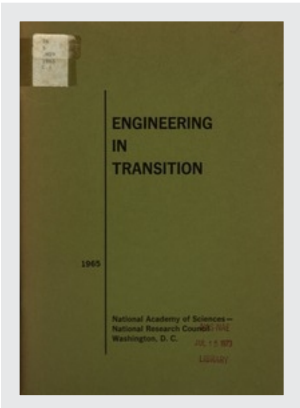

Engineering in Transition

DETAILS

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ENGINEERING
IN
TRANSITION

Annual Meeting of the
Division of Engineering and Industrial Research
National Academy of Sciences — National Research Council
held in Washington, D. C.
15 March 1965

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FOREWORD

The Division of Engineering and Industrial Research held its annual meeting on 15 March 1965 in Washington, D. C. "Engineering in Transition" was the general theme, and the Division chairman, Dr. Richard C. Jordan, presided. The afternoon session included presentations of papers on the transitions occurring in three significant areas: education, research and development, and manufacturing processes. A general discussion in which the speakers answered questions from the floor followed the presentations. The evening session climaxed the theme of the meeting with remarks by Dr. Frederick Seitz and Dr. Augustus B. Kinzel, presidents of the National Academy of Sciences and the National Academy of Engineering, respectively. Their thoughts on the extension of the partnership between science and engineering that is anticipated with the recent creation of the National Academy of Engineering were appreciated by the Division members and professional staff.

The Division wishes also to express its grateful appreciation to the invited contributors to the afternoon session of this meeting:

Frederick C. Lindvall, Chairman of the Division of Engineering and Applied Science, California Institute of Technology, spoke on "Engineering Education in Transition." Dr. Lindvall received his academic education at the University of California, the University of Illinois, and the California Institute of Technology. His doctorate is in electrical engineering, and, prior to taking up academic duties, he obtained industrial experience in the electric-railway industry and with the General Electric Company. His professional activities on campus have been devoted to engineering education and to broadening his earlier interests to include mechanical and aeronautical engineering. Dr. Lindvall is a past president of the American Society for Engineering Education and is currently a member of the Board of Directors of the Commission on Engineering Education.

C. Guy Suits, Vice President and Director of Research, the General Electric Company, spoke on "The Changing Approach to Engineering Research and Development." The University of Wisconsin and the Techniche Hochschule of Zurich are the institutions of Dr. Suits' professional academic education. He has described himself as a "research physicist", and his earlier employment with both the U. S. Forest Service and the General Electric Company involved activities in that area. Dr. Suits was recognized as an outstanding scientist by his election to the National Academy of

Sciences. He was recently recognized for his outstanding accomplishments in engineering by being named one of the founding members of the National Academy of Engineering.

Gayle W. McElrath of Bayer, Kobert and McElrath, Inc. and the Department of Mechanical Engineering, University of Minnesota, spoke on "Transitions Occurring in Manufacturing Processes." Professor McElrath studied mathematics both as an undergraduate and graduate student and also taught mathematics before becoming active in industrial engineering. In addition to his duties as the head of the industrial-engineering activity at the University of Minnesota, he is a partner in the firm of Bayer, Kobert and McElrath, Inc., an industrial-engineering consulting firm. He is the author of several fundamental textbooks, such as "Introduction to Probability and Statistics," and has served as a vice-president of the American Society for Quality Control. Professor McElrath is now a consultant to the U.S. Air Force School of Logistics and to the Ordnance Management Training Agency at Rock Island.

During the evening session, the Division members and staff were pleased to give special recognition to Dr. Willis A. Gibbons as an honored guest of the Division. Dr. Gibbons, chairman of the Division from 1952 to 1954 and a retired Director of Research of the U. S. Rubber Company, represented the 18 men who have served as chairmen since the Division came into being 47 years ago. Among the former chairmen he was honored to represent are many famous names. These include the first chairman (1918 - 1919), Henry Marion Howe, Comfort Adams, Frank Jewett, Elmer A. Sperry, Charles F. ("Boss") Kettering, Vannevar Bush, William L. Batt, William F. Durand, and Admiral Edward Cochrane. These men have, by their personal professional competences, represented the fields of metallurgy, electrical engineering, automotive engineering, naval architecture and marine engineering, mechanical engineering, aeronautical engineering, and chemical engineering. Many of these were active members of the National Academy of Sciences in their lifetime and worked with the Academy in engineering activities and for the furtherance of science and engineering as inseparable partners.

The purpose of this report, published as a supplement to the Annual Report of the Division of Engineering and Industrial Research, is to bring to a wider audience the content of the formal papers and the exchange of views presented at this meeting.

Richard C. Jordan, Chairman
Division of Engineering and
Industrial Research

AFTERNOON SESSION

The Annual Meeting of the Division of Engineering and Industrial Research, National Academy of Sciences-National Research Council, was called to order at 2:00 P. M., 15 March 1965. The Division chairman, Dr. Richard C. Jordan, presided and introduced the theme of the meeting, "Engineering in Transition."

ENGINEERING IN TRANSITION

Richard C. Jordan

From before the time of Leonardo da Vinci until about 1750, engineering as a profession was in its infancy and frequently linked with the military both as to incentive and product. The publicly accepted image of engineering today developed approximately in the period between 1750 and World War II. During this time developments such as the steam engine, the patent system, the factory system, the internal-combustion engine, machine tools, manufacturing methods, electric-power generation and distribution, industrial organization, rapid mass transportation, banking and credit, and high-speed communications have swept over civilization in rapid succession and are the dominant economic and social forces existent today.

Yet a third transition now appears to be developing. The engineer has moved quickly from the attitudes and traditions of the craftsman and skilled artisan to a pattern of greater intellectual depth and social awareness. No longer would it be possible for Timoshenko to come to this country, as he did in 1922, and search unsuccessfully in several schools for a teaching position. The inarticulate student engineer of the 1920's with a T-square in one hand and a slide rule dangling from his belt no longer exists. The more modestly intellectually endowed engineering students of the 1920's would find the challenges of an engineering education today considerably more demanding and, in some cases, beyond their grasp. In part this may explain the slower than anticipated rise in engineering enrollment during the past few years.

Yet any attempt to categorize the stages of engineering development is an oversimplification, since these changes have occurred in an unmarked flow. However, if there ever was a time in history in which there was a discontinuity in this flow, it is today. The matrix for this lies in three not entirely unrelated explosions occurring in the world today. The population and the science explosions are well known to all of us. Yet how many realize that the Malthusian predictions of populations limited only through poverty and starvation have actually been reached in some parts of the world. In several Southeast Asiatic areas, the majority of the population is now under 15 years of age. A third rapid change is the political explosion that has resulted in almost a third of the world's population receiving its political freedom within the past 25 years.

The technological and scientific revolution is the change with which the engineering profession is most concerned and the one that dictates the title of our session today. Between 1947 and 1963 industrial production has virtually doubled. The number of scientists and engineers employed by industry has doubled, but the number of blue-collar workers has remained essentially the same. From 1950 to 1960 the top 5 per cent of income earners switched dramatically from domination by doctors, dentists, farmers, and small business owners to engineers, managers, technicians, and corporation officials. The number of top-ranking corporation officials with degrees in science and engineering has risen from 7 per cent in 1900 to 20 per cent in 1950 to 36 per cent in 1963, and with a predicted value of over 50 per cent by 1980. Indeed, there are now more high-ranking corporation executives with degrees in science and engineering than there are with degrees in business and law. These are merely evidences of the transition in engineering upon us.

It is for these reasons that we have chosen the topic "Engineering in Transition" for our meeting today. The coverage will by no means be comprehensive. The three phases that have been selected concern education, research and development, and manufacturing. Later in the day at our dinner meeting, one of the truly important developments that has occurred within the past century in the engineering profession will be discussed. This concerns the new National Academy of Engineering and its interrelationships with the National Academy of Sciences-National Research Council.

During the last several years the Division of Engineering and Industrial Research has undertaken a searching analysis of its own framework and its position relative to this transition in engineering. One of the first steps in this effort has been the publication of a bulletin entitled "Interests and Activities of the Division of Engineering and Industrial Research." This provides an historical résumé of the Division's activities during its 47 years of existence and probes into some of the potential directions that it should or must take in the future.

More recently the Division has formed a Long-Range Planning Committee to explore more fully its directions and to recommend a framework for implementation. This committee has been chaired by Dr. J. W. Hinkley, and the preliminary report, while still incomplete, contains a paragraph describing one of the trends that will greatly affect social, economic, and political structures and that is closely tied to the theme of this meeting:

> "The first of these broad trends is an increasing rate of application of science and technology to the economies of the industrialized nations of the world, and, more significantly, a major increase in the sophistication and complexity of the technology. This increase in both the

pace and the quality of technological development will be accompanied by correspondingly greater impact on the economic, social, and political patterns of modern society. As revolutionary as the past fifty years may seem, even more radical changes and dislocations in society lie ahead. These are problems that the engineer, a principal agent in the process, cannot ignore."

ENGINEERING EDUCATION IN TRANSITION

Frederick C. Lindvall

The announced subject of this discussion is "Engineering Education in Transition." Less politely we might restate our subject as "Engineering Education in Confusion." At any rate, I am confused by the many currents and countercurrents, such as over-emphasis on analysis and under-emphasis on synthesis, concentration in depth or breadth in basic engineering-science areas, four years, five years, graduate study, professional schools, uniformity or diversity, bifurcation, obsolescence, and so on. So I wonder whether we are redoubling our efforts to attain unclear goals. I speak as an individual, and I do not represent a party line.

I am further confused in this presentation by an embarrassment of riches in subject matter and, at the same time, a fear of falling into the groove of an often-played record. It is easy and not unwise to brush aside details and conclude that education for the future must be flexible, adaptable, and non-specific, consisting of basic science, classical and modern, mathematics, the engineering sciences, the humanities, and hopefully, some design and synthesis. These are nonevanescent values and can ensure that the half life of an engineering education is not just 10 years, as the current wisecrack would have it.

It is confusing to consider seriously anything but the "fundamentals" or to depart from the wisdom of Alfred North Whitehead, who said, "A well-planned university course is a study of the wide sweep of generality. I do not mean that it should be abstract in the sense of divorce from concrete fact, but that concrete fact should be studied as illustrating the scope of generalities. This is the aspect of university training in which theoretical interest and practical utility coincide. Whatever be the detail with which you cram your student, the chance of his meeting in after life exactly that detail is almost infinitesimal; and if he does meet it, he will probably have forgotten what you taught him about it." To describe an engineering education of lasting value, we might use the old French expression, "La plus ca change, la plus la même chose." These generalities, although valid, are not particularly helpful in dealing with specifics, and if taken too literally, could be an academic retreat from reality.

How may the problem of engineering education be stated? We often tell our students that a problem well stated is half solved. This is a comforting but somewhat illusory thought when applied to education of engineers for our burgeoning and accelerating technology, where, indeed, we have not one but many problems. Yet we can surely identify some of the major factors that define our problem and examine some of the conflicting requirements that indicate not one but several solutions.

In the first place, the very term, engineering education, suggests uniqueness and uniformity that are neither necessary nor desirable. In fact, we should be concerned with education for the entire spectrum of the engineering function, which ranges from technician support through advanced research and development and into management. Implicitly, the education is to develop the engineer's professional responsibility in his role as the applier of science to meet the needs and desires of mankind. He bridges the gap between the classic worlds of science and the humanities in a very real way, and must make social value judgments as well as technical decisions in his work. As the Princeton economist, Dean Douglas Brown, stated in a challenge to engineers, "The profession of engineering must seize the initiative in acting as a bridge between science and human needs. The scientist is not asked to apply his finding through design. The businessman or politician does not know what science offers or how to apply it. The engineering profession is the channel by which science can greatly improve our way of life, provided it assumes the initiative of leadership rather than the passive role of the hired consultant." This challenge neatly states a part of the educational problem -- the requirement that the engineer must be concerned with human values. Wise people before Brown recognized this need for breadth in engineering education and, as early as 50 years ago, introduced the humanities and social sciences into a few engineering curricula. General acceptance of the concept was slow and grudging, but today some measure of the humanities is an integral part of the education of an engineer. It has been a major step in the evolution of engineering from a craft to a learned profession. The need for a broad education is an important part of our problem statement.

Resistance to including the humanities in engineering education has come less from scorn for their impracticality than from reluctance to have them displace technical material in the curriculum. This, in fact, is an expression of a deeply rooted time constraint that continues to frustrate curriculum change. The traditional four-year course of study leading to a bachelor's degree in engineering is, in effect, a constant-volume system from which something must be extruded if new material is added. We struggle within this constraint today less because of the humanities content than because of the increasing amount of basic science, mathematics, and new fundamental knowledge. The constant-volume system, or four-year box, now operates at higher pressure and density than formerly, and contains little material that would meet older criteria of immediate practical utility. It is probably more useful for the future than for the immediate present. Surely we can no longer cling to the earlier concept of four years for a professional engineering education. We are acutely aware that the four-year box is a part of our problem. At the same time, we cling to a belief that for some students, at least, a four-year terminal-degree course is appropriate. This position is sound and for the totality of the engineering function is desirable, provided that this more limited goal does not compromise more extensive professional education.

We are thus led to a vital part of our problem statement--a recognition and frank acceptance of the principles that no curriculum can be all things to all people, and that branching educational paths lead properly toward different engineering goals. Some 10 years ago a committee of the American Society for Engineering Education sought to establish the concept of parallel programs or branching paths in engineering education. Strong, almost universal, opposition came from the engineering schools, arising from an unwillingness to be identified with any type of curriculum that could be misjudged as inferior. Differences in objectives of curricula were lost in concern over relative levels. Names identified with curricula objectives -- for example, "professional general" designating immediate practice and "professional scientific" for research and development functions -- were thought to be suggestive of class distinctions. Obvious differences would exist in curricula having the two objectives as stated -- that intended as education for research and development would stress scientific content and analysis heavily, while the education leading toward immediate engineering practice would properly emphasize synthesis, design, systems concepts, and economic analysis in addition to the basic science, mathematics, and humanities appropriately common to both branches. The professional-scientific program would imply graduate study, or at any rate more time in school than the professional general branch, because industry is not well equipped to teach science and mathematics. In turn, the colleges are a poor environment in which to learn the realities and sophistications of advanced professional practice.

Fortunately, the branching of engineering education necessary to achieve different goals is coming to be recognized in action as well as in concept. A good many schools offer, in addition to other engineering curricula, options in engineering science, engineering physics, or similar courses that concentrate on science and analysis. Some schools offer the branching paths at appropriate undergraduate levels through designated options or, less formally, through course electives. Even for the doctor's degree, some schools recognize a difference in orientation -- the design function or the research function -- with programs terminating in the degrees of Doctor of Engineering or Doctor of Philosophy. And, on a larger scale, the situation in the state of California may be mentioned. The master plan for higher education in California and its precursor, the Strayer Report, define educational objectives for the university system, the state college system, and the junior colleges. The broad objective for the university in engineering would fit most closely in the "professional scientific" category, while the goals of the "professional general" engineering curricula would be met by the state colleges. The junior colleges would continue in close collaboration with the state colleges and the university system to provide for large numbers of students the first two years of college work transferrable to a four-year program elsewhere and to offer vocational and subprofessional training as two-year terminal programs. The university will put heavy emphasis on graduate study and research, the state colleges more emphasis on undergraduate work. Thus we see here and elsewhere a trend toward the multiple-path approach toward different engineering goals.

None of these paths followed in school produces a professional man or completes his education. We recognize all too clearly today the continuing-education component of professional practice, and the need for more conscientious effort on the part of engineers in order to stay au courant, or, to use the cruder expression, to combat obsolescence. This continuing education is, of course, experience, it is self-study, it is breadth of interest, it is alertness and intellectual curiosity. The colleges can help in the continuing-education process through specialized courses, short or long, refresher material in mathematics or science, new basic concepts or methods, through executive refresher experience in the manner of the new Sloan effort at MIT in advanced training of engineering executives and teachers, patterned after some of the successes of schools of business administration in similar activity. University extension work, in-plant courses of study, part-time or full-time graduate study, correspondence courses, and a variety of other plans all have a place in continuing education. However, the only really important element is the effort of the individual engineer himself, his desires, and his active participation in the learning process.

We see here another facet of our total problem -- the importance of self-learning, self-teaching, in formal eduction at all levels. In our traditional university patterns, the course is the unit of education, and an appropriate combination of courses meets a graduation requirement. As a result, the student quite naturally identifies learning with "taking a course." The course is usually a combination of lectures, textbook assignments, home work, examinations, and classroom discussion, all reasonably well organized to cover the material the instructor considers important. The pace is usually set for the average student, with due regard for the time demands of other concurrent courses. Depending upon the instructor, this organization of subject matter may be "spoon feeding," or it may require considerable student effort to work through the material of the course without a rigid time table. Unfortunately, most courses are rather tightly scheduled, with the result that students are used to having the material organized for them. The experience of learning a subject without an ordered series of assignments, problems, and tests is rather exceptional. Consequently, I am not surprised when a practicing engineer asks me: "Where can I take a course in linear programming," rather than asking: "How can I learn about linear programming from texts or references you might be able to suggest?"

The notion of learning a new subject by independent study rather than through a guided tour in the form of a course simply does not occur to most of us who have had our learning well organized by instructors. Undoubtedly, the organized course is an efficient means for studying a subject, but it is also an intellectual crutch, which may not be available to a practicing engineer seeking to extend his knowledge into new fields or to master advances even in his own specialty. Thus a vital part of our educational problem is to seek new methods and techniques of study that will help our graduates to be more self-reliant in their continuing education. Programmed learning in book format may prove to be a self-study technique of importance for some subjects, or, as one author told me, the rigorous exercise of writing a good program will have shown him how to write a good textbook along more conventional lines. It is hoped that newly proposed federal legislation will include substantial support for centers of research on the learning process, which will lead to more education by individual accomplishment and less by organized instruction. Knowing how to explore a new subject has more permanent value than the mere passing of some courses. As a word of caution -- a shortage of competent teachers could lead to greater use of organization and techniques that will make the student an even more passive learner. On the other hand, if we are clever enough, we may be able to turn a teacher shortage into greater student self-reliance.

Thus far, this description of the problem of engineering education in this era of rapidly expanding technology has considered curricula, students, and practicing engineers. A key element is the professor. He needs help, too. He is also vulnerable to this unpleasant occupational disease of obsolescence. The basic science and mathematics he studied 25 years ago, and which have since served him well, are still viable, but inadequate. In a vigorous academic environment, the professor has more opportunity to remain in step than has the practicing engineer, because he has convenient access to libraries, other faculty, seminars, and if he wishes, he can visit classes and privately take the examinations. However, if the school itself is a bit behind the times for any number of reasons -- inadequate resources, geographical isolation, lack of leadership, limited objectives, excessive inbreeding, and so on -- an ambitious professor will lack the stimulation of a scholarly environment and the opportunities for self-improvement. He can take leave and work in a more challenging atmosphere for a time, but this poses teaching problems for his home school while he is away, effort by his host institution in making suitable opportunities and facilities available to him, and financial problems for the visitor himself. There are costs, direct and indirect, at the host institution, particularly when adequate planning and arrangements are made for the visitor so that he may derive as much benefit as possible during his period of residence. Multiply this single example by the large number of faculty members on a national scale who would welcome a few months or a year in another environment, or at another institution -- not necessarily a university -- where a vigorous spirit of scholarship and research exists. This need is worthy of a major effort. An experiment with an organized effort between two institutions is now in operation in the engineering schools of the Universities of Colorado and Illinois, initiated by the Commission on Engineering Education, and supported by a grant from the Charles F. Kettering Foundation. Some Colorado and Illinois faculty have been interchanged, some graduate students have shifted, some special seminars and lectures have been organized. The exchange of people and ideas in teaching and research is mutually stimulating, with the smaller school receiving the greater relative benefit. We will hear more of this experiment in faculty development. Similar schemes involving pairs or combinations of schools should be initiated. Interest is high, but capital is needed.

Additional facets of the problem of engineering education today might be explored, as indeed they are in various professional journals, the American Society for Engineering Education, and the Engineers Council for Professional Development. A large study is currently in progress by ASEE on Goals of Engineering Education, under the general chairmanship of Dr. Eric Walker, with Dean George Hawkins of Purdue as director of the undergraduate portion, and Dean Joseph Pettit of Stanford as director of the graduate-study phase. The study should be comprehensive, and should establish guidelines for the immediate future. It is noteworthy that, of all the professions I have observed, engineering has probably done the greatest amount of self-evaluation of its education continuously and in a series of major studies over the past 40 or 50 years, and the Engineers Council for Professional Development has achieved substantial improvements in engineering education through its accreditation procedures.

Certain things are emerging as solutions to parts of the total problem of engineering education. Some of them have been mentioned here -- continuing education, acceptance of the fact that a four-year terminal program is insufficient for some of the engineering needs, faculty development, and the concept of branching paths to different educational goals. Concurrently, we see a rapid increase in graduate education at both master and doctoral levels. The White House report of 1962, "Meeting Manpower Needs in Science and Technology," recommended a program "designed to achieve a substantial, unprecedented acceleration in the rate of production of advanced degrees in engineering, mathematics, and the physical sciences." The federal government has responded with increased numbers of pre-doctoral fellowships in engineering available through the National Science Foundation, NASA, and the National Defense Education Act. This gain in student assistance is very helpful, but this increased federal support has had some adverse effect on industrial fellowships. It is unfortunate if a serious imbalance between federal and private support results. After all, we don't want our students to grow up thinking that Washington is the only source of support and of interest in his welfare. However, the net gain for engineering graduate study has been very substantial.

Federal research and development activities have been enormous, as we know. Industrial research and development also is very substantial, but exactly what is industrial in the sense of strictly private money, and what is industrial in the sense of federal money spent via industry, is not clear. As Dr. Killian of MIT stated in a talk in Los Angeles recently, "We are a research oriented society here in this country, but that research and the consequences of research have not penetrated very deeply into the bulk of American industry." We know of many outstanding industrial research activities. We needn't identify them. But in the smaller and medium-size industries, the techniques of research and the opportunities of research have been realized only in part. It is probable that this segment of the economy will add to the demand for engineering graduates with advanced training.

A proposal that has stimulated much discussion concerns professional graduate work preceded by a pre-engineering baccalaureate program. This concept has certain attractive features, not the least of which is that the pressure for professional material in the undergraduate program is removed. On the other hand, this approach obviously is inconsistent with the desire to maintain four-year terminal curricula designated as engineering, and reinforces the idea of separate or branching paths toward different goals.

As engineering education has moved toward more scientific and analytical content, the question has often been asked: "What distinguishes such study from curricula in applied science or applied physics?" Further soul-searching leads to the conclusion that a distinctive element in engineering is the synthesis and design function. Here we face a major difficulty. The engineering design courses of a generation ago are unsatisfactory in meeting modern needs, and have all but vanished, leaving a serious professional void. Fortunately, serious study by various committees and group projects is in progress to find ways of teaching the philosophy of design and synthesis, and applying it to real problems of some scope, rather than to details or elements. One promising approach is the Design Case Study, for which the effective case method of schools of business administration is a model. Each design case is a comprehensive statement requiring much effort in its preparation if it is to be a challenge for the student. The educational value of such cases remains to be tested, but the experiment is certainly worth a good college try. Other techniques are being tried, such as the design clinic. The need for good design education is clear. The methods are much less certain.

"Systems engineering" is a popular word these days. A recent study was made under the general auspices of the Office of the Commission of Engineering Education. As I read through the report, I came to the conclusion that there was no real agreement (a) that there was a body of knowledge appropriately defined as systems engineering that could constitute a discipline in the true sense of the word, and (b) whether or not there should exist curricula labeled systems engineering, or if such should exist, should they be at the undergraduate or graduate level? I remember some years ago when Dr. Ramo wanted to set up pre-doctoral fellowships in systems engineering at our school and at MIT. I stated that we were not about to announce a curriculum in systems engineering. Ramo's reply was: "I know you are not, and you shouldn't, because the things I think are important in systems engineering you are already teaching, and just a general background of these courses is what the systems engineer needs." In this Commission of Engineering Education report, a statement was made by an industrial man who has considerable systems engineering experience himself, to the effect that he would not know what to do with a bachelor candidate who came out with a degree in systems engineering. He would know a little bit about a lot of things, but not enough in depth really to get into systems engineering as it exists today.

I might remark parenthetically, in view of the fact that I have been meeting with electric utility people here this morning, that systems engineering is not new in the utility business. Some people are rediscovering things that utilities have been doing for years, and are doing in a very sophisticated way today, such as computer control of the energy flow through interconnections to get the minimum cost per kilowatt hour.

Systems engineering is, as one of my old engineering friends said, "what any good engineer in charge of a project always has done," but on the other hand, there are powerful new tools and techniques.

A new direction in engineering education is the recognition of the inter-disciplinary or multi-disciplinary nature of much of modern engineering. This is reflected in the course and curriculum structures of some schools in which subject matter common to several engineering fields is stressed, instead of treating the basic principles and concepts differently and in separate subject packages. Much remains to be done in unifying such basic material, and the result could lead to better understanding and much more effective use of student time. In a broader sense, engineering education is developing deeper roots in the physical and the life sciences. The problems of the solid state, environmental health, and biological systems are examples. At the secondary school level, much progress is being made in the teaching of science and mathematics. The impact of the new high school physics and the new mathematics is evident in the better preparation of many entering students. As this wave rolls along, the level of undergraduate instruction will continue to rise.

Thus, along with the many confusing problems in engineering education, there are many encouraging signs. We are in transition. We have always been in transition; only today it is more dramatic, or traumatic, depending on your point of view. We cannot expect to reach a comfortable, steady state, for we are a research-and-development-oriented society, and science and our technological application and innovation will continue this challenging environment of change and transition.

THE CHANGING APPROACH TO ENGINEERING RESEARCH AND DEVELOPMENT

C. Guy Suits

I did a double-take when I saw the title, "The Changing Approach to Engineering Research and Development," because I could find a number of things that I would like to change. But nevertheless, it relates to the theme that I would like to present.

Preparing a talk on this subject for a group of engineers and research scientists is made easier by the fact that there is never a real problem as to where to start.

In spite of the traditional exactness of the scientific method and the precision of the engineering approach, it is certainly desirable on the occasion of a discussion of this sort to start by defining -- or if you prefer, redefining -- such vague terms as "engineering," "science," and "research." In the work of these great professions, over a period of years, we have successfully defined thousands of both straightforward and highly subtle terms and concepts. We have done this with confidence, with precision, and with some degree of exactitude. But alas, when it comes to defining the professions themselves, our confidence often disappears into a morass of semantics.

Today, fortunately, this subject does not make it absolutely necessary to define the subtle distinctions between basic research and applied research. In fact, I mention these two troublesome terms only because some recent success in defining them has given us a lead toward simplifying some of the terms that we must consider today. You will recall the now-classic suggestion that "If I want to do it, it's basic research; if they want me to do it, it's applied research." Taken a few steps further, it has been more recently suggested that "If it costs twice as much as we thought it would, it's research; if it really works, it's engineering; and, of course, if it makes a profit, that is professional management."

More seriously, a strong case can be made for the belief that since the objectives and methods of research are distinctly different from the objectives and methods of engineering, the term "engineering research" is misleading and subject to misinterpretation. What really is meant by "engineering research" is, I presume, finding answers to problems that arise in design and development. This is sharply focused work, as contrasted with the investigational, broad-ranging nature of scientific research.

For illustration, the eventual development of the thermonuclear fusion process for power generation will require such extensive new knowledge that it is, today, a strictly scientific problem. This is a bona fide research endeavor. But fission power has developed so extensively that it is now almost entirely a job for engineers. The fantastic recent achievements that have made uranium competitive with fossil fuels in many areas must properly be described as engineering accomplishments.

The concept of a fuel cell for industrial portable power application provides another example. No fuel-cell system presently known is ready for the industrial market, by virtue of prospective costs, which are too high by about one order of magnitude. The most painstaking effort in the refinement of engineering design cannot overcome this economic barrier. Thus, the industrial fuel cell is simply not ready for engineering. It may be ready at some future date, if scientific research does provide much new knowledge and understanding of catalysis, surface reactions, and the complex electrolytic environment of these systems. Since knowledge and understanding are the primary needs, the industrial fuel cell is still "in research."

If we can achieve clarity with respect to research on the one hand, and engineering on the other, the insertion of the word "development" between them adds an element of confusion. What, indeed, is development? It is a fact that the common "R, D, and E" terminology causes consternation and anguish in some quarters. One of my associates, whose judgment I value highly, points out that "development" is simply one part of the engineering job -- a part with no clear boundaries -- and he then states categorically: "The lumping of research with development is a destructive concept."

In a corporate-level research laboratory for which I am responsible, we meet almost daily the necessity of defining the boundary between research and whatever-it-is that follows research, including engineering. We define this boundary in the following way: As a policy and operating practice, we extend research in the direction of applications, to the extent of demonstrating the technical feasibility of new phenomena, new concepts, new processes, and new materials. This demonstration generally falls far short of establishing related engineering concepts, principles, and designs, and does not provide answers to questions of economic feasibility, manufacturability, or marketability.

On the basis of this preliminary discussion, I might paraphrase the "changing approach to engineering research and development" referred to in the title assigned for my discussion as "a new and more sophisticated recognition of the distinct and different roles played by research scientists and engineers in today's changing world." In emphasizing distinctions and differences between scientific research and engineering, I wish in no way to imply that there is a lessening interdependence of the two professions. But, rather, I hope to contribute to mutual understanding that will provide an improved basis for cooperative effort.

In many major technical endeavors today and in the future, particularly in industry, engineers and scientists will continue to work side-by-side, each contributing essential elements to the total accomplishment. I am suggesting, however, that, in so doing, both must retain their professional identity.

With each new day, the need for greater understanding of engineering objectives and problems by scientists -- and of research objectives and problems by engineers -- increases. But the fantastic growth in the complexity of modern technology, and the human limitations -- physical, mental, time -- which make it possible for a single individual to encompass only a smaller and smaller part of the expanding whole, combine to require more dedication on the part of all. There must be more dedication to research on the part of researchers, more dedication to engineering by engineers, and less of the inefficiency that is bound to result from unnecessarily confusing or overlapping of roles.

Let me now identify the role of engineer somewhat more accurately. In my thinking about this, I have benefited from discussions with and suggestions from many senior engineering associates in our company, and I am grateful for their contributions to this discussion.

Francis K. McCune, vice president - engineering services, has given careful thought to the appropriate role of the engineer in industry. He says, "The work of the engineer is balancing available inputs to synthesize and to optimize so that his end product, which is a design, will enable the organization which he serves to produce a competitive value at a competitive cost." By "design" is meant here a concept of a project or an entity which uses the abilities of the business enterprise to produce something that meets customer requirements, and which is worth more than it costs to produce.

It is engineering, then, that produces designs. The engineer has three major sources of information to use in the design process: The first source is scientific knowledge of nature. The second source is engineering technology. The third source is "non-engineering" knowledge and technology. All three contribute to the profitable linking of industrial resources and customer requirements.

I will discuss these three sources of "information for the engineer" in reverse order, since the focus of my discussion today is the interrelationship of the engineer and his scientific resources.

"Non-engineering technology" essential to the engineer who is engaged in creative design work includes knowledge of customers, knowledge of business systems, knowledge of manufacturing capabilities, knowledge of economic -- and, often, political -- environment, knowledge about people and their motivations, and knowledge of a frighteningly long list of other things. Teaching engineers -- and future engineers -- how to acquire and properly use this "non-engineering" information is, of course, a subject unto itself. Happily, I will not have time to discuss it.

Under the heading of "engineering technology", we find existing knowledge about natural laws based on previous scientific research and proved by application; a large body of systematized and codified design knowledge that has been arrived at by generally empirical methods not necessarily based on scientific research; and, inevitably, it includes the non-codified, non-systematized knowledge that can best be termed "engineering lore." Sometimes the latter hasn't been written down simply because it can't be. The experienced chemical engineer may find that the easiest way to determine the start of a chemical reaction is to use his sense of smell. Needless to say, "engineering lore" includes a large component of practical experience. Particularly in regard to this source of his information, the engineer has the responsibility to add to as well as use.

I would like to spend a good deal of my remaining time on "scientific knowledge of nature," as a third source of engineering information. Here we are talking about recorded natural facts, based on systematic observation and measurement, plus unifying ideas and concepts that correlate wide ranges of such facts and make possible accurate prediction of other facts not yet observed, measured, or recorded. Without in any way diminishing the continuing and growing importance of other sources of information for engineers, it should be emphasized right here and now that this source -- knowledge of nature based on new scientific research -- has increased tremendously in volume and importance to the practicing engineer during recent years.

Actually, many of the complexities of the relationships between research and engineering, which are the focus of my remarks today, are a result of the tremendous, explosive expansion of both science and engineering in recent years. Witness the sudden emergence and growth of completely new science-based technologies such as nucleonics, solid-state electronics, synthetic polymer chemistry, new mathematics for information systems, related computer and automation technology, and many others. Generally, new discoveries from scientific research in these areas were applied in the first instance by scientists who employed the demonstration of technical feasibility as a practical teaching aid that would hopefully speed the new concept down the road to utility. Thus, Enrico Fermi and his scientific associates actually designed and built the first nuclear reactor at Stagg Field. This demonstrated the technical feasibility of the fission chain reaction. It has taken an additional 20 years to engineer, manufacture, and market reactors, and thus to demonstrate the economic feasibility of such systems.

Because the transition of new knowledge to new applications has been accomplished so rapidly in recent years, there has arisen a popular -- but false -- public impression that science has "taken over" engineering. "Scientists" often get the credit for space achievements, for example, which most properly belongs to engineers. Indeed, the tremendous pace of new discoveries, and the accelerating dependence of the engineer on new research, has had a number of other consequences. Not only the public, but even some educators, managers of industrial organizations, and managers of technical operations have developed a tendency to try to "merge" scientific research and engineering, or at least to "fuzz up" the distinctions between the two functions. This is unfortunate, and we should avoid it.

Although I am generally optimistic about the ability of engineering education to meet the challenge posed by the explosive expansion of technology, the problems are not trivial, and in the current excitement some confusion is evident. Successful scientific research requires aptitudes and attitudes -- and particularly an inquiring mind -- as much as it requires specialized training. This discipline is not particularly appropriate to the engineer who intends to engage in the tasks and to pursue the objectives and to make the contributions in engineering that have just been described. Moreover, an emphasis on the teaching of research methods and techniques to future engineers as a matter of formal training -- and, particularly, graduate-level training -- would appear to be an illogical diversion in this context.

But a reasonable pattern for producing engineers does seem to be evolving. We conceive it to include: four years of rather liberal education in science, humanities, and mathematics leading to a bachelor's degree; then one or two years of education in creative design engineering, at the graduate level.

Expansion of education in engineering at the doctoral level is urgently needed, but with a caution that needs emphasis: the motivation should not be the "winning of a doctorate race" with scientists, nor the achievement of status symbols. What is required, at least by industry, is an increasing number of "doctor engineers" who have had the benefit of truly advanced work in engineering, rather than research-type Ph.D. training in a scientific discipline.

There is a continuing good case to be made for the viewpoint that graduate study for engineering careers in many industrially important fields should be concurrent and intertwined with actual employment. The mix of information and proficiency that is most appropriate for the many fields of engineering varies widely, and to achieve a proper balance in a context of actual need presents many advantages. On-the-job engineering situations can provide excellent motivation for education beyond the bachelor degree, and are essential in guidance as to the directions that continuing education should take.

These views, of course, assume continual upgrading of undergraduate curricula through better development, expression, and teaching of the central ideas of course material, and by the flow of new substance from research to curriculum and from graduate courses to undergraduate courses.

The extension, seemingly ad infinitum, of what the educated engineer must be educated in is, of course, not just a result of the belief that he must know more about his scientific resources, but also because of the sheer massiveness of engineering technology and the need for a more-than-complete liberal arts background encompassing economics, business administration, political science, psychology, philosophy, and even -- it is to be hoped -- learning how to express what he thinks. In this context, I have quoted before -- and can't resist quoting again -- what one of my associates has called "The Dean of Engineering's Lament." It goes like this:

"The course I've constructed will surely create
The greatest engineer alive,
But the day before he'll graduate
He'll retire at sixty-five."

One obvious -- but unfortunately not wholly satisfactory -- answer to the quandary is specialization: the specialized engineer. Among the great problems of modern education is keeping the student engineer, scientist, and technologist from becoming too specialized, especially in the wrong things. As a practicing specialist in industry later, the graduate has the problem of retaining enough flexibility to permit response to the ever-changing demands of modern technical employment. In particular, interdisciplinary "systems" engineering problems have emerged -- including military systems, automation, space, sophisticated industrial processes -- requiring graduate engineers with unprecedented versatility and great breadth of capability.

I hope it does not appear that I am trying to encroach upon the discussion of a separate topic on today's program, the subject of curricula for engineering education. On the contrary, my aim is to emphasize further what industrial companies can contribute to "engineering in transition."

1. Industry will undoubtedly continue its general support of higher education in the United States, including engineering education. We do this recognizing that the colleges and universities are the source of our most critical human resources and that their continuing strength and effectiveness are vital components of industrial progress.

In the midst of all the current discussion about engineering education, I think we should not give the impression that industry is unaware of the truly remarkable job that is being done by some of the leading colleges and universities. They are producing the best educated -- and at the same time the most adaptable and flexible -- engineers in history.

2. Industry can develop and improve educational courses of its own that will provide newly hired graduates with specific knowledge about the industry, the company, and the conduct of engineering in the industrial environment.

3. Industry can seek new and better ways to provide "engineering internships," combining regular or temporary employment with study at an engineering school. This can be accomplished in a variety of ways already in practice, and I believe some creative thinking in this area would produce many additional ideas. In our own company, we have various arrangements for alternating engineering employment and study at a college or university. We have study courses such as Advanced Engineering and Creative Engineering Programs. Since 1963 we have had a program conducted in cooperation with Brooklyn Polytechnic Institute, which combines our Advanced Engineering Program with periodic full-time study leading to a doctorate in engineering. Some 30 of our engineers are presently participating in this program, and the first doctorates are expected to be conferred next year. Meanwhile, the success of the initial program with Brooklyn Polytechnic Institute has encouraged us to start a similar program at Rensselaer Polytechnic Institute. In all, at least 250 General Electric engineers are now eligible for and interested in these cooperative programs leading to doctorates in engineering. Obviously, we hope this idea will "catch on" with other companies and other universities.

4. Industry can develop and expand programs for encouraging "after-work-hours" study by providing tuition refunds.

5. Industry can generate better industry-education relationships by encouraging senior engineers to aid institutions of higher learning in roles such as adjunct professor or adviser, and by using consultants from the campus in its own work.

6. As an extension of the above, industry can seek the help of engineering schools in preparing special courses designed for working engineers. An example from our own company is the "Modern Engineering Course," which has been given five or six

times in the past three years to groups of top engineers, particularly engineering managers.

7. Industry can throw the full weight of its support behind the professional engineering societies, encouraging the remarkable work they are doing in disseminating information, establishing standards, and generally enhancing the stature of engineering as a profession.

8. Industry can recognize in all of its managerial planning the key role of the engineer in initiating innovation as well as in taking new ideas from conception to profit.

This means constantly providing and updating those three sources of information required by today's engineer: scientific research, conducted not by him but with his present and future needs in mind; support programs aimed at keeping him abreast of current engineering technology; and well-thought-out managerial planning to give him pertinent help and information from the areas of marketing, manufacturing, employee relations, and government relations -- along with the host of other "non-engineering" facts he must have to do his total job.

Our own company has a new planning operation at the corporate level which has as one of its aims the development of techniques for integrating the viewpoints of all business functions and factors into corporate planning. Better orientation of scientific research and engineering should be one of the many beneficial results of this type of effort.

9. Industry can promote closer relationships between scientists and engineers in a variety of other ways. New information-flow techniques can be and are being developed. The reporting of the results of world-wide research can be and is being speeded. The integration of technological efforts in highly diversified companies and industries is being accomplished.

In any event, let's continue to mix engineers and scientists together in appropriate proportions for mutual support of their mutual aims for accomplishing the challenging tasks ahead. But let's not mix up their professions. To do so is to lessen their ability to make unique contributions to progress and greatly confuses the basically important questions of the education, training, and management of these key human resources.

In summary, the "changing approach" we have been discussing today means that we urge: (a) the more definitive delineation of the specific work of the engineer, (b) the recognition of the equally important, but distinctly different, role of the research scientist, and (c) the recognition that the engineer must have access to a variety of kinds of both "engineering" and "non-engineering" information in order to make an optimum contribution through his efforts.

TRANSITIONS OCCURRING IN MANUFACTURING PROCESSES

Gayle W. McElrath

I am pleased to be here this afternoon to meet and talk with you on topics that are so important and vital.

One of the problems of a speaker is communication with his audience. There is not one of us with the same background of education and experience. Even when the word "engineer" is used, each of us interprets the meaning of the word somewhat differently, depending on the personal framework of reference that we have built on the word "engineer."

A speaker must try to hear what he is saying through the ears of his audience. As ego-busting as it is, what the speaker says really isn't important; the only important part of this lecture is what the audience hears. A speaker tried to generate situations that maximize the intersection, if you will, of what he says with what the audience hears.

Dr. Jordan asked if I would speak on the topic, "Transitions Occurring in Manufacturing Processes." However, I am going to take some poetic license, as have the previous speakers, and will restrict my talk to specific areas and problems. To cover the entire waterfront of transitions occurring in manufacturing processes would be a tremendous task.

When we talk about transitions occurring in manufacturing processes, we might think of the functions of an engineering department called process engineering, manufacturing engineering, technical staff engineering, or metallurgical engineering. Other department titles might be chemical department, chemical engineering department, ceramic engineering department, and food technology department. In short, we might think about a department that is referred to as having the know-how to take care of the technological problems of a manufacturing process activity.

First, let me review something that will be "old hat" to many of you -- the present-day demands on manufacturing processing which call out the need for engineering transition.

Second, I wish to discuss some of the tools for transition.

Third, I will present what might be called an "Engineering Action Program."

Present Demands for Engineering Transition

Manufacturing is becoming increasingly complex, whether it be in the multi-plant operation or in a "basement enterprise." We live in a time of accelerating scientific and engineering discovery and change. There is no debating the fact that our era is witnessing a technological explosion that defies the imagination.

There is a demand for closer specifications, instant customer service, higher-quality products, without once forgetting that the enterprise must make a profit.

Time is of the essence. The need for speed in doing things is becoming increasingly paramount. There is a need for faster manufacturing breakthroughs that respond to scientific discoveries, faster product planning, phase-in and control, faster process audit and feedback, faster decision-making and evaluations, with a higher degree of reliability. These existing conditions are forcing the engineer identified with manufacturing processes to depart from a narrow product-oriented "fire-fighting" activity, which is primarily post-mortem in nature, to that of a more mature, systems-oriented activity that is predictive and preventive in nature. The manufacturing engineer is forced to consider the entire plant facility as a system and develop what might be called a total manufacturing engineering program. It is becoming increasingly foolhardy to make random improvements in an operation and not to use some method of integrating modern tools that are accessible to the manufacturing facility.

However, in the face of the above considerations, the fundamental concept of the role that the engineer must assume in the present science-engineering-oriented society has not radically changed. Thankfully, in spite of the present scientific discoveries and inventions, there still remains a society composed of people for the engineer to serve. The engineer who finds himself in a manufacturing processing function of an industrial activity still has the same role to provide a creative imagination and innovation, which are so necessary and important to translate what science has to offer into a greatly improved way of life.

Tools for Transition

Automation

It is not a new idea that the engineer's responsibility to a manufacturing process is primarily that of problem-solving. The nature of the problems, the manner in which they may be chosen, and the present "tools" available to solve them have taken on a brand new and revolutionary perspective.

Automation is a tool for the manufacturing process engineer to use. However, the moment the word "automation" is used we become immediately aware that automation has been, and still is, greatly misused. It has confused the public, escaped definition and agreement among academicians, and has brought new problems to industrial management.

Mr. R. C. Archer, Vice President, Manufacturing, International Harvester Company, speaks of automation when he remarks, "I am sure that you will find it difficult to determine (referring to automation examples in his company) whether the processing employed is 'mechanization' or 'automation.' The differences are of little interest to the Harvester Company. We are interested in both if they provide us with lower costs, higher quality, greater safety, or improved working conditions."

In addition, Mr. Del S. Harder, Executive Vice President, Basic Manufacturing Divisions, Ford Motor Company, reflects, "As some of you may know, I coined the word (automation) in the year 1935; although the term did not come into extensive use until about 1947. At that time its meaning was largely limited to the linking of machine tools with automatic transfer and handling equipment. Today, however, its meaning goes far beyond the definition it had even those few short years ago. Its meaning has expanded and changed with each new application."

Sir Leon Bagrit, in his article, "The Age of Automation," states that "It (automation) is no more than a tool, but a tool of such immense possibilities that no one can yet see the full extent of what it might achieve for mankind....Automation is that part of which I have called the 'extension of man' which integrates all of sensing, thinking, and decision making elements. In combination, they are the elements which produce the nearest we can get to that very efficient 'machine' we know as man. Perhaps this is why there is still very little full automation anywhere in the world."

In essence, however, the basic ideas of automation are not new. Automation uses the fundamentals of process control. The transition that is taking place involves the much wider applications of the principles of process control. However, the ultimate development in automation is a completely integrated automatic sequence.

More important for the engineer in manufacturing processes, however, automation presents new opportunities in cost reduction, increased production, better quality, reduced inventory, more reliability, increased worker productivity, better working environment, and personal growth.

The Computer

Another tool for the engineer is the high-speed digital computer, which is becoming more and more "common place" in the manufacturing processes. In so many situations, if the engineer approaches his problems in the traditional manner, he will not get enough accurate information quickly enough to make sound decisions to obtain optimum productivity and profit. There is a demand for real transition.

A few of the well-known areas of application of the computer for the engineer in manufacturing processes are: data analysis and problem solving; integrated data-processing systems; computer control of production processes (automation).

The engineer is fast finding that the "seat of the pants" approach to analysis of problems is not sufficient and that he must learn about designing industrial experiments based on statistical methods. The computer depends on correct product information to help solve complex manufacturing problems. The engineer, more than ever, needs to know a statistical approach to design of industrial experimentation.

Statistical Engineering

"Statistical engineering" is a tool in a manufacturing process that deals with problems associated with process variability. The utility engineering within manufacturing operations lies in the analysis of variability of the process. A manufacturing engineer is continually faced with the problem of identifying the factors or variables that affect the quality of the product, processes, or service. Now he has a tool that will give him a measure of the impact of the factors that he has selected in his analysis. Statistical engineering might very well be called the science that deals with process variability through the analysis of measurements.

There needs to be a very significant transition from the "old timer" who relies solely on experience, judgment, hunch, and hopes to solve his problems to the engineer who not only realizes the importance of effective methods of measuring but also has been open-minded enough and mature enough to realize the need for planned data, designed experiments, and the analysis of process variability. Problems dealing with the technology of the industry, the capability of the machines or processes, and the acceptance or rejection of product or process are all typical problems that face today's engineer involved in a manufacturing process. The classical attitude of this engineer toward statistical engineering is that statistics does not work in his especially different situation. However, those who make the effort to understand the basic concepts and methodology of statistical investigation are soon rewarded with answers that are more reliable, less expensive, and extremely useful.

Data Processing

The speed with which industrial data must be handled has forced many companies to program their operations information flow into a high-speed data-processing system. Purchase orders are automatically typed out. The status of the inventory is given immediately. The computer may question several parts of the manufacturing process before a commitment is made when considering an order. If the check points spell out availability, then the customers' orders can proceed to enter the system whereby it is processed with or without the continued aid of a computer facility. In the ultimate the integrated data-processing operation presents a complete simulation of the production system. Now the manufacturing engineer has the opportunity to determine an economic balance that must be considered wherever a computer is involved.

The engineer in transition must become more engineering-economics oriented than he has in the past.

Engineering Economics and Manufacturing Cost Analysis

Most manufacturing engineers know little about basic manufacturing cost analysis or engineering economics. However, here are tools that give a sound basis for economic decision-making and evaluation. It is a known fact that industries are in business to make a profit. The manufacturing processing activity is indeed expected to contribute its share. However, today's engineer is almost proud that he knows nothing about the standard cost system or about the economic alternatives that might be considered. We need not be shocked at the lack of know-how and interest that the engineer has toward economics. Not once in his engineering curriculum is this area a required subject, except for those who have chosen industrial engineering or a business option.

The transition and almost the revelation to manufacturing process engineers, both young and old, is that now more and more they are expected to communicate in terms of a dimension of money alternatives - the price tag for operation.

The manufacturing engineer needs to communicate with people from several of the functional areas: financial, engineering, administrative and operative, planning, marketing, purchasing, and so on. Their common interest and objective is to make more profit for the company.

Operations Research

Today there is an area that is becoming increasingly important to the manufacturing engineer. The area is often called operations research. If we were to accept a simple definition we would define operations research as the scientific approach to decisions. The approach might be called the "information-reasoning" approach to decision making versus the "experience-intuitive" approach. Some would say that operations research is the scientific approach to operational problems for greater fulfillment of objectives. Whichever, the definitions of such tools as linear programming, queueing, dynamic programming, Monte Carlo methods, simulation models, optimization, game theory, etc. are available for a more sophisticated approach to problem-solving. The direction of the transition in a manufacturing processing operation, which is to consider problems from an analytical quantitative point of view, has been greatly influenced by the development of the many mathematical, statistical, and economic approaches in operations research and analysis.

Engineering Action Program

In the introduction to this paper I referred to an engineering action program. At this time I wish to briefly outline my thinking and define for you the basic concepts and functions of such a program.

A Profit-Oriented Program

The objectives of any program within the manufacturing process activity are rather straightforward and clear. They always include two primary objectives: (a) to produce to customer satisfaction, and (b) to generate a profit for the company. It is only too often that the engineer, because of his technological know-how and educational reference, does not feel that he must concern himself with such objectives. However, if he is going to make a contribution within the manufacturing processing environment, he cannot escape these basic objectives of the company. The worthwhileness of any activity within the manufacturing processing area has one metric. This metric is profit.

Some Basic Concepts

If an "Engineering Action Program" is to succeed there must be some basic agreements concerning the freedom of endeavor and the willingness of management to accept and support certain premises. The following are presented for your consideration.

The management must give the program the right to be concerned with any activity that adversely affects the process, product, or service. To this end, the engineer has the opportunity to search for problems whose solution will be of most benefit to the company. Which problems might these be? The answer becomes quite obvious. Those problems whose solutions are most promising to make the company a profit.

In order to get some handle on the areas of major dollar losses, there needs be an extension of the accounting system that calls out the costs identified with problem areas. That is, if profit improvement is a prime goal, it just makes sense that a reporting system that particularizes the losses must be developed.

An effective system should report such significant losses as downgrade, downtime due to poor scheduling, overtime due to re-runs, excess inventory due to poor planning, idle labor due to poor programming, scrap, repair, rework, reoperations, etc.

A source document that reflects these losses must report the loss at the point of discovery and should record the details of

who - the responsibility for the loss
what - the type of loss
why - the cause, if possible to determine
when - shift, date, time
where - department, operation, etc.

The actual cost estimates are determined through standard cost extensions that have been developed in cooperation with such departments as, for example, accounting and process engineering.

The detailed source-document information from the various significant areas of the plant can now be organized and processed by a computer. The computer cumulates the data, sorts according to rank order, and points out the loss distribution. Regular reports are provided for top management and the line supervisor, as well as for the manufacturing processing engineer and other interested staff. Obviously, there are several combinatorials of data that can be offered for analysis. For example, there can be a report covering all departments giving the manufacturing costs according to each unit contributing to the losses. Another report might summarize the losses by product identification. Still another can present the losses identified with defect types within one product. A fourth report presents a breakdown by department and products within the department, and within that product the descriptions of the specific defect.

This reporting system, tailored to the management needs for analysis, has a significant effect on the degree of support of all the levels of management. The system can assure corrective action on important losses by concentrating problem-solving effort on the high dollar losses. Unnecessary and wasteful effort directed toward low losses is prevented. Such a reporting system aids management to place logical pressures on the sensitive areas. The continuity of the reporting system also allows the management to assess the results of corrective action and follow-up.

Training Requirements for the Engineering Action Program

To assure sufficient and continued support from all levels of management, training courses in the philosophy and management of the Engineering Action Program are developed for top management, middle management, supervision and technical personnel. Non-technical course attendees represent all functions such as accounting, scheduling, maintenance, operating, etc. The technical course attendees represent all phases of engineering - industrial engineering, plant engineering, etc. - as well as the manufacturing processing engineers.

Each course is tailored to the group involved. The courses for the non-technical personnel present the concepts associated with the modern approach to quantitative decision-making and evaluations. The course material includes the ideas basic to the analysis of process variability and the methods of implementation associated with such an analysis.

The goals of the non-technical courses are:

- to emphasize the need for correct product and process information direct from the manufacturing process itself;
- to introduce new ideas and concepts relative to the principles of quantitative decisions and evaluations;
- to present to the non-technical personnel the purpose and need for an organized effort to promote the cooperation of the line and staff to solve the more technological manufacturing processing problems within the operation.

The content of the course for the technical group is longer and presents the material in greater depth. The presentation might be divided into four important areas: basic concepts of decision-making and evaluations under uncertainty, statistical engineering, designed experimentation, and maximization problems. Keep in mind that all the technical group is exposed to this training. To this end, the disciplined professional training of the technical personnel within the organization results in a joint sophisticated quantitative approach to manufacturing processing problem-solving. Statistical engineering now can become a viable force that may be fundamental to management decision-making and evaluation.

Statistical Engineering and Designed Experimentation -- Some Case Histories

1. Experimentation with melting practices revised methods resulting in new controls for the operations. This reduced out-of-specifications heats to one third of the former loss.

2. A Wiebull Distribution analysis of time between breakdowns pointed out the need for improved preventive maintenance scheduling. This drastically reduced breakdowns in a rolling mill.

3. Experimentation in drawing methods indicated the need to revise pickling practices. The revised methods markedly reduced losses.

4. Investigation of raw material buying practices, where the price was determined by variable quality, showed consistently that certain buyers were overpaying for raw materials. Training programs helped reduce this overpayment.

5. Experimentation improved the process methods and equipment factors in a packing operation that reduced downgrading of premium-priced gourmet product to standard product.

6. Experimentation in a ceramic operation with conveyor factors reduced losses in damage.

7. Positive control of color and shade of the ceramic was accomplished through experimentation that proved the accepted published theory of color control to be defective. Process and method controls were established under a new and revised theoretical concept resulting in positive color and shade control in an industry where this was considered to be unattainable.

8. Through an engineering program a high-precision machining plant revealed some basic problems of machines and methods. These were corrected and quality improved. Notwithstanding the cost of correcting the processes, the program was paying for itself within four months after it was started. Customer reaction improved steadily while over-all savings mounted.

9. Within nine months a large brass manufacturer saved in excess of $100,000 over and above the entire investment in his quality-control program. His customer complaints were drastically reduced.

10. A rubber manufacturer paid off the investment in his program and produced further savings by reducing his scrap losses to less than 20 per cent of the former level within six months. Customer rebates were also drastically reduced.

Summary

Truly, the engineering function in the manufacturing processing area is in transition. I have pointed out the need for transition, the tools for transition, and some of the ingredients of an Engineering Action Program for transition within the manufacturing processing area. There is an underlying fundamental to the entire activity of problem solving for improved and more reliable decisions and evaluations. That is the fundamental of quantitative analysis and designed experimentation. The activity is truly transitional. Modern progressive analytical disciplines may be built into the engineering function, which makes it possible to determine the reliability of the process of acquiring new knowledge by observation.

DISCUSSION

The meeting was opened to questions from the floor directed to the panel of speakers.

Question: What are the engineering educators represented in the audience trying to do within their respective schools to reduce the two years of shock into which the student goes when he enters industry?

Dr. Lindvall: Well, in the first place, I think the students are continually advised of the fact that there will be a shock. They are continually being told that they might not be immediately useful in the sense of turning out a design in the first month of their employment. But I am sure all of the students realize, with all the harping we have been doing on the fundamentals, that they have a great deal to learn in industry. We keep saying over and over again we do the part we think we can do best in the educational process, and that industry has to step in and do the things that the colleges can't do well. There is one route that one can take, and I think it is perhaps not a very good one. That is to bring too much of the industrial atmosphere into the school, and run a junior-grade design shop, or to act as though it were a little branch of the research and development organization of a company.

Professor McElrath: I would like to make a remark in connection with that question. I think that perhaps this is one of the methods by which the coefficient of shock is lessened, and I don't feel that it is a watered-down approach. That is the cooperative programs that are started among the universities. You are quite well acquainted with them, I am sure: a quarter in school and a quarter in industry and a quarter in school, for perhaps the last couple of years. I think this does a great deal for those kids that are really interested in the professional approach to the engineering activity. Really, I don't think of this as a downgrade of the other attitudes in terms of the problems of engineering. That would be a different emphasis, so that the students really, I think, in the cooperative programs, are a little bit better braced for what they might be up against. By the way, we have tried new employees on this type of program that we were talking about just a little bit before. In a problem-solving orientation, perhaps the student who is just out of a university is a fresh student. He has a fresh student outlook, and probably he is a fresh student, too. Here, then, is an opportunity for him to start to participate and to start contributing to the company. It is a satisfaction to the company, and it is a satisfaction to the student. All of a sudden, right now, he is utilizing his professional skills.

Question: I would like to ask Dr. Suits why it was found necessary to introduce a course in creativity at General Electric, and whether or not it has been successful. In other words, wouldn't it have been better if you had engineers and scientists who had received that course in undergraduate training?

Dr. Suits: This course in creativity, as you may know, has been in progress for a long time. One of the important points that should be made is that it doesn't teach creativity. The objective is to see if it is possible to develop a better environment in which native creativity can flourish and mature. I think it has been quite successful in this context. Its origins really came from the rather nostalgic idea of "where are the Edisons of today?" It was evident that the Edisons were around, but they were just having a harder time being identified in large organizations and among many associates. That in turn led to the idea of early identification and apprenticeship with known creative individuals. We did not begin with the intention of developing creativity, but identifying young creativity and giving it an environment in which it could grow, with sponsorship that had demonstrated creative abilities for a period of years. So that has been the idea back of the creativity course. Relatively small numbers of individuals have been concerned, but there have been some rather spectacular cases of creative work within this environment. I think it has served its purpose in giving additional opportunity for the maturing of creative aptitudes in particular individuals.

Question: It really is a mistake to call it a course, then. It is really an opportunity.

Dr. Suits: It is really a strategy for the edification and further development of creative aptitudes.

Question: Dr. Suits, to follow up on the same question, what correlation do you find between the individuals you identify as being highly creative and their performance in creativity seminars and their productivity in research, development, and engineering later on.

Dr. Suits: I think just looking at the graduates of the creative engineering course, we made quite an effort over some years to see if we could analyze what is happening in this sort of a plan. The individuals who have gone through this treatment have really done remarkably well. It has been a good means of enhancing their creativity. The application has been more to advanced product engineering than to research. Generally research scientists haven't been in this type of plan. But people whose academic origins were in engineering, who had the aptitudes, and who intended to go into design engineering -- frequently complex design engineering -- have done remarkably well as a result of this treatment.

Question: As an educator, I have been concerned with the identification of creativity in an educational environment. I have been interested in the fact that some of the most creative people I have known have not done too well scholastically. We all know examples. One that comes to mind is a chap who was a motion-picture operator with a grade school education and employed by an industrial concern. The company developed by virtue of the patents held by this one individual who had not been educated in a college environment. In another large industrial concern, one of the most creative engineers I know is one who, at the beginning of the war, identified certain problems and projected his company into a completely new environment. Yet, this chap almost failed at one of our Big Ten universities a few years before. He did finally graduate, but with a low grade point average, and certainly would never have been admitted to the graduate school of any good university in the country.

What relationship do you find in industry between scholastic achievement in college and the creativity of the people you hire?

Dr. Suits: This is a very interesting question. Many of my associates have been concerned with it over a long period of years. In the first place, it would be desirable, if it were possible, early in an academic career, to identify creativity. When we look at the records of a college graduate, there is generally little or nothing in the formal record of his academic achievement that really pertains to creativity. He has satisfied academic requirements, but one of the courses was not creativity, and he did not get a mark in it. So identification is really a very desirable thing. By and large, we have no means of making this identification in advance. It is a discovery that is made later, after the start of the professional career of the individual. Now, the second point I would like to make is that I do confirm the impression you have, that quite a number of creative individuals may have been not exactly at the top of the academic heap. I think this is inherent in the creative process. Creative individuals tend to have somewhat imaginative but undisciplined minds. The discipline of formal course work isn't exactly the best discipline for a creative mind. This same individual who has very creative ideas might have said to heck with it when he got to the week before examination. He was interested in something else, and didn't want to take the time for it. So I think there is a relationship that perhaps cannot be proved, but is strongly suggested in the lack of top academic achievement by many individuals. The third point that might be made in this context is that, in an industrial organization, we are very interested in creative individuals, but we don't want every engineer to be creative. We would have chaos if that were the case. We want a few Thomas Edisons, but we certainly don't want a thousand of them. So any program concerned with creativity is not necessarily concerned with large numbers of people, but relatively small numbers of highly skilled people with very unusual aptitudes and originality. Their identification early in the scholastic career would be very desirable, and it would be very helpful to industry to see something in the academic record that would suggest the very unusual qualities of these people.

Question: You are not saying that you have to be poor scholastically to be creative, are you?

Dr. Suits: No, definitely not. Cases come to mind of individuals who have had both top academic qualifications and very creative aptitudes. I think these two specifications, although not precisely in conflict, aren't completely coherent. If an individual made straight "A's" for four years of college, he has certainly subjected himself to a very strict formal regime of study and performance. That may have left insufficient time for the complete play of a highly imaginative mind.

Question: I believe Dr. Lindvall mentioned one of the ways in which creative activity can be encouraged, and that is the use of independent study, which many schools are adopting more and more. We have at my institution, what we call unrostered work, which a man can substitute for his regularly scheduled classes, and this frees him from the regimen of prescribed courses with formal lectures and so on. It is this freedom which is needed for those individuals and I think the schools are making them available more and more.

Professor Jordan: I might comment on the previous question relative to high scholastic average and creativity. I have heard one prominent man at a large technical company say they are somewhat afraid of the straight "A" student and prefer the strong "B" student who evidences creativity. Certainly the independent study and project activity being encouraged in a number of schools, is a promising one.

Another means of early identification of creativity is through the part-time employment of undergraduate students on research activities. We have tried this, and found it useful in identifying potential graduate students.

Question: I would just like to make one comment in addition to what Dr. Suits said in respect to creativity. I agree entirely with him, but there is another facet that is not often mentioned. You have to have a receptive climate in the organization he works with. New ideas are tender things that are easily destroyed at the inception.

Professor McElrath, are there other processes of manufacturing where profit is not involved? We think of one in building highways, for example. I wonder how you could apply the logic, your approach to the implementation, to the problem-solving problem, to a public service process, say a post office or highway building. Profit is easy to define, but how can you define what you are trying to optimize in a public service?

Professor McElrath: That is a very interesting question, but I have yet to see the organization that didn't like to come up with a net favorable balance. We ordinarily don't have as a goal a maximum amount of deficit that we can go into, so whether you talk about it as profit, net favorable balance, or meeting the budget, it really doesn't make too much difference from this point of view. Again, what I am trying to stress, and I think the point that you are trying to bring out, is the fact that the dollar bill, in order to get things done, is a vehicle, and somewhere along the line it plays an important part in implementation. We have a very fine hospital on the campus at the University of Minnesota. Some of the research and development that goes on there certainly is done without the cost factor, and it is supported by some very fine foundations. But when we get into a comparable situation of running a hospital, and in the clinic, and when we find the activities that are going on that are somewhat comparable to a manufacturing process, if you will, then we have to think in terms of a dimension, and that dimension is the dollar bill, really, because it must be afforded some way or other. Somewhere along the line, someone is stuck with the budget. This trick goes down into the objectives, and to the amount of work that this person can get done. It seems to me that, even at a university where we are doing contract research, this is an important factor sometimes. I don't want to treat your question in a trivial way, but it is there, whether you call it profit or not, I guess is what I am trying to say.

Question: Might I paraphrase it a bit. Profit is the result of the lowest possible cost and greatest customer satisfaction, and that applies to highways as well as industrial problems.

This question is directed to all the speakers. Last month I visited a number of engineering departments of universities in the western part of the country, and ran into several points of view among educators on what directions or trends their program should take. These were all the way from the view of one mechanical engineering department head, who said that his boys would still know how to design a product, and would know what it would mean to get sand on their hands in making castings, and that his department was producing practical design engineers, to the other extreme, represented by a dean who said, "We are producing research people -- people who are going on to graduate study -- and industry better darn well learn how to use our people, and those companies that don't are going to be in trouble." My question, gentlemen, is to what extent should there be input from the engineering schools in preparing its curriculum, and to what extent should the university go out and look for this kind of input from the user of engineers?

Professor Jordan: I would like to call on Dr. Eric Walker to try to answer this question.

Dr. Walker: We always say there should be diversity in education, and if we listen to the users of engineers we will get diversity. However, one always remembers the Edsel, and I am sure if we slavishly follow the desires of industry, we will get some Edsels as well as some excellent models.

Professor Jordan: Do any of the other speakers wish to add to the comment?

Dr. Lindvall: It is just more or less in line with what I was trying to say, that there are a number of engineering goals, and education shouldn't try to meet all of those goals with one standard pattern. Students may work in a campus foundry and get a little experience there. They may have an idea of what that particular school foundry was like, but may not have much idea of a modern production foundry. On the other hand, we can get completely cut off in terms of practicality by pushing all students on the research and development side of things without any feeling for what people are going to do with these ideas from engineering research. We have a broad spectrum of students and a broad spectrum of needs in this country. With respect to the question of how educators get input from manufacturers, well, I personally catch hell all the time from people in industry who come around and say, "Well, your Cal Tech students are way up in the clouds, they don't understand reality. We don't know how to use them in our business." On the other hand, one of our alumni said to me one day, "If I want a student who can help me out next summer designing simple bridges on a construction job up in the mountains, I wouldn't get a Cal Tech student, but in my office, for the long pull, for any new concepts and new ideas in bridge design, I think I will take the Cal Tech product." He was willing to wait a little bit and not call on a practitioner to do his job. We also get inputs a little more formally. I remember I worked on an ASEE committee some 10 years ago that was trying to set some guidelines for the future. We had a subcommittee composed of industrialists representing a fairly wide spectrum of activity. They came in with some suggestions, which rather shocked the professors, in terms of the need for more science, more mathematics, more fundamentals, and a minimum of teaching the details of how we do it today. I don't know whether the new study that you are sponsoring, Eric, is soliciting industrial input.

Dr. Walker: Yes, actually it has what statisticians say is a properly chosen sample of industry, and is not falling into the trap we fell into on the last one, where we got only Cal graduates who worked for the Bell Telephone Company.

That is an overstatement intended only to make a point.

Dr. Lindvall: We had a Caterpillar Tractor man on that committee.

Dr. Walker: Yes, we did.

Question: A little over two years ago, the Society of Naval Architects and Marine Engineers launched a rather modest program that you might be interested in hearing about, because it might have further application in connection with the use of seniors in colleges. The Society has some 40 panels, task groups, and committees in its technical research program. In the course of a year the activity in these groups may involve over 120 meetings. You can realize the tremendous scope of the administrative problem. The technical administrator found himself inundated, as one of the speakers mentioned, so we went to one of these colleges and asked whether they would supply seniors who could come over and take minutes. It started in a modest way that year, and it has now expanded to include three colleges. These seniors come over perhaps five to seven times a year and watch these key leaders of industry in action. They record their comments and then write up a technical report. I have talked with these young men and find them all enthusiastic about it. The schools give them some credit in their academic work. So far it has been very successful and may have further application.

Dr. Lindvall, is it possible to get a doctor's degree at Cal Tech in design, and what is the trend in the country generally in this area? In other words, is the Ph.D. still the standard doctoral degree for engineers, and is it based more on research than on design?

Dr. Lindvall: I can say that we are working at this program. Last year one man did get his doctor's degree on what I would call a real design problem. He had done the thing from scratch. His thesis reads like a model for the way to go about solving an engineering need, carrying it all the way through to production of the unit, and actually demonstrating that it really worked. There is another doctoral candidate completing his work this year who is a little farther out in his approach. He took a look at this prosaic machine in all print shops known as a paper cutter. He made a complete study of paper cutters that are available, and what they consist of. He took a completely new look at the paper cutting problem and designed a machine that is sitting on the floor of one of the laboratories to demonstrate to anybody who will look that it will cut paper. It is cheaper, smaller, and much easier to use than anything else on the market. His thesis will be entitled, "The Genesis of a Design."

Professor Jordan: Perhaps Dr. Newman Hall would like to comment.

Dr. Hall: I won't comment at length, because it is not my position to take the place of the speaker. I think the most important thing we are trying to stress, both on the part of student and faculty, is the development of more effective means of involvement in the real situation that the fellow is going to encounter when he gets in the industrial environment. We don't know how far this can be pressed, but there is an increasing feeling, I believe, on the part of many educators, as Fred's comments have confirmed, that the experience which he must have in an educational institution must partake of the reality of the actual engineering situation to the optimum degree possible. I say optimum, because this must be done at the same time that we make no sacrifice in the degree to which he becomes familiar with the fundamentals that he must have if he is going to be effective in the industrial environment. I think that there are some very encouraging developments, and Fred in his remarks earlier alluded to these. It is important that the faculty members know, if they are going to be engineering professors, what the problems are, and how to handle them. To the extent that they do not know how to handle them, their treatment of fundamentals is going to be irrelevant in terms of engineering design. I think there are problems in this direction; however, certainly we are working at this very intensively.

Professor Jordan: Thank you. I think if there is any one thing we can be assured of, it is that engineering education is going to take varying forms in the next few years. Even though you get this feedback from industry that was proposed a short time ago, my own experience is that with the same company you can get different feedbacks as to what should be involved in engineering education. I know that in one large company we involved in this sort of thing; one faction from the company was very much concerned with the removal of the skilled forces from engineering education, the graphics, the graphical communication, and that part of it, and another part of the company said they didn't care whether any of our graduates ever saw a drawing board or a T-square when they got out. I think this is going to be a continuing discussion for some time.

Question: I don't think I can recall at the minute any manufacturing process that could tolerate the variability in raw material that the educational process has to tolerate. One of the functions to be performed in education, it seems to me, is to allow each of these individuals to do as much as he can do for himself with his capabilities. I think a sincere effort is made to do this. Nevertheless, it is very difficult to provide the number of hours of personal contact that would help the individual to develop himself when there are so many of these individuals, so the tendency is to put them through a certain more or less mechanized operation. One thing that hasn't been touched on here is motivation, and that is vital I think, not only in industry, but in any kind of activity that the engineering graduate gets into. It isn't something that can be taught in a school necessarily, but what is being done in our educational machinery to try to help a young engineer develop this thing that we call motivation.

In view of the comment that was made a moment ago about the Edsel, I would like to ask Professor McElrath whether that could be cited as a classical case of a breakdown in the coordination of engineering with the other elements involved.

Professor McElrath: There are many thoughts on this whole point of the Edsel. From a serious point of view, there is great variability, in terms of marketing, concerning the need of such a car -- the timing of its inception, if you will -- and the point of view that the buyer has when he goes about looking for this kind of car, and the design of the car itself.

When we had an automotive conference in Detroit, this was one of the points of conversation. There is absolutely no zeroing in on an answer as to why the Edsel behaved as it did. So one generates his own point of view. I think that there was a lack of cooperative enterprise across an endeavor to put out a new product, and people were not communicating. I think it was this lack and a breakdown of many of these facets that in general might have been noticed by some of the signals that were given. But the drive to put out a new car was pretty strong.

Dr. Walker: I wasn't going to ask a question, but let me comment on this scene as I see it. Let me first comment on your comment that we have a very variable input. That is because the human race is a product of unskilled labor. We say that the engineer's job is to produce something people want. Then we quote statements about the engineer's taking manpower, materials, and energy to produce the things that people want and people will buy. But let us remember there are other people in the world who try to make things that people want and people will buy. A novelist writes a novel, a composer composes an opera, a poet writes a poem, and a painter paints a picture. These are all things that the author hopes people want and will buy. But can we say in any of these whether one is doing creative synthesis or whether he is doing analysis in the way our engineering students analyze and our engineers synthesize. I think no one will quarrel with the fact that when a novelist writes a novel he is synthesizing something. A painter paints a picture and he too is synthesizing something. But if you look at universities, you will find that we give few doctor's degrees for synthesis; we give them for analysis. A student can go into a physics department and make some measurements on the sound of liquid hydrogen between one hundred degrees and zero degrees centrigrade, and for it he can get a doctor's degree. Maybe people want this information and maybe it satisfies the student's curiosity, but it is not the same thing as producing a new machine, a new opera, a novel, or a painting.

Currently I am reading The Rector of Justin. If it had been written by Mr. Auchincloss at my university while he was a student, he couldn't present it in partial fulfillment towards a doctor's degree. If a student painted a masterpiece or wrote an opera, he couldn't use that to get a doctor's degree, and I suspect that if a student invented or designed a new kind of nuclear reactor he could not get a doctor's degree for it. One of the reasons is that we're just not geared up to this sort of study -- design and synthesis. We distrust it. We have difficulty in distinguishing between the charlatans and the bright and productive students. I think that in some way we educators have to turn around and say that it is part of our job to encourage creativity, not only in engineering but in the arts as well. I suspect that we are going to do it in the arts before we do it in engineering. In that analysis I hope I'm wrong, and I hope the engineering educators will prove me to be wrong.

Professor Jordan: I think many of us are concerned that you can get a doctor's degree in music that is not based upon the creation of music.

Dr. Walker: You get it for analyzing somebody else's music.

Professor Jordan: Correct.

On this note, I will close the meeting.

I again want to express our appreciation to the several speakers for their excellent presentations.

EVENING SESSION

Dr. Frederick Seitz, President of the National Academy of Sciences, and Dr. Augustus B. Kinzel, President of the National Academy of Engineering, expressed their views regarding the joint responsibility of the two academies to ensure that science and engineering work in partnership for the national good. The comments of both speakers are presented here under the theme "Thoughts on the Science-Engineering Partnership."

THOUGHTS ON THE SCIENCE-ENGINEERING PARTNERSHIP

Frederick Seitz

Friends and fellow engineers: I am pleased to greet you again this evening, speaking with two hats, namely, as president of the National Academy of Sciences and as an engineer. I might remind you again that I am a member of three engineering societies, although I do have to be cautious since I am told that members of the American Institute of Mining, Metallurgical, and Petroleum Engineers are really not considered engineers by many in the profession.

I assure you that I will be brief for I know that you are waiting to hear the great message from Dr. Kinzel.

Let me next apologize for being somewhat late this evening. As you know, the Director of City Planning of the Soviet Union visited our city this week and the Soviet Embassy had a reception for him this evening which I was privileged to attend. Grant Mickle informs me that he spent a good part of last evening with our Soviet visitor at an informal discussion. Doubtless the problems concerning the density of highway traffic are rather different here and in the Soviet Union.

We have had a remarkable year in the last twelve months in more ways than one, since several major events have occurred. Not the least significant of these was the creation of the National Academy of Engineering. I believe that Dick Jordan has rated it one of the most important events of the century when judged from the standpoint of the family of scientists and engineers in our country.

One would like to think that this estimation of the creation of the National Academy of Engineering is a valid one. As I said one year ago when I spoke to this Division for the first time, the creation of the new academy does not represent the first tie between the National Academy of Sciences and the engineering community. For one thing the Division of Engineering and Industrial Research can be traced back for about half a century. Still further, the charter of the National Academy of Sciences granted in 1863 makes it clear that the Academy has responsibilities for advising the government in fields of engineering as well as in those of pure science. Indeed, the Academy has attempted to live up to this obligation to the best of its abilities for the last century.

During the first fifty years of the life of the Academy the responsibilities for advising in the fields of engineering were taken care of adequately by the simple process of electing engineers to the Academy. In this era about 15 per cent of the membership were engineers who usually chose to team up with physicists within the structure of the Academy. Apparently engineers were not very sensitive about their relationships with scientists before World War I.

It was in 1916 that the decision was made to give much more explicit recognition to engineering within the Academy and a separate Section on Engineering was created. I should emphasize, however, that this decision was made in the main by the scientists within the Academy who felt quite strongly that the Academy could not serve the nation properly unless its engineering component was very strong.

I believe you know the story of the last 50 years reasonably well. Creation of the Section on Engineering within the Academy led to the election of Frank Jewett, along with eight other distinguished engineers during the latter part of World War I. Dr. Jewett played an enormously important role in the Academy, not only as chairman of the Division of Engineering and Industrial Research but also during World War II as President of the Academy.

I believe you would enjoy reading his retiring address in 1947 in which he describes his own outlook toward the Academy. He pointed out that the responsibilities of the war had compelled him to spend eight years under conditions in which almost all of his attention was focused on exceedingly practical problems related to applied science and engineering. He hoped that following his retirement in 1947 the Academy could turn a great deal more of its attention to the problems related to basic research. He did not realize at that time, of course, that pure and applied science would continue to occupy such central positions in governmental affairs. The world crisis had not ended in 1945, but merely shifted to a new phase.

Let me turn to the new academy. As you know, it will have essentially complete autonomy in selecting its members and in the determination of the rules by which it conducts its affairs.

It is hoped that the National Research Council will remain as a unified entity in the sense that it is now unified and will be the operating arm of the National Academy of Engineering, as it has been the operating arm of the National Academy of Sciences since 1916. To further the sense of unity of the National Research Council, I am pleased to say at this time that we are now completing arrangements to place the activities of the Research Council in a single centralized office building at 21st Street and Pennsylvania Avenue, which we hope will be ready for occupancy by the middle of 1967. Many details will have to be worked out concerning the interrelationships of the two academies and the National Research Council. If, however, we have good will and the proper leadership in the period ahead, I have complete confidence that we can work out all the important details in a way that will work for the constructive good of all.

In giving thought to the internal characteristics of the new academy, my foremost hope is that it will put a very high emphasis on quality. It may be necessary in the years just ahead to make compromise with any other matters in order to assure the development of the new academy, but I do not believe it can ever be desirable to compromise with quality if the new academy expects to maintain the abiding respect of the professions it will be expected to serve.

It is, of course, inevitably true that the most distinguished members of a profession are very busy and do not always have the time one would like them to spare for the activities of an academy. This price, however, is one well worth paying as long as those who do participate have essentially the universal respect of others in their profession.

The decision to create the new academy within the framework of the original charter of the National Academy of Sciences was not lightly taken by anyone involved. It was in fact a decision made after several years of serious deliberation. It is the overwhelming opinion of everyone involved to date that the arrangement has far more advantages than disadvantages, whatever the disadvantages may be. For one thing, I hope that the 102 years of history and experience that the National Academy of Sciences has gained in its various activities and operations will speed up the rate at which the new academy becomes a viable functioning organization. I can promise you that we will do everything possible within the Executive Offices of the National Academy of Sciences to help.

Let me conclude my remarks by emphasizing two points that those who direct the new academy can evaluate in any manner they choose.

The officers of the new academy have expressed a special interest in having a tie to the Division of Engineering and Industrial Research, that is, to your Division. I heartily favor such a link but wish to emphasize that the tie of the National Academy of Engineering to the National Research Council should by no means stop with this association.

Although the National Research Council is divided into eight divisions, and although it has a number of committees and boards in addition to yours, it is actually a highly unified structure. The interest of engineering extends throughout that structure. For example, the Division of Chemistry and Chemical Technology is no less involved in modern engineering than is the Division of Engineering and Industrial Research.

It might seem that the Division of Behavioral Sciences is somewhat removed from matters of concern to engineering; however, those of you who are involved in industrial management will know that the behavioral sciences are very important for modern engineering.

Similarly it might appear that the Division of Mathematics is somewhat removed from modern engineering. The mere fact that a number of applied mathematicians are with us tonight indicates the pattern of the future quite clearly. It is my opinion that the new academy could gain a great deal both for itself and for the future if it formed a deep bond with the field of applied mathematics early in its history. I must admit that the membership of the National Academy of Sciences has not exploited in a way that reflects the enormous revolution that is taking place in applied mathematics at the present time. As you know, the mathematicians within the Mathematics Section of the National Academy of Sciences tend to be very pure. The Engineering Academy can profit from this fact by developing a unique strength that will add much to its greatness in the future.

The second point I would like to make is the following. The membership of the National Academy of Sciences has on the whole taken only a fleeting interest in education in science in a formal way - particularly education at the four-year college level. The Academy has felt that it would do most for the scientific professions by giving primary attention to graduate and postgraduate education, which are closely tied in with research. In this connection, the National Academy of Sciences stimulated the creation of the famous National Research Council Fellowships about 40 years ago, and thereby did much to speed up the closing of the gap between the levels of scientific education on both sides of the Atlantic. I should also mention, of course, that the National Research Council has had an Office of Scientific Personnel, under the leadership of Dr. Trytten, which, while keeping an eye on the upper levels of professional training in the sciences, has also served as a source of advice for training at the secondary and college levels. On the whole, however, the members of the National Academy of Sciences have not felt that the Academy should be a forum for discussion or implementation of concepts in the more elementary form of education for science.

I have a feeling that the National Academy of Engineering cannot afford to take the same attitude toward the more elementary forms of engineering education. If I look over the various factors that have led to the creation of the new academy, some of which are genuine and others of which are probably less real, I believe that an appreciable fraction can be ascribed to defects in American engineering education. It seems to me that these defects must be corrected rapidly in the future and that the new academy both could and should assume some responsibility for the transition.

We all note that there is a rapid rise in education in engineering at the Ph. D. level. This is obviously a corrective step in the right direction. It is still probably true, however, that much of engineering education, even at the graduate level, is still too highly specialized for the good of the long-range welfare of the profession. It is by no means obvious to me that the pattern of graduate courses in electrical and mechanical engineering should be essentially different. I do not want to dwell on details of this kind here, but I strongly recommend that the new academy devote some of its energy to these problems.

A reform in engineering education will obviously not take place overnight. One can hope for significant progress in a decade and really major progress in one or two generations -- that is, in 25 or 50 years.

Augustus B. Kinzel

I want to tell you how much I enjoyed what Dr. Seitz had to say. Obviously, I am in complete agreement with everything he said, and a few extra new constructive points that he has emphasized will be taken very seriously.

One of the things Dr. Seitz has just told you is that the National Research Council was born by virtue of needs created by the then forthcoming World War I, and it was so created because the organizational structure of the National Academy of Sciences was such that the service required under the then situation could not be as effectively rendered as it could be by changing the organization set-up. Thus the National Research Council was born.

Now, in World War II, we had to look again at the picture, and unfortunately, because I think it was sad -- the structure that we then had comprising the National Academy of Sciences and the National Research Council again was determined to be inadequate to the occasion.

They got Vannevar Bush to Washington and set up the Office of Scientific Research and Development.

Now, the National Academy of Engineering is born as a result of World War III, the Cold War, and significantly dated, as it were, by Sputnik. It was after Sputnik, immediately after Sputnik, that the President of the United States established on his staff a special assistant to advise him on scientific matters, and the total effort in the area of science and technology was stepped up at a very great pace. And then it was found, by the engineering community at least, that something was still lacking. This lack was also noted in Congress, in the Executive Branch, and by the National Academy of Sciences. The lack was that the engineering point of view in the investigation and consideration of problems having to do with the country's total effort was not being obtained in full measure.

Many thought that the way to take care of this was to set up a National Academy of Engineering under a Congressional charter, and go to it. Some of us, however, realized that such independent action would not be in the best interest of the nation. If you had two totally independent organizations, each giving advice to Congress in areas that overlapped and impinged, the result from a pragmatic point of view is obvious. First, rivalry develops and the two organizations quickly get to sword's point; and second, the politically motivated play one organization against the other for their own aims. So, the problem was how do you set up a National Academy of Engineering in such a way as to prevent this. Specifically we did not wish to create a rival group, but to meld science and engineering just as they are in practice.

All of us know that the way things really happen is that either an engineer dreams up something and does it without a theoretical background, and then the scientists come along and explain it with the result that we then make even greater progress, or the scientists make a finding and the engineer makes that finding economically useful to man. More and more is the second way of accomplishment evidenced, the scientists making a finding, which is carried on through by scientists, and the innovation is carried on by the engineers.

So, the problem was how to organize. Well, it took a lot of pushing, pulling, quarterbacking, and what-not, to arrive at a solution, a solution satisfactory to those of us who had the objective of getting a National Academy of Engineering so placed that the total effort of both academies would be made not only much more effective, but would also be unified. This was done finally, thanks to the real statesmanship of Fred Seitz, and I can't over-emphasize his role in bringing about what we have today.

Our National Academy of Engineering was organized on the 10th of December, 1964, with 25 members. I am not going to go into the detailed history up to that point. The 25 organizing members were appointed by the National Academy of Sciences on nomination of the Engineers Joint Council, a beautiful melding right there. It started out in the right way and the problem now is to carry on so as best to serve the interests of engineering, science and the nation.

The very first and most essential thing, of course, has already been mentioned by Fred. We must maintain quality. By quality, specifically, we mean quality of membership, and we must maintain quality of membership in the right areas. It would be a simple matter, for example, to have a very high-quality membership, but limited to research directors or research faculty members in one or another of our great educational institutions. But if that was all we had, it wouldn't be very long before we ceased to be in a position to render the increased service for which we were established. So the problem of membership is a very serious and difficult problem. We are wrestling with it right now.

On Wednesday, the Council will meet to elect the first group of new members. You may say, well, if they are going to meet on Wednesday, you, Gus Kinzel, being on the inside, know who they are going to be. The fact is, I don't, and the reason I don't is that the point of view on which nominations are made between the membership committee and the Council is not exactly the same. These are things that we have to work out.

In an organization such as this, which is self-perpetuating, it must be remembered that once you set a pattern with a majority of a certain type of person in the membership, you cast the die, because that kind of person will elect, for future membership, his own kind. This is what has happened in the National Academy of Sciences. As a member, I can be a little bit critical of the National Academy of Sciences and, with all due respect to the wonderful set-up that we have in the National Academy of Sciences, it is sad that we have only 50 in the engineering section, and that it is extremely difficult for an engineer to be elected to the National Academy of Sciences -- even a very good engineer. Most of those who have been so elected have been elected because, in addition to being engineers, they were scientists. So we have this problem, and we are wrestling with it.

You might be interested to know that I haven't an exact count on the number of nominations proposed, but that is only because we didn't put them on a computer. We are not going to elect people because they represent organizations; we are electing individuals.

We have had a number of curious happenings. For example, in given companies -- and I won't mention any, of course -- you suddenly get, within a period of ten days, some 50 letters, recommending the same individual in that company. Then another thing that has been most amusing -- why don't these fellows realize how transparent it is? You find what we call membership clubs where six fellows get together, and each group of five nominates the sixth, so you get six nominations from five different people, right around a circle. Well, I suppose you have to expect that kind of thing when you are setting up something that will presumably be in a position of power. You have to expect that sort of thing when you are dealing with power and also when membership in the National Academy of Engineering presumably will be truly cherished, just as membership in the National Academy of Sciences.

It is a major kudo. In any event we are striving for quality in the National Academy of Engineers; for if you have quality, then your advice has strength, and if your advice has strength, you are in an influential position.

Now, the next thing that we have been wrestling with, and still are, has been the matter of sections. It is obvious to all of us in the engineering profession that the present divisions of engineering, in both the academic world and the engineering society world, have less and less meaning in modern-day engineering; e.g., civil, mechanical, mining, metallury, and petroleum. The world doesn't work that way any more, at least not at the top level.

Clarence Linder and his committee have done a lot of work on this sectionalization, and we may finalize it or semi-finalize it at our meeting on Wednesday. The general approach is to have sections dealing with or conceived in line with the systems idea; i.e., energy, communication and information, transportation, materials, agriculture, food, and the like.

If we can work this out, and I think we can in this case, the present divisions, such as civil, mechanical, and so on, will be subs in each of these systems groups, but almost not recognized as such. If we can work this, as I wrote in an article that is going to be published very soon in the Journal of Engineering Education, it could well set the pattern for the structure of an engineering curriculum in the future.

The day of the handbook engineer is gone. The handbook engineer is being rapidly replaced by the computer, and it won't be very long before this almost total. It is the systems engineer, the interdisciplinary -- I will use all the favorite words -- the interdisciplinary, sophisticated engineer who can look at the total problem, which involves science and technology across the board, human behavior, social impact of the totality, human response to a machine, and so on. All this is part of the engineering that is beginning today, and will be the real function of the engineer in the not too distant future.

Sure, we are always going to have to have lesser lights in the engineering world, but I am not worrying about having enough of them. It is the fellows with the really broad approach that can look over a problem in its entirety and divide it into its essential parts, throw those essential parts into a computer for solution, or to a handbook fellow -- the fellows who are going to write the new type of handbook in future engineering -- that are of concern. I could go on for quite a while, but I think that this gives you a little feel of what we are trying to do, and how we are trying to do it.

DISCUSSION

Question: As a newcomer, I would like to have a little more information, perhaps from Dr. Seitz, as to who the National Academy of Sciences reports to, and where it draws its funds from. I have been a little confused about its relationship, for instance, with the President's Science Advisory Office, and so on.

Dr. Seitz: The picture is as follows: We are first and foremost a private organization, but we do have a federal charter that places us in position to advise the government when called upon. That means that we have official governmental recognition. We have an endowment, which is unfortunately small. It pays for only a modest part of our activities. The great bulk of the activities - the 15-odd million dollars worth of advisory work generated by some 400 advisory committees involving some 5,000 scientists and engineers - is paid for on an item-by-item basis. About 80 per cent of the proposals that come to us are funded by various agencies of the federal government. About 20 per cent are funded by private organizations such as industry, often collectively, like the food industry, by state enterprises, as in the Highway Research Board, and by private foundations.

We do not exist as a line item in any Congressional budget, except in so far as our individual studies appear in the agency budgets. In one sense we hold out a hat. On the other hand, the pattern is well enough recognized by this time and the agencies find our services sufficiently indispensable, that there is in a sense an automatic flow. It wouldn't be automatic if the quality were low, but the fact that we render services that can be rendered in no other way is now recognized so clearly that we continue essentially on an even keel. Individual components of our advisory work may at any one time face difficulties, but statistically the support is fairly well balanced.

Question: Would you mind mentioning the Academy relationship to OST and NSF?

Dr. Seitz: They are official agencies. The NSF, for example, is an official agency of the executive branch of the government. It goes to Congress for its money, following a route in which it prepares a budget under the guidance of the Bureau of the Budget, sends it to the White House, where it is reviewed, filtered, and approved, and then passed on to Congress, which votes on it. The Office of Science and Technology is an office in the executive structure headed by Dr. Hornig, who is also President Johnson's special assistant. The Office of Science and Technology is part of the government structure created by Congressional action. It has a budget which is mainly an operating budget, and which appears as part of the budget of the executive offices.

They are all part of the government. We are, except to the extent that we are recognized as a special organization, somewhat in the nature of a nonprofit corporation although a very special kind of nonprofit organization that can be used by the government or other bodies for advice.

I happen to serve in an ex officio way on Dr. Hornig's Advisory Committee. Dr. Bronk not only served ex officio on that committee, but also was for many years the chairman of the Science Board of the National Science Foundation.

Dr. Kinzel: I think you should add that in the National Academy of Sciences we frequently request proposals, and amend requests from agencies, if we think they are inadequate.

Dr. Seitz: Yes, that happens, although if we think the problem is one we should take on, we frequently help them reframe it. There is usually considerable dialogue when a request is made, to make sure that it is put in a framework that we can handle. Sometimes an alternate group is appointed.

Question: What will be the position of the National Research Council relative to the Academy of Sciences and the Academy of Engineering?

Dr. Seitz: Let me take a first stab at that. Our plan is that the National Research Council remain as an entity, or unit, much as at present. As I say, we actually hope to increase the interpenetration of Research Council divisions with one another by providing physical proximity in a consolidated office building. Presumably some of the problems to which the National Research Council dedicates itself will come through the channel of my office, and some of them will come through Dr. Kinzel's office. We are establishing a committee that will tie the two academies together in examining the disposition of requests. We expect no change of any essential kind in the way the National Research Council operates. I should add that it has been agreed upon by the offices of the National Academy of Engineering that, in the period ahead, the office of the Foreign Secretary of the Academy, now under Professor Harrison Brown, a colleague of Professor Lindvall, will handle the activities of both academies as far as foreign problems and related matters are concerned.

Dr. Kinzel: I would just like to add a word to that. As you heard a little bit earlier, the Academies, I am putting it in the plural this time, receive requests for advice from the government agencies and other agencies. Now, the kind of request will determine the way the subject matter will be approached. If it is a bit of advice that requires a study group to delve into the thing primarily thoughtfully, maybe getting some figures together, and so forth, this is handled by setting up a special committee or group in one of the sections, or perhaps across the board, to do what has to be done in order to come up with an answer. But many of the requests and proposals actually require a research operation of one kind or another. These research operations are carried out by the National Research Council, so that, in a sense, the National Research Council is an operating arm -- you might say the operating arm -- of the National Academy of Sciences, and of the National Academy of Engineering. Is that accurate, Fred?

Dr. Seitz: That is good.

Question: Gus, you implied by your discussion that there was a nominating procedure for membership in the Academy of Engineering. It was my understanding that there was to be no such nominating procedure. I think you ought to clarify that.

Dr. Kinzel: Well, there is no nominating procedure in one sense of the word. For nomination in the Academy of Engineering, and at the present time until we get better organized, the modus operandi is as follows: Anyone may send in a nomination, and the number of people that have nominated themselves are legion. We have a membership committee. The membership committee considers every nomination that is sent in, and then makes recommendations to the Council. The Council is not limited in its action by the recommendations of the membership committee, although I would be a little surprised if the Council went too far from these recommendations. At the present time the members are nominated by the Council and elected by the membership. This is the state of affairs up to the first annual meeting, which will be the 27th of April. Subsequent to that, we go into another procedure somewhat but not critically different. Incidentally, we asked the membership committee at this time to make up to 75 recommendations to the Council. I think it is perfectly fair to tell you, unofficially as it were, that they have come up with many less than that, for a variety of reasons. And the Council will probably submit for election at its meeting on Wednesday a still smaller number, the reason being that we have the quality factor absolutely and foremost in our minds, particularly at this first election. We hope within the next year or so to have about 100 more members, and within the next two or three years, to get up to a membership of about 300. This is the goal. But we would rather go slow than make a mistake.

Question: I would like to address this question to Dr. Kinzel. Academy Research Council staff members are on the firing line, so to speak. One of the questions that we really are not quite clear on is: What gap is the National Academy of Engineering going to fill? In other words, we are asked what gap the National Academy of Engineering will fill that the National Academy of Sciences is not filling.

Dr. Kinzel: That is a nice $64 question. The National Academy of Sciences, through the operations assigned to the National Research Council, has done a very creditable job in serving the nation on engineering matters. We feel, however, that this service can be increased in both quantity and quality by having an engineering group tackle these things directly from the engineering point of view.

Further, the National Academy of Sciences has long taken the position that there are certain areas with which they do not wish to be concerned. Many of you may know that there has been much discussion over the years as to whether the Highway Research Board properly belongs in the National Academy of Sciences, or even in the National Research Council. Certain other groups have graduated from the Academy-Research Council structure to independent operation, or have been asked to undertake independent operation quite properly. Perhaps under the National Academy of Engineering it would be the same, but not necessarily so. You can have an emphasis on engineering, and the engineering point of view, and the engineering project, when you go at it from that standpoint, which you can't have when you go at it from the other. Fred, I think maybe you ought to answer this question.

Dr. Seitz: I would like to frame it in a somewhat different way, not at all contradictory with what Dr. Kinzel has just said. If you examine the role of the membership of the National Academy of Sciences, you will find that what they do in essence is to provide counsel. They act as a kind of board of directors that elects an executive committee, namely, the Council, to establish rules and guidelines. Historically, the National Research Council has had very broad freedom to conduct its affairs within guidelines that have been set down by the Council. In addition, of course, the community of members of the Academy do get selected as individuals to participate in a much broader spectrum of affairs. They are asked to serve on government committees, and the like. By adding the membership of the National Academy of Engineering to the trustee body, one draws so to speak on a wider range of talents to bring into the establishment of the guidelines.

Moreover, one has a pool of men in the membership of the Academy of Engineering that can be drawn on to serve the national welfare. The membership list of the Academy will find its way to a large number of organizations, governmental and non-governmental. I predict that the members will find themselves asked to serve on committees more frequently. Regarding the nature of the work of the National Research Council, I do not expect that the staff will notice any great difference in the future. It is true that, from time to time, perhaps once in two or three years, a question will be raised in the Council as to whether an activity, important though it may be, should be kept on under our auspices, or set out on its own. There are a number of organizations that were started within the National Research Council and have eventually become independent. The Industrial Research Institute is one very good example. The American Geological Institute is another. From time to time there will be other organizations, born within the framework of the National Research Council, which achieve stature and then become independent bodies. During the 10 years or so in which I served on the Council, it is safe to say that whenever evidence has shown that there was a uniquely good reason for keeping an organization within the framework of the National Academy of Sciences, there has always been a unanimous decision to retain an association. Dr. Kinzel has mentioned the Highway Research Board. I recall a meeting in which a question was raised concerning it. There was overwhelming agreement that the Highway Research Board should be retained as it is within the framework of the Academy. The Academy provides it something in the nature of protection from a wide variety of forces that might be brought to bear on it if it were not part of the Academy. As far as I can see, the association, which is now 45 years old, should continue for another 45 years. I hope the relationship will remain a happy one for the Board.

Question: A question for Dr. Kinzel, perhaps also for Dr. Seitz. Is it foreseeable that with the establishment of the engineering group now, what we call the National Science Foundation may over a period of time become the National Science and Engineering Foundation?

Dr. Kinzel: I will take a first crack at that one. I would say that we cannot foresee a change in the name, because these things get wound up in Congressional action, and the like. However, we already see a movement in the National Science Foundation to encourage proposals and to give grants in the engineering area. It hasn't gotten very far yet, but it is definitely there.

Dr. Seitz: Somehow, in the post-war period, the term "science" came to be used in a collective sense for pure science, applied science, and engineering. It would be a mistake to try to reverse that, because, after all, you got accustomed to names. As a matter of fact, if you tried to change the name of the National Science Foundation, I am not sure what we would end up with. Sometimes it is better to let things rest as they are. It should be emphasized that the National Science Foundation has done all it can do to strengthen its Division of Engineering and to make it a viable part of the structure. I think that action is the important fact and should be emphasized.

As you know, the Science Foundation not only regards engineering as one of its domains, but has also been putting money into the social sciences. Thus, it regards its mission to be very broad.

Dr. Kinzel: I might add that within the National Science Foundation there has now been created a section on engineering under Dr. John Ide.

Professor Jordan: There being no further questions, I express, on behalf of the Division members and staff, our very great appreciation to Dr. Seitz and Dr. Kinzel for providing us with a further understanding of the related roles of the two Academies and their National Research Council.