transcends the technical problem of making supply and demand estimates. It will require some complex negotiations in the context of good faith.

QUESTION: Senator, you spoke of something we might call "FPEC"--an organization of food producing and exporting countries, similar to OPEC in the petroleum field. What mechanism will be required to bring this about--just leadership on the part of the Administration, or would legislation be necessary? As far as I know about export/

import shipment licensing, the government does not influence prices, as, for example, the last big Soviet wheat deal. If our government had sufficient information about demand and supply, under what aspects of the law could it step in, control, influence, or otherwise modify the terms of the agreement between the Russians who are buying and the people who are selling? You commented that we need to be concerned with prices.

SENATOR HUMPHREY: We need diplomatic and political cooperation with other food exporting countries--Canada, Australia, and New Zealand, for example. We ought to work together in the international market. I am not advocating that we gang up on the rest of the world in the food area.

The problem with the Russian wheat deal was basically a lack of information at the time and the nature of our trading system. We do not have state trading. We do not even have a wheat board as the Canadians do. We deal through private firms and they are expected to share information with the government on a timely basis. This information must be compiled quickly so that it can be useful in telling us what the demands will be upon our supply. We have learned a lot in the last two years, but there is room for improvement. When our reserves are low at the end of the crop year, good reporting information is critical. We had a carryover of about 175 to 200 million bushels of wheat at the end of the crop year on June 30th, and that is a low reserve. When you get down to that point, I think that the Secretary of Agriculture should monitor exports very carefully and we should have a better system of control. Perhaps we ought to have an export licensing system. This is highly controversial, but we ought to take a good look at it.

We need an improved information system and we are working on it in the Office of Technology Assessment. We need a system that alerts us to a short supply situation without putting on export controls. Unless we plan and prepare accordingly, we will have some serious political repercussions at home, such as a tremendous backlash against rural America. That must not happen.

We certainly need legislation to set up a reserve system. For 25 years we had what we thought was the curse of food surplus and the idea was to get rid of it. We mandated the Department of Agriculture to dispose of it, and the Public Law 480 program was designed to do this. Having gotten rid of the surpluses, we now find that we need to get back some of those reserves.

DR. MELLOR: From the vantage of low-income countries there would be cause for concern about an organization like the "FPEC"--e.g., who would run it, for what reasons, and the political implications of it. It is probably a good idea, but most Asian and African countries are not sure about it and would not know how to approach it. I expect they would treat it with great delicacy.

QUESTION: We are told that if more food were available to the poor, say in India, that this would in some way have an effect on population growth, that it would decrease because not so many sons would be needed to help feed the family. We are also told that population behavior is primarily related to customs. Both may be correct. The customs might change as the quantity of food increases, and this would induce a big transient. But, if you increase the food supply, population would go up and then you would again get a decrease in the food supply. Has anyone estimated the size and length of this transient? It might be very, very serious because 50 percent more food may be required. In ten years the food may not be there, and the situation will be a lot worse.

DR. PAARLBERG: In the developed countries, Western Europe and the U.S., the transition from high birth rates to relatively low rates and a reasonable stabilization of population took 150 years. The developing countries do not have that much time to make this transition, and I am not sure that the historical experience of the western world is applicable to the developing world today. That is why the effort to increase food production must be accompanied by a strong program to limit the population growth rate.

DR. MELLOR: An increase in food supplies and incomes of poor people is a necessary but not a sufficient condition for lower birth rates. I emphasize the necessary aspect of it because it gets glossed over too often.

I would argue for getting on with economic development, but through a process that ensures participation, and then adding a really vigorous program to lower birth rates. Raising incomes and participation of the poor brings down birth rates much more rapidly nowadays than it used to. The reason is due in good part to the kinds of population programs we have been applying in these countries. Birth rates went down faster in Japan than in the U.S. and Western Europe, and faster in Taiwan than in Japan. They have been coming down faster still in South Korea. The birth rate is clearly coming down extraordinarily rapidly in Singapore and in Hong Kong. These countries, except for Japan, were all considered low-income or underdeveloped countries ten or fifteen years ago.

I want to re-emphasize the point that the measures needed to get participation of the poor and bring birth rates down over time must cope in the short and intermediate term with an accelerated rate of growth in demand for food. I suspect that institutionally we have better means to deal with the food supply problem than we have for the population problem, but they have to be considered together.

DR. WILCOX: My concern is how you adapt engineering to the social institutions. The real question is: How can we adapt our food production technology so that we can make use of it in other countries? I am thinking now, for example, of irrigation and water supplies. How can we take an irrigation plan that will work with the institutions of a country when these institutions vary from country to country?

Another example is fertilizers. We have the competence to produce fertilizer and the elements we need are there. It is a matter of institutionally organizing ourselves to produce it and make it available in countries that need it. Again, this requires a country-by-country adaptation of the engineering capability in fertilizers to the institutions of these countries.

Another important topic is weather modification technology. A different range of institutions is involved here, because it is something new. But, it may be a great possibility if we can continue to improve our knowledge. From a report of a Woods Hole research program I learned that wastes of cities along the seacoast were being used for fish development. Greater use of waste recycling is a real possibility even in the poor countries. However, I would re-emphasize that these possibilities must be fitted into the institutional situations that exist there.

MR. NEYLAN: The area we do not understand well and have not looked at enough in thinking of the problems of the developing world is the area of institutions. Mr. Dennison referred to this in speaking of the difficulties of getting a project moving in a developing country. One of our problems in understanding their institutions is that we look at the developing countries with the prejudices of our backgrounds, depending on whether we come out of economics or out of technical engineering or science. Development is not just economic development or just technical development; it has to be a marriage between these two.

DR. MURRAY: I have listened to comments on what is needed to increase food production: plant breeding, machinery, etc. It is my observation that in many parts of the developing world most of the energy and labor for agriculture consists of women and children and that the most significant advance might be a longer hoe handle. Women in Kenya, for example, are working with a hoe handle that is too short. What does it take to get acceptance of small changes such as a longer hoe handle?

DR. MELLOR: In a Kenyan rural development project aided by the World Bank about 40 percent of the households are headed by women. Essentially, all of the farming and food production is done by women. Western extension programs which were introduced, work only with the men. This reflects a very substantial and difficult problem of traditional cultural attitudes of Western people about how to develop agriculture, rather than the problem of traditionalism among people in the developing countries.

We are too prone to think that Indian or Kenyan farmers are backward because they do not accept a new technology. We should recognize that it is not suited to their set of circumstances. They are as interested in increasing their production and income as the American farmer. Cultural hangups that impede rural development often exist also within the Western-educated middle classes in developing countries who have great difficulty understanding how their own farmers think and operate. They have great difficulty, therefore, building suitable institutions to bring technology, information, and physical inputs to their farmers. In the U.S., too, the urban middle class does not understand the problems of our own farmers.

into a country like Bangladesh or Indonesia means investments in an industry that is extremely capital-intensive, the worst kind of industry for countries with limited capital resources and one that creates very little employment and, therefore, very little participation. The international community would have to put in substantial capital, which again raises a complex question about political relationships.

MR. DENNISON: A fertilizer plant in Bangladesh does not have to be huge unless it is built for extensive exports. The Chinese have shown us this. Also, the number of people employed in a fertilizer plant represents a fraction of the total that could be involved. There is the whole distribution system and a whole network could be created if this is combined with a public works program to build access roads, bunding water and irrigation. Such a program would employ many more than, say, the 850 people working at the actual plant site.

MR. PIKARSKY: Senator Humphrey said it takes leadership to translate what we are discussing here into action in the political and legislative process. This seems to be rather lacking here because we do not have people from the White House listening. I do not see the bridge from this type of group to public decision-making and policy.

DR. SEAMANS: Both Academies fully recognize this. We have been testifying about the need for a council on science and technology at the presidential level. The nearest thing to it today is the President's Science Advisor, who is also the head of the National Science Foundation. We invited his right hand man to be with us today. We recognize that at this time we have limited influence over some of these political and policy matters.

QUESTION: Are the international agricultural research centers really multinational in operation? Where can one find information about how they are run and managed?

DR. MELLOR: The Rockefeller Foundation has a publication on this subject. The centers have international staffs and international boards of directors, though people in the low-income countries would probably say that they are run by the U.S., other high-income countries, and the World Bank. In the long run we must have more participation of low-income country nationals in the centers'

I agree that there are many small things that can be done to improve farming, but I am not very optimistic about the small changes in technology that could have been expected to be conceived within the rural society of the developing countries. They have been experimenting for thousands of years, and I do not think they have developed the wrong kind of hoe for themselves--though it may seem so to us.

MR. DENNISON: When I spoke about a new ethic for the profession, I meant that it should be part of a new ethic for our society. How can we in every conceivable way begin to get maximum efficiency, to recycle, and find new uses and new means for our resources, including fertilizer? A good deal of fertilizer is wasted. We know this and agronomists agree.

The great thing about the engineer is that he functions not only as a professional, but also as a manager; he gets feedback and develops action against the feedback. An active engineering process is a constantly correcting process. It is an extremely important process to bring into the world food situation, along with other disciplines, not as a panacea but as a dynamic and controlling factor.

MR. RODDIS: I share the concern over gas being flared off in the Middle East. We have a real need for energy to produce fertilizer, and this waste is a great tragedy for mankind. If we can find a political mechanism to do something about this, we could also do a great deal to relieve the food situation and other problems associated with population. We should do something about this. Cyclical over-production/under-production takes place in almost any competitive industry. It happens in the paper business, the same as it does in fertilizers, and I could name others.

DR. MELLOR: The flared gases are located mostly in Third World countries, in the Middle East, Indonesia, and Bangladesh. I see two problems here from the United States' point of view.

First, do we want to help bring about a massive shift in the world's fertilizer production to countries that are not very much subject to our control, and with which we are likely to have substantial differences of interest in the future? There is some reluctance to do this. Second, putting massive fertilizer production facilities policy-making process.

DR. LEOPOLD: Some people have spoken of the need for systems analysis in approaching the food-population problem. You will be interested to know that there are two computer models of world food and population in existence in our office (and probably a third one in process). Access to them can be arranged through Dr. Wade Blackman in the Science and Technology Policy Office of the National Science Foundation.

MR. BAXTER: The problem of food is probably one of the most important issues facing us. But we have a whole lot of problems and programs in this country, and many people think we are not doing enough about them--e.g., pollution abatement, welfare funding, veterans assistance, and mass transportation. Where does this particular problem fit on the scale of priority problems we must set our minds and hands to? This is one question that COPEP and each one of us here will have to answer.

PARTICIPANTS

Speakers and Discussants

Charles Cargille, M.D., World Population Society
Peter Cott, The Population Institute
Charles S. Dennison, Consultant
Hubert H. Humphrey, U.S. Senate
John Mellor, Cornell University
Eloise Murray, American Home Economics Association
Don Paarlberg, U.S. Department of Agriculture
Warren Wilcox, Congressional Research Service

Guests and Observers

Ali Cambel, National Science Foundation
Sharyn Carlson, The Johns Hopkins University
Nelson Denlinger, Senator Humphrey's Staff
Emanuel Haynes, National Science Foundation
Charles Huckaba, National Science Foundation
Carl Leopold, National Science Foundation
Anthony Neyland, World Bank
Harry Piccariello, National Science Foundation
Russell Stevens, National Research Council

COPEP Members Present

Edward Wenk, Jr., Chairman
Myron Tribus, Vice-Chairman
Vinton W. Bacon
Raymond Bauer
Samuel S. Baxter
William D. Carey
Joseph Fisher
Milton Pikarsky
Nelson W. Polsby
Louis H. Roddis, Jr.
Abe Silverstein
Abel Wolman

NAE Officers

Robert C. Seamans, Jr., President
William E. Shoupp, Vice-President

Staff

Micah H. Naftalin, Executive Director
L.F. (Barry) Barrington, Study Director
Robert F. Manske, Professional Associate
Laurence I. Moss, Executive Secretary
Pushpa N. Schwartz, Professional Associate
Hanna Hunt, Administrative Assistant
Elizabeth Grove, Secretary