THE CONTRIBUTIONS OF SCIENTIFIC, EDUCATIONAL, AND NONPROFIT INSTITUTIONS TO TECHNOLOGICAL PROGRESS

14 October 1952

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Publication No. L53-38

INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

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COMMANDER ENGLISH: The universities and nonprofit institutions have frequently been called the fountainhead of basic research, without which we would have no applied research and no development. These institutions, frequently with no end in view other than a desire to expand the frontiers of knowledge and science, have furnished many of the physical laws, new ideas, and the trained researchers that this country needs to maintain healthy technological growth.

Our speaker today has had a lifetime of experience in developing these new scientific frontiers. His writings alone on the subject of the critical shortage of engineers last year have done much to focus attention on the dangerous trends away from the scientific, educational, and engineering professions by the young college students in the past few years.

We are fortunate to have with us today Dr. Solomon C. Hollister, Dean of the College of Engineering at Cornell University, to discuss with us "The Contributions of Scientific, Educational, and Nonprofit Institutions to Technological Progress."

Dr. Hollister, it is a pleasure to welcome you, sir, again to this audience.

DR. HOLLISTER: General Greeley and gentlemen: The assignment of a discussion on "The Contributions of Scientific, Educational, and Nonprofit Institutions to Technical Progress" appears to me to be a most timely assignment--timely because these contributions need better identification, timely because these contributions need better evaluation in terms of our present and future national outlook, and timely because of the considerations that must be given these contributions and the institutions providing them if we are to give continuity to our national security.

It might be well at the outset to define the institutions about which we are talking. The first category includes the nonprofit educational institutions, the colleges and universities, which carry on the training of scientists and technologists and which also conduct a considerable amount of fundamental or basic research. The second category includes those research foundations and other institutions which operate without profit and which for the most part do development work. The third category includes those scientific societies organized for the purpose of disseminating the results of research and other investigations to other workers in the particular field.

I have used two terms thus far that need further explanation. One is the term "fundamental or basic research" and the other is "development. By "fundamental or basic research" I mean those investigations which lead to new, broad principles of science. These are based upon a combination of experimental investigation and analytical study. They lay the groundwork for a wide variety of applications, but do not in themselves undertake to spell out what these applications are, or how they may be achieved. At this point the development operation takes over. Based upon the fundamental principles discovered through fundamental or basic research, new gadgets, apparatus, or systems are devised which have a specific objective for use or function. I may illustrate these two types of investigation in this way: The discovery by Roentgen of X-rays and their nature was in the area of fundamental or basic research. A device for the X-ray of metal parts and the development of techniques therefore may be called development research, or simply development.

The great majority of development research laboratories are operated by industrial corporations. Very few of these laboratories concern themselves with basic or fundamental research. By their very nature they are concerned with the immediate fruits of development in terms of a commercial product. Usually the workers in such laboratories participate in patent royalties. Both from the standpoint of the company and from the standpoint of the worker in such a laboratory, more immediate returns are had from commercial products than from basic research.

Even the nonprofit research institutions not connected with colleges or universities receive their research assignments in the nature of contracts either from the Government or from industry. In the main, both the Government and industry are interested in specific end results. The research institution is therefore engaged in the research and development work which will lead to immediate end results. In the end, therefore, the independent research institutions, whether for profit or nonprofit, function largely in the area of development, while the colleges and universities are functioning in the area of basic or fundamental research.

I might interrupt at this point to say that government contracts of a very significant nature have been given by armed service areas and offices of universities and colleges which have to my mind done much to sustain the strength of the universities and protect them against having their personnel siphoned off to other development laboratories.

The technical societies are largely instruments of communication. They provide a forum in which there may be interchange of ideas, which may be carried back to the laboratories for application in either fundamental or development research. This situation, however, did not always obtain. Societies like the Royal Society of Great Britain, Royal Academy of Science in Paris, Royal Academies in Berlin and St. Petersburg, and the Accademia del Cimento were not alone for purposes of communication between the members, but they actually conducted experiments as one

would do in the university laboratory. The early societies, therefore, are to be classed with the colleges and universities; whereas the later societies may be thought of as instruments of dissemination rather than as instruments of research activity.

In order to establish the proper scale of the contributions by these different organizations, a quick historical review of their development would seem pertinent. The oldest of the universities now in existence were founded in the eleventh century. Their programs consisted of two parts, the lower one being known as the trivium and consisting of grammar, rhetoric, and logic; and the more advanced one, the quadrivium, consisting of arithmetic, geometry, astronomy, and music.

Nothing in any way resembling our modern scientific instruction was to be found even in these subjects prior to the seventeenth century. It was in the middle of that century that there was founded, under the patronage of Leopold of Tuscany, the Accademia del Cimento. It was organized in 1657, and lasted only 10 years, when its patron became a cardinal and withdrew his support. During the brief 10 years, however, Torricelli made his famous experiments on the weight of the atmosphere and developed the barometer.

Before this academy was discontinued, there were organized two other important academies, the first in England under Charles II, and the second in France under Louis XIV. In 1700 the Berlin Academy was founded by Frederick the Great. Twenty-five years later Catherine I of Russia set up the St. Petersburg Academy, which was brought to full flower and great strength by Catherine the Great. There was great rivalry, I might say, between Catherine the Great and Frederick the Great as to the status of their two academies; and they spend a great deal of time nursing these academies along, in order to try to vie with each other as countries as to the state of their culture. These four academies were the predominant leaders in development of research in the seventeenth and eighteenth centuries.

I might say that Euler alone, although a professor in the academy at St. Petersburg, upon his death left enough material to fill the next 25 volumes of transactions. His contributions alone run to about 125 volumes quarto. He was the inventor of some of the most important of our branches of mathematics, mechanics, and physics. In the last 14 years of his life he was blind. During that period he contributed alone to the Berlin Academy, partly as a corresponding member and partly as a member on loan to that academy, 70 monographs, one of which was a computation of the perturbations of the moon.

It was not until the nineteenth century that the quadrivium was extended along more modern lines. The quadrivium, you recall, was

arithmetic, geometry, astronomy, and music. Physics and chemistry did not really come into being until the eighteenth century and did not become important areas of university instruction until the nineteenth century. Even at the time of the Civil War, the universities and colleges in this country were set up on the basis that they were strictly liberal arts and classics and were to have nothing to do with these branches of science, which were thought to be strictly vocational.

In our own educational institutions, engineering education was making its feeble beginnings 100 years ago. Research in engineering in our educational institutions did not begin until the latter part of the nineteenth century. In fact, the first graduate degree that I know of was given in engineering in 1870, the first doctor's degree in 1872, the first doctor's degree in electrical engineering in 1885, and the first doctor's degree in hydraulics in 1896. As the educational institutions picked up the work in research, the academies declined in importance as sources of research activity and gradually became organizations for the discussion and dissemination of scientific discovery and information.

We frequently lose sight of the shortness of time since the beginning of the modern scientific era. Algebraic equations were first written in 1591. Our coordinate system of space was established by Descartes just 325 years ago. In the year following, the fundamental beginning in the area of dynamics was established by Galileo, a professor at the University of Padua.

It might be well briefly to review Galileo's work as an example of basic research. He discovered the law of falling bodies. A body falling without resistance from the medium through which it falls will traverse in equal successive increments of time, spaces in the proportion 1 to 3, to 5, to 7, to 9, and so on, which means the square of the height. He announced the first two laws of motion, now known as Newton's Laws; and it is interesting also to note that Newton gave him specific credit for them. The third law of Newton is really only an axiom of the other two. Armed with this basic information, Galileo then for the first time correctly described the path of a projectile moving in a medium offering no resistance. He did not design ammunition, nor did he design a weapon, but he laid the basis upon which the performance of our modern weapons may be predicted.

The nearest to Galileo in predicting the trajectory of a projectile was Tartaglia, who 100 years before him announced without proof that a projectile would continue on its path until nearly spent, would then follow an arc of a circle until headed vertically downward, and would then fall freely the rest of the way. Prior to Tartaglia there was only the theory of Aristotle, who said that a projectile would continue in a straight line until it had spent itself and then would fall vertically to the ground.

Galileo's contribution had two major consequences. He introduced the fundamental laws of motion and of gravitation; but, even more than this, he established the pattern of development of knowledge by experimentation rather than by a system of philosophizing, as had been the Aristotelian method.

Incidentally, it is of interest to note that Galileo was in possession of these fundamental principles before he was 30 years old. It is also interesting to note that in the eighteenth century the next great book on dynamics, which clarified impulse, momentum, and similar concepts and placed them in proper mathematical form for future work, was a Frenchman named d'Alembert, who with Diderot, brought out the great French Encyclopedia. D'Alembert's work in dynamics was published in his twenty-seventh year. I might also say that Newton had possession of fluxions before he was 30 years old. There are many cases that we could identify, if we took the time, of young men, really young men, having flashes of deep insight into scientific systems.

Galileo did his teaching in the area of geometry and astronomy. He was therefore within the pattern of the quadrivium. As I have already said, this pattern did not deviate materially until the middle of the nineteenth century. At the beginning of that century, the schools in Germany and France were becoming strong technologically.

Our oldest school in which engineering has been taught in this country is undoubtedly the United States Military Academy at West Point. Judging from a catalog of its library of 1830, its work was based chiefly on the work of the French engineering schools and the French scientific tradition. This French influence faded out, however, because of language difficulty, and did not become a lasting influence upon our teaching of engineering. Gradually we shifted over to the English tradition, which, except for the influence of the University of Glasgow and Professor Rankine, was not so advanced as were the French and German schools. At the close of our Civil War, there were only six institutions in America teaching anything like an engineering curriculum, and this entirely in the field of civil engineering, which got its name in contrast to the military engineering of the old French and German military schools.

In the rise of the German technical schools, it was a national policy to support these institutions and to staff them as strongly as possible. The best man in each field was to be found in the university or technical school, not in industry or in government agencies. The enormous development industrially of the German Empire up to the First World War was in large part a consequence of this policy of education in the technical field and in other underlying sciences. During the period prior to World War I, it was the custom for a considerable number of American students to take advanced degrees in Germany because of their strong technical position.

Thus in the last 150 years abroad and 100 years in this country, we have seen the rise of scientific and technical education. In other countries institutions of higher learning are operated by state subsidy or direct support. In this country some of our strongest institutions are privately endowed and receive little or no state support.

Over the span of about three centuries, the professors in the learned academies and in the universities and colleges have been chiefly responsible for the development of our knowledge of the basic sciences. Without this knowledge we would still be in the same stage of civilization as was prevalent in the Middle Ages.

But the chief product of these institutions has been trained men—men who could apply these principles; men who could discover new principles; men who could teach others to do these things.

America has still to achieve a leading position in the sciences. Take, for example, the development of nuclear physics. Becquerel, Curie, Einstein, Bohr, Rutherford, and Fermi were all born and educated in other countries. But America is now gaining and will attain supremacy if we can sustain strong programs in science.

It has until relatively recently been the national concept that this country has had an inexhaustible supply of talent. Our rapid rise in industrial strength as a nation has given support to this concept. Until relatively recently, also, the supply of trained men has been adequate to meet the demand so far as the technological field is concerned. At the present time, however, we are experiencing a shortage of both engineers and scientists for the first time in the Nation's history. In fact, we have come to the situation where the supply of technological and scientific graduates is no longer dictated by the law of supply and demand but instead by the birth rate.

Under our national educational policy, we would expect high school graduations to fluctuate with the birth rate, since it is our policy to send all these boys and girls up to a given age to high school. As a result of the depression in the early thirties, we are in a period of lower high school graduations than occurred in 1940. This will not be corrected until nearly 1960, when the trend will again be upward from the 1940 figure. (See chart 1, page 21.)

Why does this shortage persist, however, in the technical and scientific programs? This curve shows in the upper portion the rate of graduation from high school. The zero on that scale is not represented but you can see that we have zigzags up and down. The 1940 figures are in here and the 1955 figures are over here. We now, of course, are right in this low part here in high school graduation. This has its result, of course, in the numbers that may be expected to to on from high school to college.

This, or course, was affected by our entry into the war. It is affected by the GI Bill, so-called. But notice that the level here would average out somewhat below the 1940 figure; so that the total numbers graduating are less than what this was. From here we begin to go up again, after we pull out of the low birth rate following or during the depression.

With approximately 600,000 males graduating from high school each year--the total in both sexes is 1.2 million, and approximately half of those are girls--why should we, for example, be graduating only about 20,000 engineers and half as many scientists? The root of this situation may be found by a deeper consideration of the makeup of our population, a consideration which we have not heretofore had occasion to recognize. The basis for it is provided by the Army General Classification Test, to which I want to pay tribute, which was a great contribution to our knowledge of our own social system. This test was given to over 9.3 million males during the course of the Second World War. It provides a survey of our population on an intelligence basis, the first such survey ever made in this country on so comprehensive a scale. (See chart 2, appearing as page 22.)

I show on this chart a curve representing the distribution of scores made on this test by the entire group tested. This, then, is simply a plot of the relative frequency of the different scores given along the bottom. The median is 100. The high point of the curve comes at about the score of 105. That means that the largest number getting any one score got the score of 105. The largest score gotten was out here at the end, and the chart is cut off here at one-half of 1 percent, or 180; so the chart is approximately symmetrical about the score of 100. Half of the scores are above 100 and half below 100.

In order to give some meaning to what these scores represent, at the beginning of World War II the Army set the score of 70 as the lowest score for acceptance of enlisted personnel. Later in the war this was reduced somewhat. At the other end of the curve I understand that a score of 110 was set as the minimum score for candidates for officer training schools.

Chart II gives attention to the area above the score of 120. I have chosen this score as an approximate dividing line above which must be drawn the technological and scientific personnel from our population. I have chosen this figure after careful study of the significance of this score in terms of civilian occupations. For example, the score above 120 includes the top 10 percent of policemen, fire fighters, locomotive firemen, railway brakemen, crane and shovel operators, truck drivers, structural steel workers, electricians, plumbers, painters, general carpenters, bricklayers, welders, tailors, cooks, and similar skilled workmen. This category also includes 25 percent of machinists, toolmakers, instrumental musicians,

aircraft and airplane engine mechanics, radio repairmen, postal clerks, and similar craftsmen. It is believed, therefore, that this score is not too high to be used as the average bottom limit for technological and scientific personnel.

I might also point out that the intelligence level is not the only criterion for becoming a successful engineer, scientist, doctor, or other person in the high-level fields. He must have other qualities. But first of all he must at least have this intelligence; and therefore it is the prime consideration.

If we consider that the area under the total curve represents 100 percent of those taking the test, the area of the group making a score of 120 or better represents 17 percent of the total. Out of this 17 percent must come all high-level personnel for whatever purpose.

We now have a basis for making an estimate of the number in a given age group, such, for example, as those reaching age 18 in a given calendar year, who may possess the intelligence necessary to study engineering, science, or other high-level subjects. According to census figures there are now and will be for a number of years to come about 1.1 million males coming to a given age in one calendar year. For estimating purposes it will be sufficiently accurate to say that this is the number coming of college entrance age in a given year. Seventeen percent of this 1.1 million is 187,000. This was the number who possessed the required intelligence level successfully to pursue such a course as engineering. It must be borne in mind, however, that this same group must provide doctors and others in the top level of the healing arts; mathematicians, physicists, chemists, biologists, and other scientists; high-level professional and business people; and the upper portion of the skilled crafts.

We can make some estimate of the number of males representing the engineering potential for entrance to college by considering the census figures representing the total number of engineers, doctors, scientists, and others who must be replenished by additions from this top-level group of young men. At the present time there are about 400,000 engineers, 200,000 doctors, and 200,000 scientists. We may allow another 400,000 for professional people of top level and an extra 400,000 for top-level craftsmen. These two latter figures I have discussed with the Bureau of Labor Statistics; it considers them to be low. Nevertheless, I use them for the purpose of arriving at an estimate in the absence of more precise data. By so using these figures the tendency would be to overestimate rather than underestimate the number potentially available. These figures give us 1.6 million total, of which the engineers form one-fourth. The engineering potential will be less than this one-fourth by the extent of the error in using the last two figures of professional people and top-level craftsmen.

We can see then that about 47,000 males from the group of 187,000 represent all that can be expected to flow toward engineering schools under normal circumstances with the population at the present level. This is on the basis only of intelligence. It should be borne in mind that out of this group of 47,000 males there are individuals who do not possess the emotional stability, determination, continuing interest, or financial means to follow through a program of engineering. There will also be a number who have not followed adequately a preparatory training program to enter an engineering institution. We cannot expect out of this group, therefore, to graduate more than 23,000 men, and even this figure will be optimistic.

I might mention that in the fall of 1950, we enrolled in the engineering freshmen classes of this country 38,000. This year it is expected that this number may be up as much as 20 percent. Whether this 20 percent represents people lost from other high-level fields, whether it represents dipping a little lower than 120 score on the intelligence distribution, or whether it represents people smoked through who would perhaps not have gone to college but who might have entered some one of the more advanced craft areas, is yet to be seen. I myself have the view that there will be a considerable shifting around in the high-level fields and that we are robbing Peter to pay Paul.

How many engineers are necessary to supply our normal economy? According to the Bureau of Labor Statistics at least 20,000 are necessary to be graduated each year under the present pattern of utilization. This makes no provision whatever for mobilization effort or for staffing the armed forces and government agencies during such a mobilization period. It makes no provision for the continuing demand of research and development, design, and testing, so essential in maintaining military materiel on an up-to-date basis.

What of the other high-level branches? We may expect that in science and medicine some 10,000 to 12,000 will graduate each year with bachelor's degrees in these fields. Not more than one-fourth of those so graduating would be able to carry on the graduate work essential in those fields.

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What is the significance of these estimates? It is essentially that we are strictly limited in the number of males available for high-level operations of all kinds and that this limit has reached a level required for peacetime operation only, without any extra burden on our economy for military readiness and alertness. It means that

we are faced with a strategic shortage of such fundamental importance that major attention must be given to it in order to provide the necessary national security and internal strength.

On a long-term basis these figures suggest that from now on, the numbers available for top-level activity are limited by the percentage of the total population of a given age group possessing the essential fundamental intelligence to carry on such work. I cannot for myself believe that we can change this kind of distribution curve very rapidly. The intelligence level of the whole group of people will persist with perhaps only very slow changes over the years. In other words a certain percentage of our population, and no more, may be expected to be available for such work. This is a situation which this country has never faced before, and we must therefore get used to planning in terms of strictly limited numbers for assignment to such duties.

Going back now to the figure of 187,000, total males available for allocation from a given age group, we may estimate that about 85,000 of these will graduate from college in appropriate fields for utilization in some phase of the national civilian or military economy. It would appear that by 1954 or 1955 fully three-quarters of this number will be graduating with ROTC commissions and will go immediately to active duty for two years of active service. This will mean that only approximately 20,000 of these high-level graduates will be available for civilian use in all categories of scientific and technological work, including the medical field.

There is no gainsaying the fact that it is essential that officers must be provided for the military forces. At the same time it is equally essential in the interest of national security and internal strength that certain civilian services must likewise be serviced and maintained. But this is only a part of the problem. The major problem, as I see it, is this: How do we do these two things and at the same time protect and enhance the development of new ideas so essential to both our security and internal strength?

One way in which partial alleviation may be achieved is to develop a more effective utilization of the high-level personnel with specialize training in all parts of our economy. Engineers and scientists must not be used for functions that people without such training can discharge with substantially equal effectiveness. The greater use of technical aides must be developed all along the line. This goes particularly for industry, which has had the habit for years of using junior engineers for aides' positions.

Another way is the budgeting of specialized manpower and the careful channeling of the supply to the areas where such persons are needed.

This suggests the possible use of a manpower table for this critical specialized group. But a manpower table operated by the Government would not be very effective. I think it should be operated by the professions themselves, voluntarily, with particular emphasis upon those in industry. In fact, the medical profession is doing something like that at present.

To recapitulate, we have seen that throughout the development of the scientific and industrial era the institutions we are considering are responsible for the development of science and the dependent technology.

There has been a steady rise of technical and scientific personnel in our economy.

We have reached the point where percentagewise no further gain in such personnel is likely.

The demand, even without the threat of war that hangs over us, is increasing faster than the supply.

Without careful planning there will be a slowing down of basic research, so necessary as a feeder to technological development.

The institutions which are responsible for the development of science and the training of scientists and technical men must be kept running if we are to survive.

Considering that we have developed our industrial strength in a mere 100 years, and that the scientific era is only three times as long, so short a period as 10 years is an appreciable proportion of the total. A slowing down or a cessation of such activity will rob us of the only possible advantage we have as a nation.

It is to the great credit of the armed forces that they have in recent years supported so vigorously not only development, but basic research as well.

I will now answer your questions.

QUESTION: Dr. Hollister, I was interested in what I inferred to be our position on intelligence distribution. I just wondered about the effect of modern communication on that, such as radio and television. I have a couple of kids and I have been suprised sometimes at how quick they are and how their curiosity is stimulated by those things. Don't you think that they will have an effect on changing this distribution?

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DR. HOLLISTER: I think that it will help to identify the people with such intelligence, but I don't think it will change the basic capacity.

QUESTION: Then the purpose of that test is to establish the basic capacity regardless of the environmental conditions or anything else?

DR. HOLLISTER: It is always difficult in any psychological test, I think, to avoid some influence of the environment situation. But the tests given are calculated to study intelligence as a basic factor, rather than to do so in terms of what they might be able to do at the moment.

QUESTION: What happens to the law of supply and demand if engineers and scientists are so overwhelmingly important in our economy? Why isn't the Government, business, and everybody else paying them enough money to attract these young men into these engineering schools?

DR. HOLLISTER: As a matter of fact, a good deal of that is going on. I am conscious of the fact that the prewar salary for young engineers was lower than it had any justification of being in terms of their functions. But you must also take into account the fact that medical students who have graduated with a bachelor's degree and want to train frequently have to pay the hospital in order to be interns. It is that kind of system that is apparently at the bottom.

The justification of college training in the cases of most of these people does not come in the first 10 years out of college. It is what happens to them after the age of 35. And I rather despair; in the face of rising living costs and the high tax burdens which the parents of these students have to bear, so that there is a squeeze both ways, there is a tendency not to send boys to college or to send only one out of a family, whereas two or three might have been capable of doing college work.

So the law of supply and demand is not working freely. And I think it would distort the picture considerably if it did work freely, because there would be violent ups and downs, which I don't think would be very healthy in any particular branch of our manpower.

QUESTION: During the late twenties and the thirties I think most of this audience would say that our colleges took great pride in applying the grade curve, resulting in a great wastage of manpower. Are we still adhering to the diabolical grade curve? Have we taken any constructive steps in the institutions of higher education to conserve that valuable manpower?

DR. HOLLISTER: I might explain that there are very few faculty members left who were faculty members prewar. This may be a good thing, for several reasons. But I quite appreciate the point that you raise, which I know has obtained in some instances.

However, in a review of the situation in the immediate postwar period we got used to a lot of GI's who were more mature, who hit the line with force, who would stand no foolishness, who would hold the instructor to scratch. Our instructors pulled up their socks, so to speak, and really liked this kind of thing.

But then the GI's faded out and the normal flow from the high schools arrived, and couldn't hold this pace. The next thing we knew we were denuding our schools to a very high extent. We are now in the process of adjusting to this.

At the moment we are making a national survey of the attrition among engineering schools, just to cover this point, to emphasize what we want to do, and that is to teach these boys and not send them home. And in my own institution we find that we are now running about 30 percent mortality on academic causes. We have, however, a total of 50 percent if you take also other causes than academic. For example, some of our boys have switched to history or agriculture or the College of Arts and Sciences. They are out of engineering anyway, and have that effect on the statistics.

QUESTION: Are you allowing any credit to the boys who come out of their war experience with some technical knowledge? For example, I noticed that at some of the graduate schools in Washington these boys are coming back and trying to get credit for electronics, communications, and other things that they learned in the service. Are we making provision for accrediting some of those things that we in the armed forces have taught them?

DR. HOLLISTER: Well, during the war there was a program carried on through the Office of Education, known as the ESMWT program, the Engineering, Science, Management War Training Program. They trained over a million people in such courses. They were given by the colleges, but not intended for credit.

It has been the custom of colleges generally to give every possible consideration to extending credit, not as an offset against the course as such by credit, but not to require work to be repeated. So in that sense I think that the point you raise is being covered in every possible way where it really has taken the place of a portion of the program that the school itself requires. I think the schools are doing everything they can in that direction.

QUESTION: There is quite a gap there in the estimated requirements for engineers. I understand that some of the current reduction of engineer school enrollment is due to a previous prediction of the number of engineers that would be needed. Would you comment on how they arrived

at their estimates of the needs, whether it was on the basis of the wartime boom?

DR. HOLLISTER: No doubt that has a good deal of the element of wartime boom. The first curve that I showed (see chart 1 at end of lecture) had a very large shaded area. But the need was determined by an industrial survey. There was an extensive questionnaire operation that went on through industrial statistical sampling. Then the sample was blown up to approximate a national figure.

Whether those figures are correct or whether they are not is somewhat beside the point. They cannot be more than a relatively small percentage in error. But the basis for any such estimation must be the pattern of utilization that is current in industry or current among whoever uses engineers; and this pattern has been such that for the first few years they have been using them as draftsmen, inspectors, and so on, whereas they should push them along at a more rapid rate.

I have taken occasion to hold up the military as an example to industry in the utilization of manpower by pushing up the responsibility of the man at a more rapid rate than industry normally does. I believe this is a situation that industry needs to study, and that industry is at present studying.

There has been during the past year a considerable revision in some of our major corporations of the placement of their engineers and the utilization of them in function, the bringing in of aides to do work that could be done by aides, in order to let the other people move up.

But I think this has got to be done a whole lot more than it has been done. I think it affects such things too as our ROTC, if I may speak candidly, because in some cases we have the training of general service officers, regardless of what their college program may be, and the utilization of those men in the professions as general service officers--for instance, as deck officers in the Navy.

Now, it is true, I am sure, that an engineer can make a very good deck officer. But does he need to be an engineer, when we are so short, even in the Navy, of engineers? Do we need to use them as deck officers?

I think all parts of our economy have got to look at this particular question in that light. Is there any way in which we can distribute these men to achieve their effectiveness more specifically? In the medical field the doctor is reinforced by therapeutists, nurses, orderlies, and various other people. The doctor himself is, therefore, extended over a larger area. And he again is required to assume a responsibility at a relatively early age.

So I think that these are factors that must require fairly careful and thorough study and high-level determination if we are to hold the line and distribute the engineers that we have, in order to get the best advantage out of them.

One of the sad parts of our utilization of engineers is that many of the older engineers are obsolescent in their engineering knowledge. They are therefore not available for use in any modern technology. I think there is going to be a tendency in the engineering colleges to extend, expecially in the scientific area, the amount of training given an engineer. Several institutions, including my own, have gone into a program for this very purpose.

QUESTION: You spoke about the small number of males in the population who are on a level to take engineering training. What is the possibility of using women in these fields to relieve the situation?

DR. HOLLISTER: There is a great opportunity for women in science. Especially there is a considerable opportunity for them in engineering. There is no reason why they shouldn't go into that. In fact, I know of some women who are in metallurgy, in chemistry, and in engineering, and in some phases of mechanical engineering--I even know of some who are civil engineers--who are practicing and who are doing very creditable work.

But, seriously, women veer off at about the college age, and they are looking for marriage; and the problem of combining professional work with marriage and a young family is a difficult problem, which we so far have not, in practical terms, solved.

But women themselves seem to offer resistance. I don't know of any college, outside of those institutions which declare themselves to be only for men on a total basis, any engineering college, which would reject a woman because she is a woman.

I know of many engineering colleges which have gone out of their way to try to attract women. We have ourselves tried to attract women to the engineering profession, because we think that there is no reason why they cannot, in certain areas at least, be perfectly able to carry on the work. It is not a question of competence. They have the competence and the proper intelligence levels. But it is a question whether they can combine it in with marriage.

QUESTION: Is there any prejudice toward them on the part of industry?

DR. HOLLISTER: I will say that there was until the Second World War. The only prejudice that I know of that exists now is based chiefly on the lack of stability of employment, and not upon the fact of their being women.

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QUESTION: You reminded us of the fact that the capacity of research foundations and universities is maintained very largely by contracts or funds received from the armed forces. I would like to ask if you think this is the best possible avenue through which to channel that considerable government effort. In other words, do you think it would be wiser and more profitable to the country if that sort of thing were administered, say, by the National Science Foundation rather than the armed forces?

DR. HOLLISTER: I am sure that so far as educational institutions are concerned, we prefer the latter arrangment for administration, that is, through the National Science Foundation. But the National Science Foundation has been unable to get the necessary appropriations to do that. We are all for it and ready for it, but they don't have the money.

I think the purpose of setting up the National Science Foundation was to do this very thing. I cannot speak too highly of the contributions made by the Office of Scientific Research and Development during the war to our war effort. I think it was of fundamental importance. It had many ramifications in civilian life, and it had a very deep significance in the military effort. I think that the National Science Foundation is the proper agency through which to feed this kind of program.

I think, if we did that, it would result in diverting some funds away from military things to go into purely basic research. I think, too, that the development work, which is going to result in military equipment and military systems, is a proper field for the military to be sponsoring for research, and that area should be followed as it is at the present time. With respect to basic research, however, although we are greatly indebted in this country to the armed forces, I think it would be better national policy if that went on through the National Science Foundation.

QUESTION: Would you comment on the progress that has been made in the development of interest tests to be given students at the time they enter college? I am interested in what might be done to give students these tests to get them into fields for which they have some ability and therefore avoid wasting time by their getting into engineering when they would be better off in law or something like that.

DR. HOLLISTER: Our experience with interest tests has been largely that the conclusions based on them would be very short-lived. I recall one boy who said he didn't want to be an engineer. He had had ample opportunity to be in contact with engineering. He thought he would like to be a journalist. It turned out that the only reason why he wanted to go to a school of journalism was that nearby was a girl in a women's college that he wanted to focus his attention on. He was persuaded that perhaps journalism was not his dish, and he was quite at sea until he got into the Signal Corps in an ROTC unit. He went to camp at Monmouth and there he got playing around in the monitoring room. When he came out of

the Signal Crops, he decided he was going to be an electrical engineer. I don't know how it would have been possible to discover prior to this sudden awakening of interest the fact that he might find his niche in electrical engineering.

QUESTION: Did he take an interest in anything at any time that showed that he was interested in some other field?

DR. HOLLISTER: I must admit personally that I have a good deal of skepticism about how much dependence can be placed on the tests. A change in the environmental situation makes such a total change.

Now, when you deal with aptitudes, then you are in a different area. But when it comes down to interest, it is the turn of the moment that may settle the man. It may not even be best for the individual, although he may be very keen for it. There is no way to detect to what extent this may be phony. So far as the tests that I have seen in operation are concerned, I am sure that the interest test is not one that I personally would place reliance on.

QUESTION: You mentioned earlier that most of the basic research prior to the last war was derived from outside the United States, and gave some historical examples of what was done in Europe. Would you recommend that there be established in this country a type of Royal Academy for scientists and engineers? Do you recommend that some specific action or program should be undertaken by the Government to subsidize professorships at various universities where there are outstanding scientists, so that we could engender some type of basic research?

DR. HOLLISTER: I think that is a very searching question. One of the sad things about the present time is the fact that so many of our top-level people in science and engineering can be drawn off into industry. Not all of them want to go into industry, however. Some of them want actually to lead an academic life, which is not an easy life, I might say. It may be to some, but it is not an easy life for anyone who is inquisitive when there are so many things that he would like to get into if life is to be a really full one.

But there are so many restrictions in industry where a man doesn't have the freedom of opportunity to pursue his interest that exists in the universities, so a lot of them prefer the university. But, even so, some of them are attracted to industry. A laboratory is built around them in some cases. I don't want to mention names, but I am sure you can conjure up the names of industries which have done just that and exploited the name of some scientist on their staff year in and year out as being a contributor to the welfare of the country, to say nothing, of course, about their company.

Those schools in Germany that have held to such a high level have received Federal subsidies from the German Government to equip their laboratories and keep them operating at a high level. Industry itself in some cases would appoint a professor as a consultant or would make some arrangement by which he could aid in subsidizing the maintenance of the professor through the institution, so that he could train more hands and more minds.

Now, we haven't done that in this country. We have reached the place where we have got to begin to think about policies of this kind and actually put such policies into effect. Here again, I think the National Science Foundation is the agency to take the lead, if it can get public support. But the public failure to recognize this situation is one of the deterrents that affects Congress so far as its action is concerned. It will act if it feels that the public is behind it. It will not act if it is going to be held up to ridicule by the public.

There is another part of your question which seemed to me to be very significant. That had to do with the support of the institutions that carry on this kind of work. Here again, the higher educational institutions are under the spell of the American public. In the first place, according to the public sentiment, everybody has to go to high school. In the second place, my boy and Mrs. Murphy's boy, if they are capable of high school graduation, should be admitted to a tax-supported university.

But universities that are publicly supported through tax money are subjected to many kinds of pressures. I know of a delegation that went to a State university demanding to know why so many boys were sent home from the freshman class. Yet in that particular case the institution was obligated by law to accept anybody who walked in the door with a diploma from an accredited high school, and the accrediting of high schools is not under the university's jurisdiction or cognizance. You can see how loose a system can develop, and why it is that in so many areas in the colleges more and more easy programs have been devised in order to take the heat off in view of the public concept of what they mean by democracy.

For my part, democracy does not extend so far that we have to put everything through the same die. I think we have accomplished the concept of democracy when we have made available to every person in our population an opportunity on a common basis. If he does not choose to follow through with this opportunity, then, so far as democracy is concerned, we have discharged our responsibility. I feel that there is an obligation on him to do the best he can. And in the same way I feel that there is a universal obligation on the part of every member of our country, every part of our population, to assume responsibilities for the operation of our country and for its defense. And I have been from the beginning a very keen believer, not in universal service, but in universal military training. I believe that is the pattern that we should have.

QUESTION: I lost some of your figures when you were speaking of the annual output of engineers. I would like your comment on the possibility of drawing some of next year's crop this year, in this sense: I imagine that in the student body who would be seniors next year there are probably variations, and that some proportion of this year's junior class might be graduated and put to work, as it were. I wonder if in that way we might draw them one year ahead of time and then keep them for the rest of their lives.

DR. HOLLISTER: We have tried accelerated programs. They have been considered by colleges. We have found that the boys themselves don't want them and can't afford them. We have the problem, therefore, of picking up the check that the boys themselves have picked up through summer work. That is one practical matter, and this affects more than three-quarters of the boys in the engineering schools.

Another one that would arise if you should undertake to shorten the program, would be that in the opinion of a great many of those in charge of engineering education we are not giving enough training now. Therefore, if these boys are going to function properly, we could not afford a reduction of the training program.

We have been following closely some of the work in some of the companies, and it would be my observation that there are today, even with four years of training, schools that are not turning out the kind of graduates that are essential and that the companies would like to have to put immediately to work after graduation in the development areas. They do not have sound enough training in physics, in chemistry, and in mathematics to meet modern needs. If they can't meet the needs right now, immediately after graduation, what does the future hold for those same people? And this is a considerable problem.

In the correspondence school area, which we have studied, it has been shown by observation that you can expect such training to work out successfully if the basic work is already in possession of the individual. But you cannot normally use self-study in mathematics or chemistry to the extent that you can in the application of the basic principles.

QUESTION: On this question of quality that we were discussing just a moment ago, could not a great deal be done by having in your high schools two types of courses, one of which was recognized as a sort of college preparation course, and then a course for the rest of the students, those who wanted to just get through and get their diploma without being labeled "dummies." Couldn't we make some progress in that direction and get better quality in the colleges and get our quantity also?

DR. HOLLISTER: I think this is a suggestion which would meet with general acclaim. The situation in our high schools for the graduating class of 1952 is that about 10 percent met the tests for quality. We can lift that to 15 in some schools, and that still leaves us with a small group. The schools cannot afford to take this small group off to

one side for special handling. So it gets down to the economics of high school operation.

We are discussing in some States now with the departments of education the possibility of undertaking advanced courses for these students, giving them a separate pattern, giving them a different load for the same pattern of education. We feel that we should work on that, because one of the great shortages of preparation in coming to college is that they don't know anything about how to work, how to study. They learn that just by having work piled on them. This would be a very good thing and probably the most economical way for the small high schools.

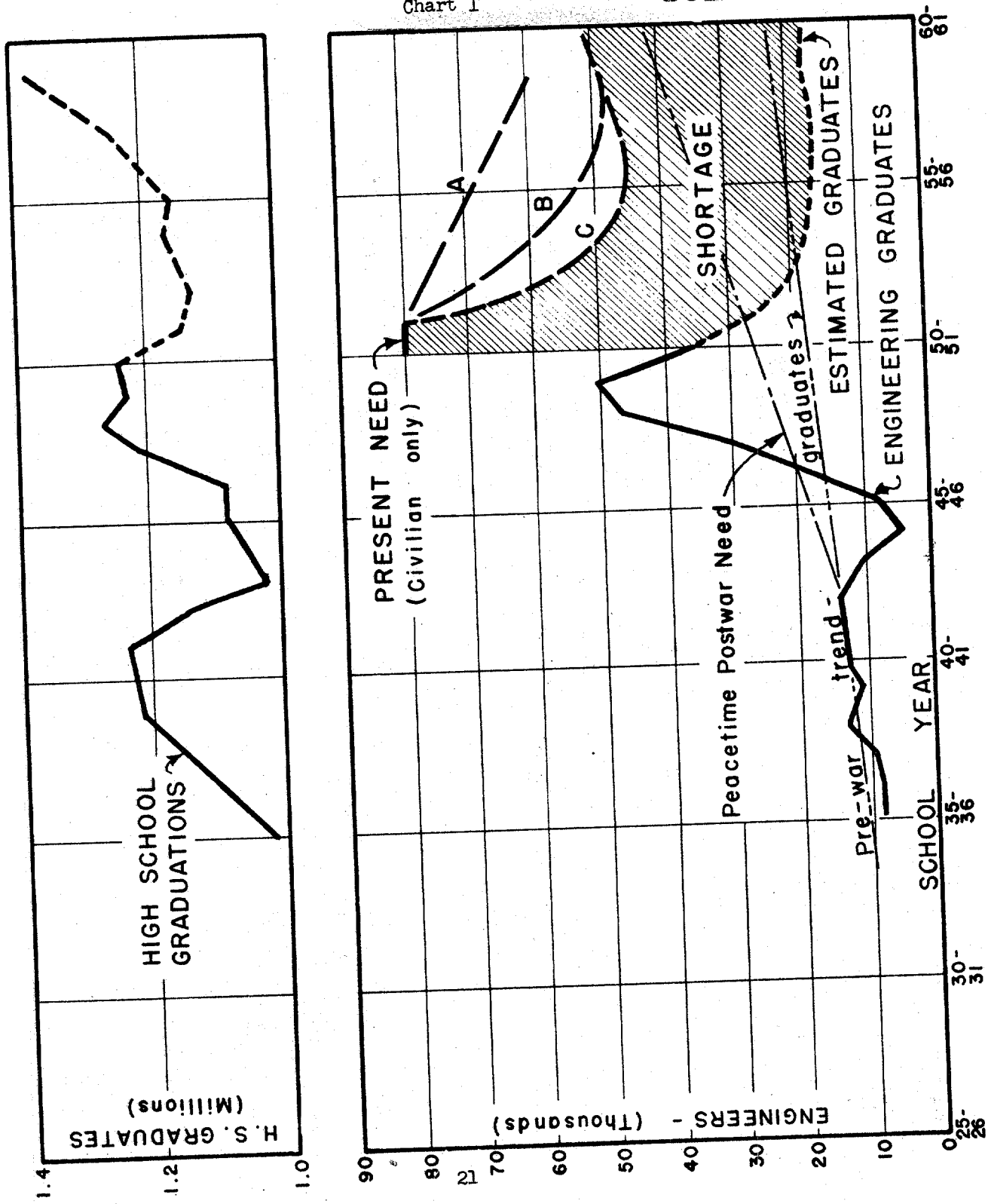
In the large high schools, say in New York City, there are two high schools that are set up just for the purpose of segregation on a talent basis. There is one high school, called the Science High School, which has an enrollment of between two and three thousand, and about 98 percent of them are headed for college.

QUESTION: What sort of results are coming from that program?

DR. HOLLISTER: Very good. In the larger centers, where it is feasible, it is actually being done. We have it in this city, in McKinley High School. In Cleveland there is one high school on the south side where the record is 4 percent for college. They are down near the soap works and so on. Up in Shaker Heights, however, there are over 30 percent going to college. So there is a different handling problem right in the same system.

CDR. ENGLISH: Dr. Hollister, time seems to have run out on us. On behalf of the college I want to thank you very much for your lecture and for a most enlightening and interesting discussion.

Chart I


H. S. GRADUATES
(Millions)
1.4
1.2
1.0
HIGH SCHOOL
GRADUATIONS
ENGINEERS - (Thousands)
90
80
70
60
50
40
30
20
10
0
PRESENT NEED
(Civilian only)
A
B
C
SHORTAGE
ESTIMATED GRADUATES
ENGINEERING GRADUATES
Peacetime Postwar Need
graduates
trend
Pre-war
SCHOOL YEAR
25-26
30-31
35-36
40-41
45-46
50-51
55-56
60-61

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APPENDIX I (Contd.)

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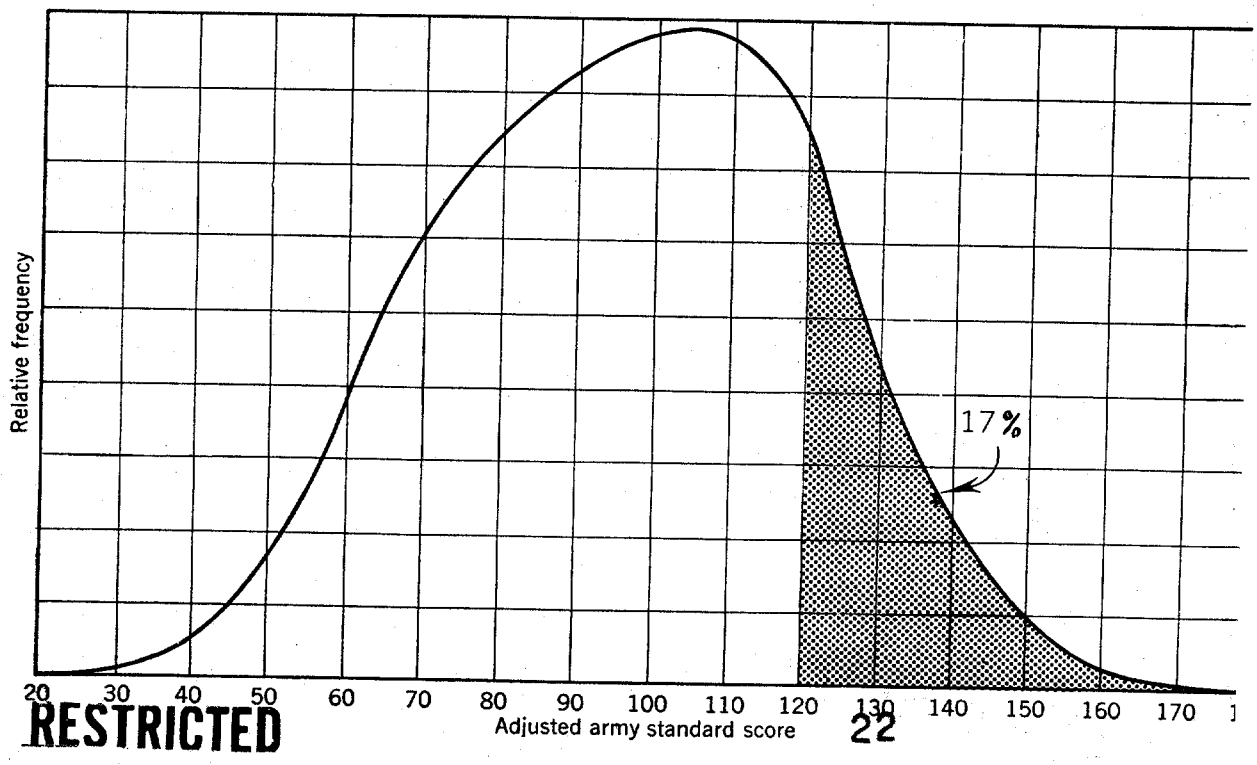
Chart II

Adjusted distribution of scores made on Army Classification Test in World War II showing percentage of trainees in various intelligence ratings



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APPENDIX II

THE ENGINEERING SHORTAGE CONTINUES*

by S. C. Hollister
Dean, College of Engineering, Cornell University

Last autumn a survey was made by the Manpower Committee of the Society to ascertain the outlook for engineering graduates in the immediate future. The result was that the freshman class was found to be substantially below that of 1949--a drop of about twenty percent.

During the winter, much publicity was given to the shortage and its consequences upon the welfare and security of the nation. Special attention was given to informing high school principals and counselors concerning the great need for engineers. It was noted that instead of a prewar rate of 5.8 percent of male high school graduates who entered engineering schools, only 4.8 percent elected this profession in 1950. Many hoped that the effort to inform secondary school officials of the situation would result in a larger freshman class in the fall of 1951.

As of June 1, 1951, the Manpower Committee made a survey of the 34 colleges that had participated in last fall's survey, to obtain the best estimate of the size of the freshman class of this coming fall. The result of this survey indicated that the expected class would be of the same size as that of last fall. Thus it appears that during the last year there has been no appreciable increase in the percentage of high school graduates desirous of entering the study of engineering.

There is little doubt that a variety of factors are responsible for the sustained low rate of students entering upon engineering. Before the outbreak of war in Korea, there was a much-published and mistaken anticipation that there would be a great over-supply of engineers; and to some extent this notion still lingers. In some quarters high school guidance counselors are reluctant to advise a boy to take an engineering course when there is only one chance in two that he may graduate (not realizing, no doubt, that the same ratio applies to collegiate work as a whole). Interesting careers for boys with similar aptitudes are developing in other field. The generalization of high school training may not provide the necessary entrance requirements for engineering unless the choice is made early; and some boys do not reach a decision soon enough. These factors, and no doubt others, tend to restrict the number that may enter engineering from high school. The writer believes that any substantial increase in the number so entering will be slow in maturing; but also that it is essential to work diligently toward achieving this end.

* Presented before the ECAC, at East Lansing, June 1951.

About a year ago the writer was brash enough to make an estimate of the annual need for engineering graduates, and placed the figure at 30,000. The Bureau of Labor Statistics had previously estimated the need through the 1950's as gradually rising from 18,000 to 22,000 over that period. This agreed with the pre-war trend of engineering graduates given in the writer's paper in this Journal in March 1949. Allowing for 10,000 needed by the armed forces as engineering specialists estimated from the Report, for a 3-1/2 million man military force, gave a average total over the period of 30,000. This did not, of course, make any provision for utilizing engineers in positions in which no engineerin training is required. At the time, some thought, and time proved, that this was far too conservative a figure.

Early in June 1951 the Engineering Manpower Commission made a survey of 378 companies and government agencies, to determine their immediate need of engineers. The result of this survey indicated a total national need of 80,000 engineers, quite independent of those needed in uniform. Against this need there were graduated 38,000 men, half of whom, the Manpower Commission determined by survey, were commited or subject to military duty. The unfilled demand as estimated by industry was therefore 60,000 by the end of June.

Some persons believe that the industrial and governmental estimate of engineers needed is too high; that it is not a shake-down figure of real need. I can only say to this that many industries expressly stated their estimate was not inflated and that it was realistic. The fact is, furthermore, that there is no other dependable figure available, and no way to get one except by the method employed in obtaining this one. Even if one discounted the total figure by 25 percent, or 20,000, there is still no comfort in the resulting unfilled shortage of 40,000.

What is the outlook? What is the important significance of these figures?

There is great risk in attempting to forecast the situation respecting manpower over the next few years; yet the writer believes the present status of engineering manpower to be so critical in the nation's welfare and security that every means available should be utilized to make adequate preparation for the future. Appraisal must be made with what evidence is at hand, without awaiting the elusive and practically unattainable perfect data.

The first factor of importance (see chart 1/) is that there is a wholly inadequate supply of engineering graduates to meet the ultraconservative estimate of need of 30,000 per annum. The best efforts at increasing interest of high school graduates may add 4,000 or 5,000 to the annual graduations in engineering--but not before 1956. With the addition of 5,000 that year the total graduations would be only 22,000.

1/ Chart has been detached and used as chart 1, appendix I. (See table of contents for position.)

The second factor of importance is that at present enrollments, and with no withdrawals for military service of any engineering students, there will not be enough graduates by and after 1953, at least to 1961, to meet the peacetime need as conservatively estimated by the Bureau of Labor Statistics, the shortage being at least 20 percent.

The third factor of importance is that during the post-war four years prior to Korea, 149,000 were graduated and employed. This is a greater rate than that of the pre-war years upon which the Bureau of Labor Statistics based its peacetime estimate for the 1950's, by nearly 90 percent. A conservative estimate of post-war peacetime need would appear to be 30,000.

The fourth factor of significance is that the industrial and governmental civilian need of engineers is far greater than the graduating class of 1951 (38,000). Whatever the military requirements for engineers may be, they are not available except by taking men from industry; thus further intensifying the needs of industry.

The fifth factor of significance is that all considerations of need are based upon the current pattern of utilization of engineers by industry and government. The first step toward bringing need and supply toward better agreement will be to change the pattern of utilization through spreading the engineer's work over a greater range, and thereby lessening the need. The extent to which policy decisions by industry and government can in this way achieve a modification will determine the extent of the reduction of need (see curves A, B or C, on chart). In any case, it does not now appear that by any present or likely pattern of utilization or available source of supply the need and supply will be brought into balance over the next decade.

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