TECHNO-ECONOMICS

7 October 1952

551

CONTENTS

Page

INTODUCTION--Colonel P. A. Kleff, USA, Faculty, ICAF..... 1

SPEAKER--Dr. Jesse E. Hobson, Director, Stanford Research Institute, Stanford, California..... 1

GENERAL DISCUSSION..... 20

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552

Dr. Jesse Edward Hobson, Director of the Stanford Research Institute, Stanford, California, was born in Marshall, Indiana, 2 May 1911. He received his B.S. degree in Electrical Engineering from Purdue University in 1932 and his M.S. degree in 1933. He was a Charles A. Coffin Foundation fellow at the California Institute of Technology, 1933-1934, where he received his Ph.D. in Electrical Engineering in 1935. He was assistant professor of mathematics at Earlham College, Richmond, Indiana, 1935-1936; an instructor in electrical engineering at Armour Institute of Technology, 1936-1937; central station engineer with Westinghouse Electric and Manufacturing Company, Pittsburgh, Pennsylvania, 1937-1941; director, Department of Electrical Engineering, Illinois Institute of Technology, Chicago 1941-1944; and director, Armour Research Foundation, Illinois, 1944-1948. He has been director of the Stanford Research Institute since 1948. He has been a lecturer in electrical engineering at Stanford University since 1948. Dr. Hobson is a member of the National Research Council, the Institute of Radio Engineers, and a fellow of the American Institute of Electrical Engineers. He has contributed articles to "Electrical Engineering" and "Electric Light and Power."

TECHNO-ECONOMICS



7 October 1952

COLONEL KLEFF: General Greeley and gentlemen: For the past several weeks some of the members of this class have been wrestling with the subject of "Techno-Economics." This is one of the six major areas of study in our Technological Progress Course. This technique of applied research is comparatively new but the term is even more recent. So far as I know, this terminology originated with the Stanford Research Institute of Stanford, California.

Today we are fortunate in having as our speaker Dr. Jesse E. Hobson, who is the Director of the Stanford Research Institute. Dr. Hobson will speak on this subject, "Techno-Economics." It is a pleasure to welcome to the Industrial College of the Armed Forces and to present to the staff, faculty, and students Dr. Jesse E. Hobson.

DR. HOBSON: Thank you gentlemen: I am very happy to be with this group this morning and to talk about one field of applied research which is of particular interest to us because I think we have done a certain amount of pioneering in this field.

I appreciate the opportunity to discuss with you today a fundamental yet often unrecognized, concept or trend in the industrial research field. A number of important changes are developing in applied research in the United States. Since our professional work involves industrial problems, it is particularly important that we be aware of technological trends and their impact upon research and development activities. For example, we know that the Nation's increasing demand for both fundamental and applied research has produced a serious shortage of scientifically trained manpower. We also recognize that an increasing percentage of the Nation's research effort is in one way or another financed by the Government. The proportion is sometimes placed as high as 65 percent to 70 percent. It is also evident that industrial companies are turning more and more to the research laboratory as a means of insuring their future technological positions. We know that industrial research has become "big business" in this country, and that business executives are finding it necessary more than ever before not only to support research but to support the right research. We read that one company spends 3 percent of its gross sales on research, that another has realized a 1500 percent return on research expenditures over a ten-year period, that all of the products of some companies have come directly from research laboratories during recent years, and that perhaps one-half of our national employment stems directly from the output of research laboratories.

554

Among all such developments and trends in applied research, we recognize that the team concept has for the most part replaced the role of the single investigator. However, there is one applied research trend in the team approach that may have escaped your attention. During recent years, applied economics has become one of the major area of industrial research. The development is a significant one because there has been developed gradually a new applied research field which some have called "techno-economics."

The term "techno-economics" describes a situation in which there is a close association between applied research in the natural sciences or engineering and applied research in economics, marketing, transportation, cost analysis, industrial engineering, and other business, industrial and economic subjects. The essence of techno-economics is teamwork by groups of engineers, economists, and scientists. As in scientific research, the process of techno-economics is fact-finding. The objective is to assemble, analyze, and present facts to aid management on decisions it must make. In assembling and analyzing economic and technical facts in applied economics studies, the same process is followed as in the case of research in science or engineering. In both cases the objective is to assemble facts upon which conclusions may be drawn. Neither case leads to the giving of opinions, consultation, advice, or recommendation. With the facts on a situation clearly stated management is in a position to make its own evaluation and to select a course of action.

The typical application of techno-economics is found when the basic problem is founded in economics, but where the facts involve one or more of the branches of science and engineering. The concept may be stated quite easily but its application has developed slowly. Certainly, techno-economics has appeared partly in response to the recognized need for a closer link between research in the natural sciences and research in the social sciences.

Even a superficial backward glance reveals the accumulating forces in business and economics that have culminated in a new and fundamental approach to many industrial problems.

Ever since the early days of the Industrial Revolution, the scientific method has had a major influence. The spinning wheel, the steam engine, power loom, and steamboat were contributions of the mechanical sciences. Electrical theory gave rise to such inventions as the dynamo, telephone, radio, and television. On the basis of knowledge developed by chemists, whole new industries came into being. Physics led to the release of atomic energy. Engineers and scientists of many kinds acted as intermediaries between research and industry, converting fundamental knowledge into practical operation. The tremendous technological advances, with their resulting gain in output per worker, increased leisure, higher standards of living, and all the rest are well

nown. Industry, of course, was directly involved in these technical dvances--financed many of them, encouraged them, and even directed hem without its economic affairs being subjected to a comparable hange. This was so because there is less available knowledge on how economics" behaves than there is on natural phenomena of the several ciences.

While the Industrial Revolution was gathering ever-increasing force, he study of economics was making far less progress. Classical economics lealt in broad generalities and in the main was based upon personal bservation. In order to develop a semblance of logic, economists were rone to make sweeping assumptions on the behavior of economic matters.

Practically all of the research work in economics during this period as of the academic type dealing mostly with the patterns of consumption roduction, prices, supply, demand, savings, investment, and other economic generalities. The economist had to leave detailed problems n an industry, a product, or a service to men trained in other fields. he problem was that the economist could deal only in generalities. This is at the root of the saying that "an economist is never a practical nan." The world knew the economist from such subjects as "the law of supply and demand," "the law of diminishing returns," "the disequilibrium theory," and "economics of the leisure class." These and other basic principles are major contributions to knowledge, but industry found them of little immediate value in solving its many problems. The best known works of the classical economists such as Adam Smith's "Wealth of Nations" and John Mills' "Principles of Political Economy" had little application to the practical problems of industry.

The first turning point came when economists began to concentrate on specific problems. Impelling social changes, the expansion of markets, increased interdependence of geographical areas, expanding functions of government, violent depressions, and perhaps most important of all, the urgent economic problems of mobilizing resources in wartime, led directly to intensive and specific economic studies. Although this trend is particularly noticeable since the turn of the century, it was not until the First World War that economics proved its practical potential. During this war the Government recognized more than ever before the prime importance of national economic statistics. This trend continued after World War I; it became even more important during the Great Depression, and was accelerated throughout the Second World War. It has now advanced even further as a casual review of current work by economists on the input-output theory will confirm. It may fairly be said that the science of applied economics was brought into play and developed to a great extent in the service of the Government.

Two or three decades ago, economics was still looked upon as being a dry and impractical subject so far as industrial operations were

concerned. A man could become an economist and engage in economics research with little or no training in other disciplines. He had to leave detailed economic problems on technologically based industries, products, processes, services, and other technical questions to men trained in other fields. The economist was simply not competent to deal with such subjects.

A second turning point occurred as industrial operations became more and more complicated from both the technical and economic standpoints. The need for applied economic research on detailed technical matters became apparent. Gradually, economists began to study the behavior of markets, prices, competition, and like factors for specific products for geographical areas for industries and for companies. Industry found that a trained economist could make great contributions to management in its day-to-day decisions. The result was that large companies began to employ "industrial economists," "market research specialists," and "economic consultants." This trend was well along the way in the eastern part of the United States by the late 1930's. The public began to hear of such applied research works as for example "Economics of the Sulphuric Acid Industry."

The economist, however, soon ran into trouble when he dealt with technical problems, products, processes, and industries. Each scientific field and branch of engineering became more and more complicated. The traditional training of the economist was inadequate to cope with the situation. Either one of two things happened in each case! The economist did his best to learn the science involved--or--an experienced scientist or engineer became an economist. Neither course was wholly satisfactory.

Out of this situation have come two solutions in the applied economics field. The first reaches back to the university level. During the past 15 years, there has been a great increase in the number of graduate scientists and engineers taking advanced work in economics and business administration. A man trained basically in chemistry, physics, or electrical engineering will often take graduate work in economics and business and later do applied economics work on technical problems which he is equipped to understand and handle. Such a man might be called a "techno-economist"; he can be found today in company after company. He scarcely speaks the same language as his counterpart of two or three decades ago. His job is to "bridge the gap" between economics and science or engineering. Even investment houses now find it necessary to have a "chemical economist," "a petroleum economist," or an "engineering economist," depending upon their fields of financial interest.

The second solution to the problem is of recent vintage, that is to approach techno-economic problems with organized teams of specialist

n whatever fields may be involved. This means that a chemist, an conomist, or an engineer might combine their skills on a given problem, ach handling that part for which he is best qualified. The technique as employed with successful results during the last war under the name operations research." There are examples of the techno-economics pproach in industry, but they are not widespread. Two or three private esearch organizations in the country have spearheaded the movement.

Now, I would like to give you a few types of techno-economics esearch. In this discussion I will use examples of projects with which e have been identified and on which we have worked. Four main types ave emerged from our studies.

The first is a combination of laboratory and economic or marketing esearch, such as might be undertaken in the development of a new process or utilizing wood wastes. The chemist conducts the process research n the laboratory. (Incidentally, this was a fluidation process which e first applied to redwood sawdust.) At the same time the economist r marketing specialist works simultaneously on costs, production prob- ems, marketing potentials, pricing problems, distribution channels, nd other economic questions. The result may be a new process, meeting ot only technical requirements but also the tests of applied economics.

The second type is economic or marketing research as a forerunner to technical research in the laboratory. This approach might be fol- owed, for example, in developing a new product from petroleum wax. The economist with some help from the petroleum chemist would determine which of several possible products offered the best economic possibili- ties. The chemist could then begin the laboratory work with some as- surance that the results, if successful technically, would be successful financially.

The third type is economic research on a highly technical industry, product, process or service, such as, for example, a marketing study on cost and pricing policies for radioisotopes. Obviously, such an applied research project cannot be undertaken successfully without the combined skills of economists and radiation engineering specialists.

The fourth type is operations research on a complicated industrial problem having many variables. An example might be the evaluation of three or four alternative methods for applying high-speed, electronic, data-handling equipment or computing devices to an inventory control procedure. This type of research often requires many specialists in- cluding economists, electrical engineers, industrial engineers, mathe- maticians, and physicists.

We must recognize, of course, that all applied economics research is not necessarily "techno-economics" research. Many investigations

in applied economics can be and are conducted entirely within the economics field without particular reference to science or engineering. However, we are interested here in technical research problems involving economics or economics research problems involving technical matters. A few examples of techno-economics research will illustrate its value to industry and the Government.

Perhaps, the foremost techno-economics field might be called "chemical economics." This position is natural since the chemical industry is a highly complex one technically, depending directly upon the research laboratory. Its markets are widespread and intermingled. Furthermore, the industry with a national growth rate of about 9 percent per year is one of the fast-growing industrial sectors in our economy.

The organic chemical industry provides a good example of the complexities that can be involved in a techno-economic study. Let us assume that a petroleum company is interested in entering the expanding petro-chemical industry as most of the Nation's oil companies are now doing. Obviously, it must consider the several chemical products that can be produced feasibly from the base raw material.

In general there are two courses open to the company. It can launch an applied research program to develop one or more new petrochemicals using petroleum or one of its derivatives as a base material. The second possibility is to produce a known product using a proven process. For sake of simplicity, we will assume it follows the second course, that is, to select a known product and process. We might assume further that it will consider only those products already having a national production volume of at least 25 million pounds and a production value of at least 5 million dollars per year.

Given these conditions, the main problem confronting the company is an economic one. It should select that product offering the optimum financial return taking into account plant investment, production cost, selling price, potential market, and many other economic factors for both the main product and for possible by-products.

The company will soon find that it cannot confine its investigation to the petroleum base material alone. Some of the chemicals it could produce from petroleum can also be obtained from other base materials such as sugars, natural gas, and even wood. At each stage in the product flow, there are alternative processes and materials. The economic study is soon complicated by many variables and becomes in part a technical investigation and in part an economic analysis. From a practical standpoint, most of the study will be confined to a few derivatives, but the alternative products and subderivatives cannot be ignore

Using petroleum as a base material there are 11 basic chemical derivatives meeting the company's volume criteria. One of these is

hylene which can also be obtained from natural gas. There are, in rn, about nine product possibilities from ethylene, one of which is hyl alcohol which can also be obtained from sugars. There are at ast seven product derivatives from ethyl alcohol, one of which is etaldehyde, also obtainable from coal and natural gas. Carrying the oduct flow further, one finds that four major chemicals can be de- ved from acetaldehyde, one of these being acetic acid. The same oduct can be derived from natural gas, coal, wood, and sugars. Then, find that five product possibilities exist with acetic acid as a se, one of these being acetic anhydride. This product, in turn, can used to produce cellulose acetate and cellulose acetate-butyrate, th of which require wood as an additional raw material. From cel- lose acetate alone come such final products as acetate rayon of the pe made by Celanese, plastics such as Tenite, and Kodapak film.

Even if our petroleum company should consider petro-chemicals only rough the third product stage, it would still have over 80 product ssibilities each having an annual production volume of over 25 million unds and 5 million dollars. The list could be narrowed rather quickly r one reason or another, but the remaining economic study is still a mplicated one. To be completed properly, it must be approached by ople who not only understand the technical situations, but who also ve training and experience on such matters as pricing, market potentials, stribution channels, transportation, competitive trade practices, sting, plant location, and over-all economic, geographic and techno- gical trends within industry.

Let us assume, now, that instead of choosing a known product and roven process, the company decided to develop through applied research new product or process. It is obvious that the problem then becomes ven more complicated; the economic studies and laboratory experiments ust go hand in hand if the company is to have reasonable assurance that ts research will produce the desired results. Such a combined research rogram would be techno-economics in its most distinctive form.

One major need in the chemical economics field is a comprehensive ource of comparative economic data on chemical products, markets, rices, and similar subjects. The need is now being met in large part y the Chemical Economic Handbook published on a continuing basis as a ublic service activity by the Stanford Research Institute. Data sheets n the Handbook cover, among other items, such matters as production, onsumption, prices, exports and imports on hundreds of individual hemical products. Compilation of this Handbook is in itself a good xample of chemical economics.

A second example of techno-economics might be called "nuclear ngineering economics." It is evident that almost any fact-finding nvestigation on economic questions involving atomic energy inevitably

touches upon highly technical matters. The only practical course is to approach such a problem with a techno-economics research team. One well-known case will illustrate this point.

In 1944 the Atomic Energy Commission began producing millions of gallons of radioactive by-product materials in the plutonium productic process. Since there was no known use for these fission products, the had to be stored in huge underground vats. The idea was advanced by a number of scientists that these waste products might be useful to industry as a source of low-cost radiation. Many authorities doubted their industrial value based on various technological and economic reasons. The problem was to assemble and analyze the facts. Are there potential large-scale industrial uses? What is the size of the market? What are the problems involved in using these waste materials How much additional research and development work is required?

The approach to this problem was to form a research team composed of industrial engineers, marketing specialists, chemists, and nuclear engineering experts. Since the possible market was in industry, arrangements were made for the team to work closely with the research laboratories and executive staffs of about 300 large companies in technologically based industries and with the leading nuclear energy research groups in the country.

It soon became evident during the investigation that there are potential large-scale industrial markets for radioactive fission products, but full development of the market will be delayed for a few years while solutions are worked out to many technical and economic problems. In some applications, such as the activation of phosphors, static eliminators and fluorescent light tubes, existing technology is well developed, and at a price of perhaps 100 dollars per curie an ann market in hundreds, and perhaps thousands, of curies exists. In other applications, such as industrial radiography and cold sterilization of drugs and foods, the technology is only partially developed in a market requiring millions of curies per year. For such uses as a portable low-power source and surface sterilization of fruits and vegetables, the basic technical knowledge was found to be available, but five or more years may be required before commercial uses can be developed. In still other applications, such as in radiation chemistr and flame propagation, the use of radioactive fission products is in the speculative stage.

The over-all conclusion, then, of this techno-economic study is that a sizable industrial market exists for the waste fission products assuming they can be sold within certain price ranges.

A third major area in which the techno-economics approach is often used is "transportation economics." It is obvious that economic considerations must enter into research, design, and development work on

transportation equipment. For example, operating cost per mile or per unit of payload is always one of the important parameters in the design and development of a new military or commercial airplane. The same is true for motor carriers and railroad locomotives. In fact, it is usually one of the economic parameters that in the final analysis limits one or more of the design features while the equipment is in the research and development stage. The problem is to obtain the optimum relationship between performance parameters and economics of operation.

One of the early considerations in any design problem is to construct operating cost curves for both fixed and variable costs in order to determine the point where the characteristic "U shaped" total cost curve in transportation economics begins to rise as additional units of transport service are added. This approach to design work is well-known and we hear often of the "marginal cost curve" and the "point of diminishing unit costs" in the transportation economics field.

The techno-economics approach in transportation economics may be illustrated with a current example from the petroleum industry. About three years ago, the Canadian Government and several oil companies in the United States and Canada decided to explore the feasibility of a crude oil pipeline from Edmonton, Alberta, to Vancouver, British Columbia. Aside from political, financial, and technical problems, a number of economic questions arose on this engineering venture. Was there ample crude oil in the Alberta Basin reserves to support this project after local Canadian demands had been met? At what price could crude oil be laid down at Vancouver? Was the demand for petroleum products in the Pacific Northwest sufficient to warrant construction of the pipeline? Could this demand be met more efficiently by imports of California crude oil or petroleum products to the area?

The answers to these questions were found only after analyzing such matters as crude oil reserves, recoverability in the fields, crude producibility, estimated production, pricing structures in Canada and the United States, California reserves and production versus demand, pipeline operating costs, and competitive prices at which crude oil could be laid down at Vancouver.

The first task was for a geologist to study the reserve and production situations in the Alberta Basin. He determined finally that perhaps 140,000 barrels of crude oil per day would be available in 1953 for movement through the pipeline. An economist found on the basis of field investigations that crude oil demand in the Pacific Northwest stood at over 250,000 barrels per day and that it might soon rise to 350,000 barrels. He also estimated that 90 percent of this market was in the coastal area. Another economist determined that at a Vancouver price of around $2.80 per barrel, Alberta crude oil would have a price advantage over crude oil moved in from California or other

fields. The techno-economic team also found that California crude oil demand might soon exceed supply from California fields thereby placing some restrictions on exports from the area.

These and other facts were laid before those faced with the final decision. The technical problems were enormous, but a plan was soon completed. You are probably aware that the pipeline is now being constructed and that it is one of the biggest engineering tasks ever undertaken in Canada.

Another major area in which the techno-economic approach is most useful is "engineering economics." The objective here is to "bridge the gap" between one or more of the branches of engineering on the one hand and economics, marketing, production, and similar subjects on the other. Perhaps, a unique combination in engineering economics is the one between electrical engineering or electronics and economics. This combination is mentioned especially because the electronics industry is expanding rapidly and it is a highly complex technical field.

We are in a position where far less is known about economics, production, marketing, pricing, and similar problems in the electronic industry than is the case for many other branches of engineering. New product possibilities and new applications of modified products are emerging almost daily from the Nation's research laboratories. New companies and even new industries are rapidly being formed in the electronics field. Consequently, there is a demand for economic facts on highly technical products and problems.

One recent techno-economic study in the electronics field will illustrate the engineering economics approach. A company in the electronics industry developed a new pressure measuring system consisting of an electronic pressure cell and amplifier. The problem arose as to whether or not the product had an industrial potential, and, if so, how large was the market. A team of electronic and marketing specialists undertook the product evaluation. They found after laboratory analysis and some economic study that the equipment was too specialized to have widespread industrial applications. The device was not suitable for industrial uses where extreme ruggedness, long life, and long stability without recalibration are essential requirements. The pressure cell would not stand severe temperatures. It was not suitable for measuring static pressures. In general the electrical engineers found that the device had excellent possibilities in research applications but only limited application for industrial use. The economists found that the current price was not competitive with other general-purpose equipment; that even at a lower price the market was restricted; and that from two to five years of research and development work would be required before any return could be obtained in the industrial market. These facts and conclusions obviously had an important bearing upon the company's plans.

Another example of engineering economics may be found in a new and ·owing field--the application of high-speed electronic equipment to ıta-handling problems for business and industry. In one case an ısurance company was interested in the possibility of applying elec- ·onic equipments to the handling of vast amounts of its policy informa- ion, insurance reports, and other routine clerical data. Engineering ɔecialists soon found that the necessary electronic devices had al- ɜady been developed and that the technical task was to combine these ɔmponents into a logical design for the problem at hand. But, first, ı industrial engineer undertook to determine the details of the data- andling problem, the nature of the input units, the flow of data, the equirement for data storage, and the output units needed. This work ent hand-in-hand with the design studies. When the data flow analysis as finally completed, the design team continued the technical work to logical conclusion.

The engineering economics approach is, of course, used frequently n essentially military matters. However, the techniques are identical o those used in purely commercial applications except for the final rofit motive. Recently, a techno-economics study was made on a new eaction turbine power unit designed as an auxiliary power plant for uided missiles. From a technical standpoint, the unit was found to eet all performance requirements. The economic analysis revealed hat the new unit would be competitive in production and maintenance ost and that a substantial unfilled market existed over a period of everal years.

We must not assume from these examples that engineering economics s confined to the electronics and military fields. The research ap- roach by teams of engineers and economists applies to any problem here technical, economic, and marketing facts must be assembled and nalyzed for a new piece of equipment or complex engineering device.

One of the more important examples of techno-economic research is 'research economics and planning." Developing a sound research program .s one of the more perplexing problems facing the management of an in- lustrial organization. Most industrial research programs involve several scientific fields. Management must be reasonably certain that ın adequate technical research program is established if it is to safeguard the future of the enterprise. Such a program must be con- ɜeived properly not only from a technical standpoint but it must also stand the tests of economics. At the same time, it must be geared to such factors as the industry's technological trends, the company's ɜechnical and competitive positions, research capacities available, ɔompany objectives and policies, and the organization's financial situation. Most importantly, potential results of research must offer an adequate estimated rate of return over cost. The facts upon which alternative research programs can be evaluated fall both in the technical

and economic fields. In establishing any industrial research progra the field should be selected first then followed by specific project

The concept of economics research as a forerunner to technical research has for many years been recognized by industry. However, there is a definite increase in the emphasis on economic phases of industrial research. This is evidence that the economic side of the problem is the controlling factor. If a new product, process, or development will not meet an economic need--if it will not earn mone for the investor--(will not ring up in the cash register) then, mone should not be spent on it regardless of technical feasibility.

One recent example in research planning will illustrate a techno economic approach to the problem. A large eastern company in the agricultural products field established a sizable research laborator during World War II to undertake work on development of various mech ical and electronic devices. For many reasons the research program has since been continued on a rather large scale. However, the area of research are quite removed from the company's main pursuit in the agricultural field and, furthermore, the work is entirely of a milit nature. The management's aim is to establish a commercial research program. It wishes to become a pioneering group in the forefront of one or more relatively new fields of technology. The problem was to select several fields and to evaluate their possibilities in both technical and economic terms.

The first step was to determine the company's assets. It has national prestige and management strength; it has several years of research experience outside its own field; an excellent facility together with technical management know-how is available; it has close ties with a number of private and public research organizations; and the company is familiar with military research and development progra and hence is in a position to recognize commercial applications of these efforts.

The second step was to establish some of the limiting factors fro the company's viewpoint. It did not wish to make a sizable long-term investment; it hoped to make use of the existing staff and management know-how; it did not desire to compete with large companies having strong engineering staffs and competitive positions. Its prime attention was directed to fields holding promise of many technological improvements.

The third step called for a group of specialists representing 25 or 30 technical fields to review the company's assets and objectives and make tentative suggestions for promising research programs. These were then studied by economists from the standpoint of technological trends, investment requirements, market potentials, distribution problems, competitive situations, and like factors. In this case,

about 50 product possibilities in eight technical fields were examined. In the final analysis, two fields offered the best possibilities for immediate returns. From a long-range viewpoint, three other fields held greater promises. With each possible field evaluated on both technical and economic grounds, the company has some assurance that its research program, if carried out successfully in the laboratory, will be successful financially.

We are often inclined to think of the techno-economics approach as being of use primarily on industrial problems. However, the same approach is used in agriculture. The combination here is between economics and marketing on the one hand and food technology or chemistry on the other. Although agriculture is the Nation's largest source of income, the food industry does not in general engage in applied research on the same scale as do the Nation's technologically based industries. (That is true whether we are speaking of scientific or technical work in a laboratory or whether we are talking about economics research.) Nevertheless, a current example shows the application of techno-economics research in the agricultural field.

One of the by-products of sugar cane production is bagasse which consists of the fibrous materials left after extraction of the sugars. Many possibilities have been explored during recent years to develop profitable uses for this material. One use on which considerable technical research has been applied is the production of newsprint. The process has been carried to the point where on an experimental basis entire issues of a large Chicago paper have been printed on bagasse paper. The process is still not completely successful, but research is continuing. Some authorities seem to feel that even if the process is perfected technically, it will not be successful economically. In the meantime a number of sugar cane producers have combined efforts to launch a techno-economic investigation on other possible uses. In this approach the economic and technical problems on each possible application will be explored simultaneously. This program has just been started, but, if successful, it will bring about a new economic situation in sugar cane areas of the world.

We are making a study of the newsprint situation in the western part of the United States, a study which is jointly supported by the consumers, the newspapers of the West, and by the suppliers, the pulp manufacturers. The shortage of newsprint remains one of the big problems of this country and, as a matter of fact, of the world.

One of the major industrial problems in the United States today is product diversification. Companies that depend upon a limited product line or market often find it necessary to diversify in order to achieve stability and continued growth. Companies producing multiple products must constantly be on the search for still other products and product application ideas.

Diversification may take several forms, depending upon company objectives and circumstances. One possibility is to direct applied research efforts to other more promising technical fields or product uses. Another is to acquire new products which have already passed through the research and development stage. Still another approach is to purchase existing production or marketing organizations. A further possibility is to develop new application for existing products.

Proper evaluation and solution of diversification problems must be based upon sound technical and economic analyses. Two examples will illustrate the point. A large petroleum company was interested in expanding its product applications for petroleum wax. The problem was turned over to a group of petroleum chemists and two marketing specialists. Over 50 ideas were investigated, many of which involved development of new types of petroleum waxes. Technical difficulties on each product were explored and market estimates were prepared for each promising application. In the final analysis, the facts indicated that 10 new product uses could be developed with some additional research and that the new market would absorb several million pounds of wax per year.

In a second recent example of product diversification, a large midwestern company in the mechanical equipment field was interested in diversifying its operation into the electronics field. After some investigation by a techno-economics group of engineers and economists, it appeared that a good possibility existed in production of precision components for electronic computers. The problems involved in beginning a new production program were numerous, and the solution was to purchase a small company already in the field with a line of new product on which some additional research effort was found to be necessary.

One of the basic objectives of applied industrial research is to develop new and improved products and processes from available natural resources, including by-product and waste materials. This type of research is becoming increasingly important not only to industry but to the Nation as a whole. Our demand for industrial resources of all types is exceeding the supply of usable resources by a greater amount each year. The recent report "Resources for Freedom," issued by the President's Materials Policy Commission, emphasizes this problem. We are faced with the necessity of utilizing known resources more effectively and of creating profitable uses for latent raw materials. Since applied research efforts in this direction involve both technical and economic considerations, we may list "resource economics" as an example of techno-economics.

A recent case illustrates the techno-economics approach in resource development. There are in the state of Nevada sizable reserves of a marginal zinc ore. It appeared that if a new process could be developed these marginal ores might be brought into profitable production.

ne problem broke down into several parts. Were reserves adequate to upport a large production program? How much transportation cost was nvolved? Could a usable process be developed? What production cost ould apply to each of several plant loads? At what price could the inc be sold? What marketing arrangements were necessary? Could a ew producer enter the market at the prevailing zinc price? And, inally, was the venture economically and technically feasible?

The problem of developing answers to these and similar questions as given to a team of chemists, metallurgists, economists, and arketing experts. Laboratory experiments and the economic studies ere carried out simultaneously, and the results, favorable in this ase, were combined into one techno-economic analysis for the company.

One of the fundamental prerequisites in resource economics is availbility of factual information on the resources of a given area. If the esources of a region are to be utilized fully and effectively, we must now, for example, what resources are available, what characteristics hey may have, where they are located, and to what extent they are now tilized. This information should cover not only natural resources, ut also industrial, capital, human, and other resources in a region. hat is needed, in effect, is a technological audit on all available esources.

There is perhaps no question but that the major concern of top xecutives in American companies is to plan and safeguard the longange future of their companies. This most certainly is their first esponsibility. The problem is to plan now for a company's future 0 to 20 years hence. But, how does one go about such a process? he problem must be divided into its parts such as raw materials, supply, echnological trends in the industry, movements in the market, size f operation desired, applied research programs, new product possiilities, executive development, and the import of any rising competition. f top management is to appraise these and other areas correctly, it ust have an orderly assemble of available facts. In most industries, this means that technological factors must be weighed in economic terms o that some guide lines of policy can be developed.

It is becoming increasingly clear that one major mistake in planning for a company's future will in time have serious repercussions on its financial and competitive positions. Aiding management in long-range planning through the assembly and analysis of facts by teams of engineers, scientists, and economists offers one of the most useful and facinating applications of the techno-economics approach. We fully expect that in the future techno-economics will provide a greater and greater service to industry on this vital problem.

Much has been said during the past five years or so about operations research and particularly its application to industrial problems. The

term has many definitions--one of the lighter versions being "quantitative common sense." Wartime development of operations research technique started with studies by British scientific teams on radar operating problems. The result, according to one British source, is that the research more than doubled the probability of interruption of enemy aircraft. Certainly, the "payoff" was out of all proportion to the amount of research effort. A simple definition of the techniques as it stands today might be "the application of quantitative analysis to operating problems of all types."

But, how does an operations research team function? There is much mystery about the approach in industrial circles and there is no real reason for this situation. An operations research team is much the same as a techno-economics team in that men in various sciences and discipline combine their skill to solve a specific operational problem. One of the principal tools of an operations research team is mathematical theory, especially probability theory and variational analysis. The over-all objective is to reduce a complex operational problem to manageable terms and to give management--whether military or industrial--the facts it needs in making decisions on important matters. In this sense, operations research is an example of techno-economic research except that it ordinarily goes further into mathematical analysis on complex problems.

One well-known case of operations research in industry will illustrate its possible applications. A company was faced with the problem of producing goods for a seasonal market. The problem was to determine the year-round production load which would meet this demand at the lowest total cost. The several variables in the problem were reduced to mathematical form and a simple mathematical model was designed. The lowest-cost schedule was then computed by using a mathematical tool known as the calculus of variations.

This operations research work required only a cost specialist and a mathematician. In another case the problem was to evaluate on a comparative basis each of four guided missiles. Solution of the problem required not only mathematical work on probability analysis but also evaluation by technical specialists on such problems as guidance, propulsion, and design.

Perhaps, a concluding comment on operations research might be that it is interchangeable on the industrial scene, at least in large part, with the concept of techno-economics in industrial research. Similarly, the term "techno-economics" could be used to describe much of the analysis work on military problems where the name "operations research" is most often used. The difference is largely the extent to which mathematical techniques are used.

Our discussion of techno-economics to this point has dealt ex-
usively with industrial research problems as they exist in the United
ates. Although many applications of this research approach are
culiar to the domestic situation, it is by no means confined to any
ographical area. Techno-economics does, in fact, have many useful
plications in the international field.

The postwar growth in international responsibilities and interests
the United States has given rise to a great increase in the need for
chnical assistance by American research specialists. Our country is
w cooperating with several European countries in a drive to increase
oductivity in the industries of western Europe. Our own studies in
rope indicate that over-all productivity in western European indus-
ies is only around one-third that in the United States. Even in
gland, industrial productivity is only about one-half that of our
untry. There is no question but that this is one of the fundamental
oblems confronting western Europe.

The United States is also committed to a technical assistance pro-
ram for less-developed areas of the world through the Point IV program
d various specialized agencies of the United Nations. We are vitally
terested in foreign technical assistance through the activities of
ch organizations as the International Bank for Reconstruction and
velopment and the Export-Import Bank. Our objectives in less-developed
reas are to work in cooperation with other economic groups to, first,
nprove health, sanitation, education, and agricultural conditions and,
econd, to develop the industrial resources of each nation. To achieve
hese objectives we must send both economic and technical experts abroad
o work with foreign experts. Only in this way can we successfully
eport American technical "know-how" to other nations. In all of our
oreign technical assistance, one objective must be to develop situations
hich will attract private capital where it is needed for industrial
evelopment.

Whether the objective is to increase productivity, to improve
iving conditions in less-developed areas, or to develop industrial
esources in foreign areas, the techno-economic approach is fundamental.
ost technical assistance problems in the international field are, first,
f all economic problems and, second, technical problems. Each technical
ssistance project should be undertaken only after a thorough analysis
f the economic situation.

A few examples of techno-economics in the international field may
e helpful. It became evident about two years ago that the mechanical-
ndustry sector of the Italian economy was in a seriously depressed
ondition and that something must be done about the problem. Some saw
he problem as one in production engineering; others thought it was
olely one of raw material shortages. The fundamental problems actually

involved such matters as taxation, capital formation, government financial controls, industrial relations, social security schemes, and other economic subjects. The approach selected was to send a team of engineers, economists, marketing specialists, and labor consultants to analyze the entire problem and outline a program of action. If solutions to the engineering problems are to be effective, a number of actions must be taken first in the economics field.

Another example of the techno-economic approach in international research involves the babassu nut industry of Brazil. Both the kernel and shells of babassu nuts have commercial value. However, they are still harvested by primitive methods in the Brazilian jungles. Last year, a group of chemists, mechanical engineers, and transportation economists went to Brazil under the Technical Assistance Program to study and report on ways and means to mechanize the babassu industry. The basic facts are now available upon which specific development programs can be developed.

One of the more useful goals of techno-economics research in the international field is to conduct technological audits of a region's resources including not only raw materials but scientific, industrial and human resources upon which development programs can be based. These technological audits provide the facts upon which specific research investigations can be launched to develop new products, processes, and industries from latent resources. It was such a technological audit on the southern part of Mexico that resulted in a major new industry based upon the local henequen fiber.

Most of our discussion today has been on specific examples of techno-economics research for industry. The applied science of techno-economics is, however, a useful tool in approaching broad national problems. The recent report of the President's Materials Policy Commission is the result of a techno-economic study of a fundamental national problem. Our own study of the Italian mechanical industries is another example. Still another case is a recent study on national policy in producing and marketing radioisotopes in the industrial market.

There is one broad question in the industrial research field to which some techno-economic research should be applied. In the national interest we need to know how much money should be spent by industry on applied research. How much money should be spent by individual companies in technologically based industries? These questions cannot be answered effectively without a correlated body of experience data on research expenditures by American companies of various sizes and technological positions. The parameters of the problem must be defined, all facts assembled, and some guide lines to policy developed on the basis of these facts. Here is one place where the role of techno-economics is to study industrial research itself. There are many other national

oblems to which techno-economics should be applied. The important .rt here is that the technique can be used on both concrete situations d on broad national and international problems.

The emphasis in all of our discussion and examples about techno-onomics has been on "fact finding" as applied to the research problems industry and the Government. One might easily say that "facts" in e economic field are not always matters of "black and white" and, rthermore, that all of the facts cannot be assembled on some situations thout excessive cost. Unquestionably, these observations are true. wever, this does not mean that the search for facts should be lessened. Greek incription from Aristotle on the National Academy of Science ilding here in Washington, D. C., emphasizes the point, as follows:

> "The search for truth is difficult. One cannot master it wholly - nor miss it completely. But, from all the facts assembled there emerges knowledge."

Thank you very much.

We will be glad to try to answer any questions, or to participate any discussion, or to consider comments you would like to make. I uld like to do two things: First, I would like to introduce to you e of my associates who is Director of Research in Applied Economics search at Stanford Research Institute, Dr. Weldon B. Gibson, who here to give me back-up protection, and who has had direct and in-imate contact with all the studies we have made in applied economic search.

Secondly, I would like to very briefly tell you about Stanford search Institute. It is a public service, nonprofit research organi-ation which was established six years ago. We have been operating a ittle over five years, with headquarters at Palo Alto, California. t has grown quite rapidly, indicating that the western part of the ited States is evidently interested in industrial research.

We have a staff now of about 525 people. We are doing contract search for industry and the Government amounting to about 5 million llars a year at the present time. Approximately half of our contract search is under contract with industry and half is under government ntract for various agencies, particularly the Department of Defense. f our work for industry, 70 percent is for western industry in the l Western States and about half of that, or a little more than half, s for companies in Los Angeles areas, although we are located near an Francisco. Our work for the government agencies is spread over e Departments of War, Navy, and the Air Force. The largest volume f contracts at the moment is with the Air Force.

We have offices in Utah; we have laboratories and offices in Los Angeles and in Portland, Oregon. We have mobile laboratories now in Utah, Nevada, and Texas. We have had a mobile laboratory in Minnesota. We have an office in Rome, Italy, to continue our work there after the study I mentioned that we made of the heavy mechanical industries of Italy.

Dr. Gibson's group has about 100 people, all doing economic research. To us this is one of the more important areas of research. It is a nice field of research. It doesn't need a lot of expensive equipment and large laboratories. You can give a man a desk, pencil and some paper and he goes to work. The people in Dr. Gibson's department are people who had good business administration training, for example, at the Harvard School of Business Administration or at the Stanford School of Business Administration, and have subsequently had several years of industrial work.

We have people from the steel industry and people from various other large industrial areas who came to our staff. These people have in their background engineering or scientific training, as well as economics.

Now may I have your questions?

QUESTION: How receptive are foreign governments to the results of some of these studies that are furnished to them gratis by our Government? And what use do they make of them? Do they always use the results of the studies as they are recommended?

DR. HOBSON: That is a very good and a very pertinent question.

As to the first part, I can only answer that from my own experience. I participated in a study made in Germany last summer on applied research I would say generally that we were tolerated but somewhat looked down upon. It was in a sense carrying coals to Newcastle to go to Germany and tell them how to organize research; there were, however, a few things they needed to learn about applied research. I don't think anything has been done as a result of our recommendations but recommendations were given.

On the other hand the situation in Italy was quite different. This was partly due to the temperament of the Italian people and partly due to the attitude of the Italian Government. We have had two missions to Italy. One was on the mechanical industry survey. We had 13 or 14 people there for nine months. A very substantial report was submitted but it was not implemented, from our viewpoint, as effectively as it might have been. The Italians have done all they could do and are taking definite steps.

We had another mission, which I headed, to study applied research n Italy. We found the situation in Italy entirely different from hat in Germany. They were receptive to suggestions. They have xceptionally good laboratories and very good programs of research, nd they were quite willing to work with us and to accept our ideas, ecommendations, and suggestions on almost any reasonable basis.

I would say that, in Italy, the government and others received the echnical assistance programs with the best possible attitude.

QUESTION: I want to address myself to you as a plain old economist ere. This techno-economics is dealing with marketing and the methods f using these new technologic products. You are inventing electronic evices that can be used, let us say, in a big financial institution, s you mentioned. You immediately throw out several hundred people. he traditional economist who addresses himself to the problem asks: here do they go, the people who are displaced by new inventions? ow do you employ them? You shift them over to other industries. echnological progress does not create unemployment in the long run, ut it does over the short run. To what extent does the techno-economist ddress himself to that type of problem when he makes recommendations?

DR. HOBSON: Well, I would say in general the techno-economist robably is not immediately concerned with that aspect of the problem. hat is at least true for an institution such as ours. We are given specific project or problem to investigate or to solve if possible nd boundaries are set up around that problem. We try to solve that roblem. In general, as you suggested there has really never been echnological unemployment. We keep finding employment through new echnology for people who are displaced. Probably in the long run here is not a major problem to be considered, but the immediate problem f dislocation would not ordinarily be an aspect of our investigation. e are given a problem to investigate. We ask: How can it be done? hat savings can be made? How can the equipment be used? How is it esigned and operated?

DR. HOBSON: I might say further in that connection that all of ur projects are taken on a confidential basis with the sponsors. ometimes the sponsor will publish the work or ask us to publish it. ther times it is considered very confidential and we can't mention he name of the sponsor or the subject on which we are working. We on't take competitive work. The study I mentioned is going to be ublished widely. We made another this spring on the economic aspects f grade crossings; that has been published.

QUESTION: Will you go over again the differences between some of hese processes that have been discussed? I refer specifically to the echno-economics, engineering economics, price research, and perhaps

that situation where members of the sales department tell members of the production department what to work on.

DR. HOBSON: There really isn't anything mysterious about techno-economics. Maybe we make too much of the name. There are generally two aspects to it. First of all, it is a team effort. You know the strength of the applied research structure of the United States is the team approach to a research problem. This, then, is carrying that team approach a little bit further, by including economists on the team. In laboratories like Westinghouse, General Electric, or Bell Laboratories, you have scientists or engineers working on problems. Now we try to include economists working with them. Instead of putting a technical problem into a laboratory and turning an economic problem over to an economist we are trying to get the two together.

There are two things that characterize what we have talked about this morning as techno-economics. One is the team approach, including scientists, engineers, and economists. The second is the fact-finding approach--getting the economic facts which bear upon the problem: the cost information, market information, distribution channels, export market possibilities. We gather all those facts and bring them together, just as we bring facts in a chemical laboratory together. Without attempting to give opinions on those facts, we find the whole fact structure so that management can make intelligent decisions.

Operations research is just one form of techno-economics research. Operations research is usually concerned with some major problem having technical aspects and a problem in logistics let us say--a technological problem having many parameters. Again it is an attempt to get the facts by getting the team of people who have all the skill and abilities needed. By applying mathematical and fact-finding procedures, operations research brings out the pertinent information. Dr. Gibson, do you have any further comments?

DR. GIBSON: I have the last part of the question--the concept of the sales department telling the production people what to do and vice versa, where the production people tell the sales people what they ought to sell. It is that sort of philosophy that brings this approach about. In many instances facts are not available but people think they know facts; they base their thinking on whatever experience they may have had. The techno-economics approach is assigning a group of people representing all areas, putting them together to get the facts in a situation so that management can make a decision.

We run into situations time after time when large companies ask us to undertake technical-economic investigations where they have a very substantial staff, handling sales research, and an economics research staff.

QUESTION: In the typical sort of problems you have been discussing, doctor, I am sure you will agree some of the parameters are of a fluid nature, particularly in any kind of analysis such as that. Do your results include some sort of equation in which an analysis can be made of the conclusions?

DR. GIBSON: There are projects which have as their objective giving of a specific answer to a specific question. These are not concerned with techniques. There are other projects in which the techniques of doing the job are of prime importance. In that case the major part of the research effort is given to the technique or how it can be done. The need for newsprint is a good example of that. Here is a national problem in which there had never been collected all of the statistics necessary to understand the demand and market for newsprint. One of the major objectives was to develop a technique for estimating the demand now, as well as in the future, for newsprint. I think when this report is published on technique development, it will be a contribution in applied economics.

There are two types of problems. Have I answered your question?

DR. HOBSON: I would like to make this further observation. Economics has been considered a social science. This is one little attempt to put some techniques at work in social science that we have found very successful in this country in the physical and biological sciences. We are thinking of carrying this approach one step further. After five years in working in applied economics research, we see that it is needed. We see this venture as successful, so we feel now that we would like to venture into other fields of social science research, applied research. We want to approach such problems as applied psychology, public relations, and sociology, taking again the fundamental basic scientific work in the field, interpreting it and applying it to the problems of industry. I think there are tremendous opportunities.

QUESTION: I am not sure I got an answer. I will try it again, from another angle. Let us take the example you use of electronic computing devices adapted to industry. I think Dr. Gibson would agree that analyzing capital investment is the same thing. The devices may not have a sufficient market now but may under certain other circumstances have one in the near future. In a case like that, do you come up with certain criteria by which the continued validity of your solution is proved?

DR. GIBSON: In this particular case it just happens that there were two sets of criteria as to the future applicability of this device. One of them was having to do with technical matters. For instance: What are the technical characteristics of the product that will be successful in certain industrial fields? Those were spelled out. On the economic side of the picture there were about six important criteria.

This product didn't fit any of them and the results of the work indicated those things that would have to be done along with the technical work--or let us say, conditions under which this product would have to be marketed. In this particular case it was developed in the research laboratory that the product had some application and perhaps 100 might be ample to fill the needs of the country in the next couple of years. What we are concerned with is mass production.

QUESTION: In this service you perform for industry, suppose industry takes your answer and it fails. Are you liable in any way?

DR. HOBSON: No, we are not. Our approach to all these problems is just the same as would be the approach of the research department of the company we are working for. As a matter of fact, we try to become part of the company and attempt in every possible way to approach the problem as would its own research department. We are given a specific problem. We lay out a program of attack and agree on that program with the sponsor. Then we proceed.

QUESTION: Is it necessary to have people in the company with you while the program is going on?

DR. HOBSON: We have frequent contacts. Sometimes people in the company work with us. We have close contact with them. We certainly do not guarantee results--you can't in any field of research. Neither do we guarantee that we are right. We try to get the facts but usually we do not interpret that data or information. That is left to the management of the company to interpret. We get all the facts and say, "Here it is. What you do with it is your problem."

QUESTION: Dr. Hobson, I am puzzled on one thing. You say you get the facts. We have numerous economists speaking on the platform here and they themselves don't agree on economic facts. You say you get economic facts and tie them up with the facts of true science, so that the scientists will agree?

DR. HOBSON: Not always; but the facts are there.

QUESTION: In scientific fields, two scientists think they have discovered a fact and you can put your hand on it. But economists don't agree. How do you tie in true science with social science?

DR. HOBSON: The information with which we work can be boiled down to facts. For example, in one problem we had with Southern Pacific, its representatives were concerned with rate structures for passenger service. We studied the population trends on the peninsula--how many people were using automobiles and what was the cost to use automobiles; how many people were using busses and what was the cost to use busses.

e did some work on the economic development of the area, based on conomic facts of past development. The Southern Pacific Railroad, y putting all these things together, could decide what the rate structure hould be and make application to the appropriate agency.

DR. GIBSON: This matter of there being a great controversy about acts in the economics field, I think most of us will agree, applies ore specifically to the general areas of economic questions and subjects. ut we are dealing here on very minute questions which we call economics -a very broad name. They are marketing questions, pricing questions, uestions having to do with a specific product or price for a specific ndustry. We admit there is some question about the exact validity of he fact, because of the fact that you have to depend on statistics in any cases, in which errors can occur. But the more you work on specific problems in those areas, the less chance there is of getting nto areas that may be controversial.

I would like to emphasize what Dr. Hobson mentioned. We have ound that the most controversial areas we can work in are those areas hich have had to do almost entirely with the natural sciences. For xample, in our studies we conducted for the Air Force in connection ith requirements over the next several years for technical facilities n a research and development program, we found that people all over he country have various ideas about what is necessary to test a new evice, engine, or airplane. In this atomic energy study, some of he leading experts in the country in the field say there is no use or the product. Others say there is a great future for this product.

DR. HOBSON: I would like to just mention that in one of our inestigations, the public newspapers have solved the problem four times o my knowledge, with four different solutions. You are absolutely ight in the point you are making. You can't avoid getting into conroversy on fringe areas either in economic research or scientific reearch. You can have difficulties in chemistry, physics, engineering, nd economics.

QUESTION: Dr. Gibson, I was curious to know how you handle these 00 researchers that are in the applied research organization. What evels do you have them under?

DR. GIBSON: The main organization is by professional fields. ctually, in this particular case, the whole group works as one organiational unit, but professional men will be employed as chemical econoists, as cost analysts, as mechanical engineers, as electrical engieers, as aeronautical engineers, as nuclear engineering economists, ransportation economists, research psychologist, according to the rofessional field. Our three big areas are industrial engineering, arketing analysis work, and economics, which may be chemical, mechanical,

transportation economics, and so forth. There are all the other professional fields of aeronautics, electrical engineering. We don't try to organize them in units around operations research, chemistry, transportation, and so on.

DR. HOBSON: One idea is that research of this type can be too rigidly organized. We try to keep our organization flexible and fluid. We organize both vertically and horizontally, with considerable crossing of lines, of people going back and forth.

COLONEL KLEFF: I am sorry we don't have time to take any more questions. I promise you, however, that both Dr. Hobson and Dr. Gibson will be present at the seminar in Room 254 this afternoon and this discussion will be continued then. If you are not tied up in other seminar you are invited to attend this one.

Dr. Hobson and Dr. Gibson, on behalf of all of us, I thank you for a very interesting lecture and discussion period.

(8 Dec 1952--750)S/ibc