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CRITICAL INTERFACES FOR ENGINEERS AND SCIENTISTS, 4 APPRAISALS. PROCEEDINGS OF THE ANNUAL JOINT MEETING OF THE ENGINEERING MANPOWER COMMISSION OF ENGINEERS JOINT COUNCIL AND THE SCIENTIFIC MANPOWER COMMISSION, NEW YORK, MAY 18, 1967.

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Contained in this booklet are the speeches given at the annual joint meeting of the Engineering Manpower Commission and the Scientific Manpower Commission. Each dealt with some problem aspect of the engineer-scientist interface. The presentation by Rear Admiral W. C. Hushing of the U. S. Navy was entitled "The Impact of High Performance Science and Technology on Manpower Requirements at the Undersea Interface," and dealt with some of the problems encountered in man's extended use of the sea. Rear Admiral William A. Brockett, U. S. Navy (retired), was concerned with ocean engineering education, and in particular, the program at the Webb Institute. Dr. Milton Harris in "The Education-Industry Interface" pointed the growing gap between industry and the universities and offered suggestions for improved mutual understanding. "The Technical Man and the Industrial World" was the concern of David Allison, who dealt with the problem of education obselescence in science and engineering and with possible solutions through adult continuing education. (DH)

CRITICAL INTERFACES

FOR ENGINEERS AND SCIENTISTS

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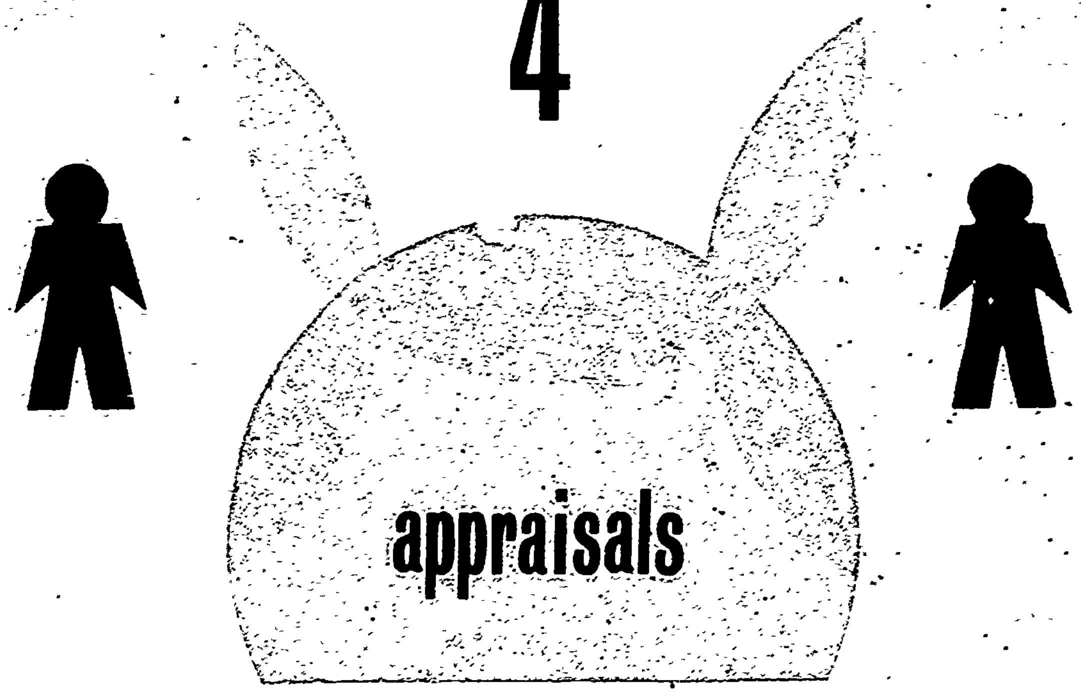

A REPORT FROM THE

ENGINEERING MANPOWER COMMISSION

OF ENGINEERS JOINT COUNCIL

Critical Interfaces for Engineers and Scientists

. . . . Four Appraisals

Proceedings of the annual joint meeting of the
Engineering Manpower Commission of Engineers Joint Council
and the
Scientific Manpower Commission

New York, N. Y. May 18, 1967

Engineers Joint Council
345 East 47th Street
New York, New York 10017

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Preface

The Engineering Manpower Commission, a standing committee of Engineers Joint Council, and the Scientific Manpower Commission, an independent organization representing eleven major scientific societies, have worked in close cooperation since their founding in the early 1950's, recognizing the parallel interests of engineers and scientists in most manpower problems today. A regular feature of the program of the two commissions is a joint meeting held annually, with each group acting alternately as the host.

The 1967 meeting was held in New York on May 18, 1967, and featured four speakers, each of whom talked about an interface where problems existed or were anticipated between engineers and scientists on the one hand and some aspect of our surroundings on the other.

As so aptly pointed out by Dr. Milton Harris, one of our speakers, interfaces can connote resistance to the transfer of ideas, or they can be viewed as a common boundary connecting two areas of mutual interest. This program was aimed at defining the areas of mutual interest as a means of breaking down resistance to the diffusion of knowledge and talent across interfaces of great concern to our society.

John D. Alden

Executive Secretary

Engineering Manpower Commission

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About the Speakers

Rear Admiral *William C. Hushing*, U. S. Navy, is an Engineering Duty Officer with an extensive background in submarines. He graduated from the Naval Academy at Annapolis with a degree in electrical engineering, and from M.I.T. with a master's degree in naval construction and marine engineering. He has also attended the advanced management program at Harvard Business School.

In his 32 years of naval service he has participated in all phases of submarine design, development, construction, and operation. He was the Supervisor of Shipbuilding at Groton, Connecticut, for most of the Polaris program, and since 1964 has been Commander of the Portsmouth Naval Shipyard, where he has continued his direct involvement with man's challenge to the "hostile ambient" of the undersea environment.

Rear Admiral *William A. Brockett* has been since July 1, 1966, President of Webb Institute of Naval Architecture at Glen Cove, Long Island. At the time of his retirement from 36 years of active duty in the Navy, Admiral Brockett was Chief of the Bureau of Ships and, as such, the leading Engineering Duty Officer in the Navy. He was educated at Annapolis and M.I.T. and completed advanced management work at the University of Pittsburgh and Harvard Business School. His career has involved extensive experience with government, industry, and education, and he is currently particularly concerned with the problem of bridging the gap between education and employment on the part of undergraduate students.

Dr. *Milton Harris* is, among many other things, Chairman of the Board of the American Chemical Society. Up until last May, Dr. Harris was vice president and director of research for the Gillette Company. Since his retirement, he has devoted his time to public affairs and serves on numerous corporate, educational, and governmental advisory boards, including the President's Office of Science and Technology, and a number of industrial boards of directors. Dr. Harris is a graduate of Oregon State University and Yale University and is an active member of the Yale Alumni Board and the Yale Development Board. He has long been particularly interested in the problems of scientists facing the transition from education to industry.

David Allison is Senior Editor of *International Science and Technology*. He was one of the founding editors of that publication when it was established in 1961. Since then he has written numerous articles for the magazine, dealing with such subjects as technical education, technical management, and the world of science and politics. Prior to joining the new magazine, he had been an editor and writer at Time Incorporated — from 1956 until 1961. Prior to that he had been an editor and writer at Business Week magazine — from 1952 to 1956. In addition to his activities on *International Science and Technology,* he is active in the affairs of his alma mater, Rensselaer Polytechnic Institute. He is also consultant to various agencies of the federal government — most recently to the newly created National Council on Marine Resources and Engineering Development.

Engineering Manpower Commission of Engineering Joint Council

The Engineering Manpower Commission of Engineers Joint Council is charged with the responsibility of developing programs to:

1. Aid in establishing the importance of engineering to the national economy.
2. Aid in maintaining an adequate supply of engineers.
3. Promote the effective utilization of engineers in support of the national health, safety, and interest.

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Scientific Manpower Commission

The Scientific Manpower Commission is a corporation founded by the societies listed below. The charge in its constitution calls for: "the collection, analysis and publication of data regarding the manpower resources of the United States in the fields of science and technology; the promotion of programs of education and training of potential scientists and technologists; the promotion of the proper utilization of scientific and technological manpower by educational institutions, industry and government; all devoted toward aiding the development of our country's scientific resources for the benefit and welfare of our people."

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THE IMPACT OF HIGH PERFORMANCE SCIENCE AND TECHNOLOGY ON MANPOWER REQUIREMENTS AT THE UNDERSEA INTERFACE

by *Rear Admiral William C. Hushing,* U. S. Navy

My main purpose is to share with you some of my concerns in dealing with the sea as a hostile environment; not that we are not used to dealing with hostile environments, but mainly that the sea is not fully recognized for the hostile environment that it is.

One of the things that I had hoped in this was to be able to consistently use, as a comparison, the very pleasant non-hostile environment that we should have in the springtime, and I was hoping that I would be able to bring to you stories of blossoms in the air and so on. But a little farther north of here, they call this the "hostile spring," and so some of the spring weather is not going to be as comparative as I would like.

Let me deal primarily then with the problems we are going to be seeing in the future, rather than those we have seen in the past. Specifically I want to consider not only the problems of exploring the ocean, but of using it as well.

Now, there is a great desire — an increasing desire, which is exemplified in the federal budget increase, and the very substantial increases in corporate budgets — to explore the ocean, to exploit it, and to make it a part of the earth which man regularly uses. But in all of this, there seems to be a great pinkness, an aura of "there is no problem." In fact there seems to be an attitude that all we have to do is to devote a little money, a little interest, and all of a sudden the wealth of the ages will be available to us. It's not so, and I think any of you who have been associated with the sea, even in a yachting way, can certainly recognize that the sea is hostile to those who do not prepare themselves to live in it.

One of the things, of course, that man has always done is to utilize the sea surface, the interface, as a convenient way of transporting himself from one place to another by his own locomotion, or by winds at the interface working on sails, or by some sort of propulsion. Man has only in a very limited way attempted to go into the ocean, and he has never stayed there very long. What we're talking about now is that sort of situation.

The challenge we are facing today is man's desire to take complex submersible, and far more important, immersible vehicles into the ocean to perform useful work; this *does* include military purposes.

The desire is great, and it is well received by our nation, as it is being increasingly received by the other nations in the world. But this desire automatically imposes upon us great constraints. These constraints generally have to do with physiology, and with engineering developments. I'm not going to talk to the physiological side of this, but rather to the engineering side, since this is your main interest as well as mine.

Some of the more severe design and engineering constraints that the sea brings to us are quite clear to those of you who do yacht. They are quite clear to those of you who go on ocean voyages; and obviously they are quite clear to those who use the ocean and its interface with air as the major avenue of commerce and transportation.

When we look at the kinds of restraints that are put on us when we want to use the ocean, we've got to look to the forces involved, the kinds of things we must be considering all the time. Obviously at the interface we have some very serious problems. Sea slap forces, for example, on external structures, particularly topside structures like the superstructures of ships, are very tremendous. We see, frequently, storm damage in freighters; we see storm damage even in naval ships. And we often see a case of a ship being sunk purely as a result of sea slap — surface forces on its superstructure and hull.

There are large static pressures when we go below the surface; and these static pressures increasingly result in hull forms which are not optimum for surface operations; and therefore we must consider whether we're going to operate from a surface viewpoint or a submerged viewpoint. We can't have both. Obviously we get into an engineering compromise situation, so that the constraint of deciding where we will operate most is a very important one in our considerations.

Large impact forces tend to reflect themselves on the structures that we are using at the interface between man and the ocean. Impact forces could be such things, of course, as submersibles running into submerged objects on the ocean floor; submersibles running into each other in their quest for a transportation runway or as they seek to exploit the ocean floor or perhaps the ocean itself in a pasturing, mining, fishing, or food growing operation. Of course, as far as warships are concerned, the large impact forces that we see most regularly are those of shock, resulting from depth charges or other underwater explosives. In any event, all submersible and immersible structures will be without any question seriously affected by the requirements of being able to survive large impact forces when submerged.

These considerations clearly lead to heavy structures. All of these considerations indicate that the vehicles which we will be using in this transition period of the next few years, are going to be peculiar as far as most United States technology is concerned. We have a very tremendous engineering technology, and a great deal of literature and experience on thin wall structures. We have very little, really, on heavy wall structures. We have very little, really, as we concern ourselves with the problems of highly restrained structures in a compressive type situation. So, the very problem that heavy structures create for us, creates the need for almost an entirely new line of technology.

Now, don't misunderstand me. There have been some attempts at this; and obviously you immediately think of some of our submarines. But we must remember that they operate, really, only in the very uppermost thin layer of the ocean. They do not descend to great depths, and unfortunately they must also, in addition to being good submersibles and immersibles, have some surface characteristics. So they're not necessarily the kind of vehicles that I'm talking about as being the heavy structures which we must be prepared to design and build and live with in the future.

All of us are quite aware of the corrosive nature of the sea, and the fact that it causes us to seek special materials. There are very few such materials, and there is not enough literature on the effects of the corrosive atmosphere of the sea under the kinds of stress conditions that we can expect to face in the not-too-far-distant future for exploitation of the sea. There is very little in the literature, for example, of the corrosive effects on steel or non-ferrous materials at pressures of 4,000 to 5,000 pounds per square inch, with accelerated erosive forces. Clearly, here is an area that we are going to have to do something about.

Machinery immersed in sea water is, of course, always subjected to pressure, unless it is contained within the structure that we're going to use. If it's contained within the structure, it is parasitical. It makes the structure bigger. It makes our payload smaller. Therefore we are going to have to look more and more to the kind of machinery which can operate in the sea, with direct contact of its operating parts with the sea water itself.

There is obviously a lack of natural illumination at the bottom of the ocean, and one of the problems that we will then carry with us all of the time is the need for illumination. I don't necessarily mean light in the sense that we are seeing it here, but rather some mode of illumination which will provide us with an effective way of "seeing" what we want to see. It could be light. It could be electroacoustic in nature; or it could be still other modes of illuminating that we have not yet developed enough to consider for submerged use.

And last but not least, man must be able to live in the submersibles that we're talking about for long periods of time, rather than short periods of time. This is entirely different than the current mode of operating in the sea in other than the submarine program. Most of man's operation in the sea today, except in the submarine program, is in transport — short periods measured in hours; maybe as much as a day-and-a-half or two days — similar to the situation in aircraft, where man is a passenger but not an inhabitant. Clearly we have problems here.

These constraints are just a few of the many. But they're important, and they give you a feel for how different our technology is going to have to be. And clearly, if our technology is going to have to be different, our manpower training and our manpower availability, and its capability are going to have to be different.

The thing that this all points up to us is that this ambient in which we are going to operate, the ocean and sea, is currently hostile to man. It is hostile in almost every way you can think. Man has not lived in a hostile environment before. If he expects to live in the sea, he is either going to have to train himself for the hostility, or he's going to have to find ways to convert the hostility to friendliness. I don't know which way this is going to go, but clearly during the early phases we are going to be living with hostility.

I think all of you are quite familiar with the federal programs that are now outstanding in this area, and the fact that these federal programs are not yet currently funded to a sufficient degree to make a really large inroad on this vast area of ignorance. I'm sure all of you are aware, too, of the major interest that many of our corporations now have in the ocean. But I'm sure, also, that you are all equally aware of the spottiness of this approach; that it is not an over-all program; that we do have to look very, very seriously towards the area that we have to start with, and to do that first; i.e. where are we going to operate, in a hostile or a friendly environment?

Up to date, the effort has largely been one of discovery and description of the ocean, except for the military vehicles. If we move to an area and a period of exploration and exploitation, the requirements are going to be entirely different, and we have to adjust ourselves to them.

The development of new knowledge is clearly the primary need. It is being attacked not only by the federal government and by corporations, but by many of our universities; and they're doing a very fine job with the limited number of people and the limited amount of equipment they have. But quite clearly, we need far more than a few Scripps Institutes, a few Woods Holes, and so on. We need, for example, a broad-based university approach to better corrosion resistant materials; that is, not only in the ferrous areas, but in the non-ferrous. We need better development of corrosion-resisting materials which can be welded; and we need decent kinds of welding techniques. These can largely be done at activities which are not directly connected with the ocean itself. We need, quite quickly, some way of obtaining consistently weldable corrosion-resistant, non-ferrous alloys in casting form. Now, this is a very mundane thing, and many of you have forgotten that casting still exists in United States technology; but castings are needed, and in number, so increasingly we have the problem of finding ways of joining castings so that they can become more complex. Obviously weldments are a solution to this, but generally we do not have an adequate source of weldable copper, nickel, or other non-ferrous corrosion-resisting castings.

It's rather interesting to note that insofar as the total United States technology commercially is concerned, there are only about three major corporations producing weldable high quality castings in the non-ferrous metals. This is clearly an area in which all of us are going to have to do more.

We need, too, to develop better knowledge about electrolytic problems and their causes and effects on submerged structures. To date, all of the structures that have been in the sea have been there for a limited period. They have been withdrawn, carefully examined, mostly overhauled or even rebuilt at frequent intervals. But we're not going to be able to do that if we expect to live in the sea, if we expect to get something out of it profitably.

Obviously, too, we need better knowledge of *low-cycle, high-stress* fatigue. Many of us are quite aware of the relatively low-stress, high-cycle fatigue which aircraft see and which many of our normal structures see. And we're familiar with the cycle descriptions that tell us when we ought to be worried about fatigue. Few, if any, are really aware of the tremendous problem that high-stress, low-cycle fatigue brings to us in the sea. Indeed, it is so serious that probably it is far more important that we know how to design structures than that we know what materials to make them out of. Probably design configuration has more effect in this particular area than does material. This is not generally appreciated, and certainly the vehicles which we see being proposed and being built for experimental excursions into the sea do not all show knowledge of this particular fact, which is only now becoming evident.

We need to understand soil mechanics at the bottom of the sea; not so much only that we might use these areas for successful undersea agriculture, but also so that we can learn how to mine soil from the surface of the sea and dispose of it without completely wrecking our entire operation. Obviously, mining of various kinds of soils at the sea bottom is an entirely different problem than scraping soil at the interface of earth and air, or any other way in which we can mine on the surface of the earth. We have the problem not only of what do we do with the materials, but how do we avoid the dispersion of the fine particles into the ambient sea in a way that would completely eliminate our illumination, whether it be natural light, electromagnetic, electroacoustic or other ways. So we need quite a bit of understanding of soil mechanics; and not the least reason we need to know more about soils is so that our vehicles won't get stuck in them after a relatively short period sitting on the sea bottom. There have been such cases. Fortunately, they have not yet proved fatal, although I could expect at any time we might have such a situation.

The method of rejecting heat from various kinds of vehicles is a rather important consideration. All of the vehicles that have propulsion or any sort of electrical generating apparatus must reject heat. We currently do it through a complex system of introducing sea water into the payload of the structure, whether it be a submarine or a shelter. This is a very difficult thing to do, and of course offers potential for serious casualties. The problem of fabricating such systems that are reasonably safe is a tremendous one, and one which we would like to avoid. Thus we need to develop new ways of rejecting heat to the sea — sort of a direct interchange, if possible; and, if possible outside the structure — again, whether it be a submersible or whether it be a shelter at the bottom of the sea.

And again, last but not least, in this small list of examples, we need more understanding of man's physiological behavior in such a system. Obviously man, operating inside of a structure at four atmospheres of pressure is going to behave differently, in the long-term, than he does at the surface of the earth. Obviously, when he goes out into the ocean and becomes weightless and carries only a small membrane between himself and the ocean, and he does this for a long time, or if he goes to depths of 1,000 or 2,000 feet, encumbered only by his breathing apparatus, the effects on him physiologically are going to be very important.

How long can we depend on man to have reasonably good judgment under these conditions? We don't know, and we aren't doing very much about finding out. And clearly, we need to be doing more about finding out.

The Sea Lab excursions — Sea Labs I, II and III — are clearly an effort in this direction. But they are minute in terms of results compared to the kind of information that we need.

Well, these things are important, and they go along with the constraint. Along with these considerations goes the fact that for the foreseeable future, the vehicles and the shelters that we're talking about, for living in the sea, are going to have to be *high performance* devices.

Now, why do they have to be high performance? Well, as far as transportation is concerned, the vehicle which must go from the surface to the bottom, or through the ocean, these days has to be heavy. It has to have all sorts of capabilities, not only propulsion, but obviously for safe return to the interface. It must contain food. It must contain an ambient control system for controlling the atmosphere. It must provide oxygen, heat, and all sorts of other environmental controls. It must provide waste elimination, and so on. I've already indicated that it must provide for a safe return to the interface — this means some sort of air tankage or similar system; ballast; some sort of an emergency eject system; some sort of decompression system. All are generally needed in this kind of device.

A shelter or a structure at the bottom of the ocean today must have all of these same sorts of things except possibly the propulsion. This means, then, that as we require these heavy structures to perform more functions and try to get more payload into them, the equipment and the structures themselves are going to have to become more and more high performance. High performance vehicles are characterized by low safety factors. They are usually characterized by high cost, both in terms of money and in terms of engineering talent required to produce them. They are also, as many of you are finding out, very expensive in terms of the amount and kind of skilled labor that is required to successfully fabricate them.

So, we have then the requirement of high performance in virtually all the vehicles that we're going to be using to explore and exploit the ocean. This is a very serious implication, because generally in the past the vehicles that have been used by man at the interface of air and water have been general purpose or low performance vehicles. What I'm suggesting is that there needs to be a complete revision in our philosophy of what kind of vehicle is going to go into the ocean. It needs to be a high performance vehicle.

Obviously high performance vehicles require special care in design, manufacture and use; and these require special kinds of people.

Now, with regard to the machinery that we've talked a little bit about, for propulsion or for generation of electrical power, AC or DC: what kind of motor-generator sets do we have today? What kind of electrical conversion devices do we have? What kind of invertors do we have? They all require enormous amounts of air or water for cooling. They all operate under limited pressure. By this I'm saying they normally operate under atmospheric pressures. But the kind of devices that we're going to be wanting are going to have to operate under pressures of four, five, six atmospheres. From a high performance standpoint, the higher the pressure that we can operate these devices under, probably the better heat transfer we'll get and the smaller they will be able to be.

Thus we're going to need not only AC and DC electrical generation and conversion devices that are high performance, but we're going to have to have them operate in the kind of conditions where they have not operated before. We're going to want to cool them directly with sea water, if at all possible. Last but not least, that sea water could very well be heavily contaminated with grit or sediment from the bottom of the ocean if we're using a mining, grazing, or other operation. And so we've got to look, then, to the internal design of these devices; modify them rather extensively from the conventional forms of today.

The instruments that we expect to use: today we're using converted Navy instruments, converted Maritime instruments, converted NASA instruments. They're not very effective, they're not very efficient, and they're extremely short-lived, except for a few that have been specifically "ruggedized." Clearly we're going to have to redesign our instrument package to provide longer periods of usefulness. It isn't going to be adequate for them to be useful for a day or two; and it isn't going to be satisfactory to provide redundancies of two, five or, as we are currently doing in some cases, ten to one, so that as individual instruments go out we can switch to the next one.

Our automatic closure devices — that is, for protection in case of rupture of various systems — are clearly another area that is going to have to be considerably developed. We have very poor automatic closure devices today, and certainly none which will close without — in most hydraulic systems — setting up a very substantial hydraulic shock which in itself may be as serious as the effect of sea water pouring into the particular device, whether it be submersible or shelter. We've got to develop devices such as this. None exist today that are particularly useful.

Light weight portable illumination devices, whether they be searchlights, sonar, or electromagnetic in nature, are required for operations below the sea surface. They do not exist today. They are going to have to be developed. Again, this is going to be in an ambient atmosphere that such devices don't particularly like to live in.

And last but far from least in this list of examples, are suitable electrical connectors, or connectors for intelligence-gathering devices. Today we have various kinds of entry from the sea into the shelter or the submersible for electric cables and various kinds of sensors. These generally depend on a hull insert of some sort, a packing gland, and a series of stopwaters of various kinds. These seem to work quite well where the differential pressures are relatively small, or where the situation can be completely stabilized. But few of the systems that I've seen designed so far — and this includes all of the experimental submersibles in use for exploration today — have a homogeneous system. By "homogeneous system" I'm talking about one which has the same kind of behavior by all of the materials in the electrical connection, from the standpoint of reaction to heat, pressure, and hysteresis. Hysteresis, for example, in electrical cable, where gas is normally trapped between the various layers of insulation wrappings and protective coverings, causes the gas to be selectively compressed by sea water. It doesn't get itself into a uniformly compressed situation, and gas pockets are developed. They often expand as the pressure is released, and quite often the electrical conductor nearby is ruptured. Also in many cases the electrical characteristics of the conductor are modified by this phenomenon. So today we don't have, really, good electrical cable insofar as pressure cycling is considered. We don't really have designs for a homogeneous interconnection between intelligence gathering devices in the ocean and display units inside the hull of the ship.

These are just a few of the many areas in which we are going to have to have a change in design, a change in our way of doing business, and the gathering of a great amount of new knowledge. Obviously, this requires people, and it requires specially trained people.

Let me appraise the effort to date just a little bit. So far, our Navy submersibles and immersibles have done very well, i.e. what we call our submarines. But they operate in only a very small portion of the ocean's depth.

The vehicles that have gone to the rest of the ocean's depth — and of course we have, in the "Trieste," gone all the way to the bottom — are generally rudimentary in nature. They are observation vessels. Their work capacity, compared to that which needs to be done, even in gathering intelligence, is very, very small. Relatively, it's infinitesimal.

They've gone to deep depths only for short periods of time, and their missions generally are short and of a specific nature. They are then returned to the interface where they usually are thoroughly examined and quite often completely overhauled between each mission. This cannot be the case for the vehicles that we are going to be using in the future in the ocean. Obviously, we're going to have something that can go down and stay there. In fact, from what we have seen so far, moving from observation vessels, such as "Alvin," "Asherah" and "Aluminaut," into the work vessel of the future is going to be a far more difficult transition than we have made so far in going from the canoe to the "Asherah" and the "Aluminaut." Indeed it looks like it's going to be the same thing for man, in that man has done relatively well as a pearl diver, perhaps, for the last 2,000 years; but when he really moves into the sea, and begins to explore and exploit it, and becomes a part of it, he has a tremendous transition to make.

In general, current undersea research vessels are slow, underpowered, of limited endurance. They are generally very unseaworthy at the sea-air interface. And they generally encompass a whole series of engineering compromises and, in many cases, errors, which would have disastrous effects for a long period of time if they were put into our major future devices.

For example, virtually all of them have little or no design from a low-cycle fatigue resistance standpoint. Many of them use dissimilar metals in close contact, thus creating a high electrolysis gradient. Many of them have inadequate recovery capability, their only recovery margin coming from dropping a few hundred pounds of emergency shot ballast. Virtually all of them have a very poor choice of basic hull material from the long-term standpoint, although from their limited use standpoint, the hull material may be satisfactory. And almost without exception, the electrical cabling which they use, which is exposed to sea, is not useful over any long period of time.

These are just a few of the things. I'd like to point out that in the Navy, as you probably know, each one of these research vessels that is used on contract or from time to time by naval personnel has a sort of preliminary review by naval ship designers. From this standpoint, without exception we've had to place rather heavy restrictions on how these vessels can be operated in the Navy research and information gathering program.

This is really not a degradation of the commercial effort in any way, shape or form, because clearly these are pioneering vehicles. But what I'm trying to point out is that we cannot just exponentially extrapolate from the pioneering vehicles of today to use vehicles of tomorrow. Today's vehicles essentially are for information gathering only.

Here are some general thoughts in this particular area. Today's advertising by big corporations, and to some extent by the government itself, of their products in the oceanographic area, almost without exception exceeds the capacity of the product. We read in the glossy slick magazines about how things were down at 6,000 feet, and how some day they'll be down at 15,000 feet, but we aren't told how many attempts it took to get to 6,000 feet, and we don't see many of the hair-raising experiences people had while they were there. Thus we get through the advertising, quite often, a false idea of the capability which does exist. And so I'm suggesting here that we have to take today's advertising about oceanographic capability with a great big grain of salt.

Another general thought. Since submersible and immersible vehicles are so complex, engineers must in many cases understand not only the basic design of the components of the specialized systems that they're talking about, but they must understand how these complete submersibles are constructed, operated and overhauled. In general engineering practice for air supported systems this isn't the case, because the components can usually be removed from various vehicles and systems, they can be overhauled in a clean room or in a shop that is specially set up. Such an approach generally is not possible in high performance submersibles. Quite often — I would say almost usually the case — you try to overhaul the component in place, because of the tremendous cost of removing it and getting it back into a system which has to be fully tested before the system can be returned to its primary use. Engineers then are going to have to very strongly influence their designs by the somewhat abstract considerations involving operability, maintainability, repairability, and, in some cases, habitability. These are not often well understood and are quite often neglected by engineers working on today's components for use in the air and at the air-earth interface.

Another item of some significance is that there is no body of trained mechanics available in the United States today with the skills that are demanded by a high performance submersible program. With the possible exception of the Navy's programs for deep-diving submarines and high performance submarines, and these only in relatively small numbers, there just do not exist skilled mechanics.

All of you I'm sure know the words pipefitter and plumber, and maybe you think they're synonymous. Well, in many places they are. But we found in the submarine program that not only are they not synonymous, but we must have several different kinds of pipefitters, specialists in different kinds of systems. We must acquire for these vehicles the kind of capability which generally requires as much, if not more, training and maintenance of competence as we require in our engineers. Indeed, in my shipyard, I am spending more money per man training pipefitters than I am training engineers. This is a very important consideration for the future of oceanography. I realize that you may not be concerned with mechanics directly, but all of us who go to sea are concerned with the quality of that particular system which the mechanic works on.

Ocean engineering knowledge I think is beginning to develop, and the effort today is primarily in this area of gathering knowledge. But each day that we acquire more knowledge, we acquire more surprises. We acquire more information that the ocean is not simply an extrapolation of the air. It's not simply an extrapolation of the knowledge we gained when we played as children on rafts or when we swam at the beach. It's an entirely different kind of beast. And what this means is that we have to start looking at it more and more from this standpoint.

A few months ago there was a meeting, a conference at one of our larger universities, on the matter that we're talking about today; oceanography, oceanographic engineering, and the development of a program for its implementation — how that university could go about improving its position. Brought together were people from various technologies, and it was rather interesting. They had, in addition to civil engineers, mechanical engineers, and electrical engineers, oceanographers and others.

They had a two-day session that at first appeared to be a complete and general failure. The people that attended were divided up into rather small technical groups. If the problem seemed to be one at or near the ocean floor, then it was conceded that the man who was involved in solving the problem had to know soil mechanics and therefore he had to be a civil engineer. If the problem dealt with pressure vessels, then obviously the man must be a mechanical engineer. Or if the problem dealt with the sophisticated electronics and intelligence gathering systems then he had to be trained either as an electrical or an electronics engineer. And of course the naval officers who attended felt that anybody who piloted or went on one of these vessels needed to be a naval officer.

What I'm trying to get at here was that each one of the technologies that was here represented thought about the problem only in terms of its relatively narrow field. Indeed, this is the way the total problem generally is being approached today, rather than as being an integrated system in which each component has equal importance.

While the conference may have been a failure as itself, it probably was a resounding success, because it not only pointed out to the participants and to that particular university, that their approach to oceanography and oceanographic engineering was completely wrong — it was completely too small — and that they had to take a far more basic approach, one which recognized that we were dealing with an entirely different situation than ever before. What we are dealing with here is a *new ambient,* an ambient with which man is not familiar; an ambient which man has exploited and been in contact with over a very limited period of his life and over a very limited period of his development. Through millions of years, man has developed his knowledge and experience at the interface of air and earth, or at the interface of air and water. His occasional incursions into the water have been marked either by rapid return, or death. He never will have really reconciled himself to the fact that it is completely hostile, until he has learned all of its lessons, and until he has learned to live with it. So the main thrust of what I have to say here today is that we must start thinking about manpower requirements, not in terms of our current day technology in air, but on the basis of an entirely new ambient in which we are going to have to work.

Man didn't face this problem, really, until now. Quite clearly, although we're talking about one new ambient — salt water — here, there are other new ambients which are going to have to be faced. What kind of ambient atmosphere is there, for example, in the various planets of our solar system? Clearly, any probe to Venus is going to have to be concerned with how our materials behave in a hydrocarbon, or some other kind of gas ambient. Still other planets obviously will require a different approach; certainly the moon, with its no-ambient, or at least low ambient, has different problems. But they look to be somewhat simpler than the ocean.

The space effort, too, when it gets to leaving the earth's gravity with manned probes, is going to face up to some other considerations that we involved in ocean exploration have faced for some little time, such as the necessity of maintaining a substantial reserve of energy to return to the earth's interface.

And so we begin to see that some of the space effort and the ocean efforts can be tied together, because while they do not deal with the same kind of animal, they can use the same kind of approach to the problem, i.e. different and probably hostile ambients, as far as man is concerned.

Let me point out a few of the basic differences between the air ambient and the water ambient that we're talking about. You know these, but it's good to remember them.

Air has high oxygen content, and man goes about unassisted. The water has low oxygen content, and man must have breathing assists.

The air is a good insulator as far as electricity is concerned. Sea water is an electrical conductor.

The air has generally a low or mild corrosive effect. The water has a high corrosive effect.

Air has low specific weight, while water has a relatively high density.

The air ambient is very compressive. The sea water ambient is virtually uncompressible, although as all of us recognize, the compressibility of water was taken into effect in the design of the "Aluminaut," which was built to be less compressive than sea water and uses this feature for purposes of stability and control at depth.

And last but not least, air is normally a poor heat conductor, and water is a very high conductivity medium.

These are just a few of the differences. They're very important, however, because they point out that all of our knowledge of materials is based on the air ambient rather than on the sea water ambient. We're going to have to acquire knowledge of materials based on the sea water ambient.

This new ambient, unfortunately, is largely unrecognized as being the principal problem. Most of the problems that are discussed in the technical manuals and in the various trade journals and at the various technical society meetings have to do with a specific mechanical or material problem. Generally camouflaged is the fact that the real problem is the use of a material in an ambient atmosphere in which it has had no test experience. Generally true also is the fact that we have over-extrapolated our own knowledge of the mechanics of the material, and the mechanics of the structure, in this new ambient. And so generally, the problem discussions that I have heard have not really addressed themselves to the true problem, but only to some of the manifestations of the problem.

The new ambient is largely unrecognized in the United States, and it is largely unrecognized in all of our educational institutions, and it is largely, from my standpoint, unrecognized in the various studies of engineering manpower requirements.

The total effort to acquire information concerned with the new ambient is very, very small. Now, there's no question that we find out a good deal about exposure of metals to corrosion at Kure Beach and elsewhere. There's no question that we find out about some aspects of sound transmission through the water in the various sonar experiments. And there's no question we find out something about temperature and salinity effects in our buoy experiments. But we're finding out bits and pieces rather than the full whole that we need to really make developments go in a hurry.

We've got to acquire knowledge about the new ambient. We've got to acquire people who are trained in it. How we're going about it, of course, is pretty well set forth in the various programs which the President and government agencies have outlined. But generally we're going about it in a not-well-defined way, and not an engineering way. The effort is spasmodic. It is categorized by duplication and, more unfortunately, by large omissions, both from the standpoint of gathering information and from the standpoint of training people.

The effect of the new ambient on manpower is clearly one of increasing rather than decreasing severity. No exploitation of the sea and no examination of its knowledge requirements has given any indication except that we must have better trained people, that we must have more knowledge, not less. Every sign indicates that we need to acquire a vast new area of knowledge. We've got to develop it, and then we've got to apply it.

As I've indicated before, there are a few areas in which we have some knowledge. I've mentioned the submarine programs and various activities such as mining, where we have developed not only skills in the usual technology, but also people with special training background and experience in submersible and immersible vehicles; in propulsion and power distribution; in weapons; in environmental control, structures, nuclear power, communications. And yet we've just scratched the surface. I must point out that there are only, in this country, something less than ten sophisticated industrial centers of this kind. Again, it's something we've got to consider. These are good areas on which we can build, but clearly they are not adequate for the purpose of sea exploitation.

All of this, too, indicates that we are going to require an increasing time in training manpower. We're going to have to train them as we currently do in the classical air-ambient concepts, and I don't see that we're going to be able to reduce the time very much by compressive techniques, including TV and what we're doing in the grade and high schools today. Clearly we're going to have to add these new ambient considerations to a basic education, just as we currently add foreign languages to the basic education in English.

But it also seems to me that if we expect to involve ourselves in the new ambient we're going to have to concern ourselves with a *different way* of training people. The ambient does not exist inland, and thus it is probable that we're going to have to take our trainees, whether they be engineers or mechanics, to the laboratory, the sea. Now, this is not a new concept. We at Portsmouth, for example, have a cooperative engineering program in which we send people to school for about two-thirds of the year, and have them work with us at the shipyard and indeed often at sea, gaining experience with the new ambient the rest of the time. It takes us five years, generally, to get to a bachelor's degree, and probably something of the order of seven to eight for a master's degree in this particular program. But it's important, because these people have knowledge in the new ambient that could not be acquired from engineering lore stored up in books, or from professors, generally. Webb Institute also has this kind of a program, and there are many other cooperative programs. I'm suggesting that maybe this is one of the ways that we will have to go in order to acquire a sufficient amount of expertise in manpower for the future in a reasonable length of time.

This points out, too, that the unskilled are less and less needed. And now I'm talking not only about the people who don't have a high school or college education, but I'm talking about engineers and mechanics who do not have their education in the requirements of the new ambient. So our definition of skills is upgraded, and our definition of unskilled encompasses more people. This means, of course, retraining programs, so that we make better use of the people who will be cast out by this new categorization.

Work periods in the sea are going to be short, by the very nature of the hostility of the element. In the early stages, they're going to have to be extremely short. They're going to have to be extremely carefully preplanned. They're going to largely depend on the limits of endurance or exposure that man or his structures can stand. What this generally means is that we're going to see more and more of the very detailed, sophisticated, kind of scheduling that is so prevalent in the major complex systems of the armed forces. PERT networks will become norms as a way of doing business. I think, in the exploitation of the sea, whether it be operating or mining or for general denial of use of a particular area to a hostile power.

The sea demands a new kind of physical fitness from our people and a new willingness from a psychiatric viewpoint, too. All of these things generally are consistently getting us into smaller and smaller groups of people who are competent to do the kinds of things that the sea requires.

What I'm trying to say here is that we not only have a new ambient, but we also have a new situation in which we are going to have fewer and fewer people competent, fewer and fewer people available to do the job, which makes even more important that all of this be part of an organized, thought-out plan, a discipline which we will follow.

Ultimately — maybe in 100 years, or perhaps even less, when man has truly acquired knowledge such as this, and has truly learned to live in the sea, either as a hostile environment or as a friendly environment — these things will change, and it may then become as easy for us to do things in the sea as it was to get here this morning, going through the air and over bus lines, and so on. But I don't see it being that easy in the sea for 100 years.

In summary, we have a far more difficult problem than has generally been expressed. We are not in a rosy-hued situation. We're in a very difficult situation. Our exposures to the sea have been short. They have been pleasure jaunts. They have been fun. But when we try to work in the sea, and when we try to live in the sea, we're going to have an entirely different situation. The most important thing, so far as manpower is concerned is that it's going to require more highly skilled people at every level, engineers as well as mechanics.

But far more important, I think, it's going to take an entirely different attitude on the part of people like you and me, to think about exploitation of the sea as being an exploitation of an entirely new ambient. Man for many, many years has unconsciously thought "air." If he's going to work in the sea, he's got to consciously think "sea." And so when you all leave here today, if you will, think "sea." It's important.

AN UNDERGRADUATE WINDOW TO INDUSTRY

by *Rear Admiral William A. Brockett*, USN (Ret.)

To introduce my remarks on the general subject of the undergraduate employee, it is probably appropriate to set the stage by giving you some facts about my school. Webb Institute is a small, highly specialized single curriculum school. It is fully accredited for B.S. and M.S. degrees in Naval Architecture and Marine Engineering. Size, and the nature of the curriculum, give us the aspect of a department within a large college or university. On the other hand, the overall administrative responsibilities remain, ranging through trustee and faculty relationships, fund raising, food service, business management and student counseling. Thus I find myself having to look through both ends of the telescope at once, familiar with detail by necessity but trying to maintain perspective and the broad picture also.

There are only three schools in the country that offer accredited bachelor's degrees in Naval Architecture and Marine Engineering — Webb, M.I.T., and Michigan. At the undergraduate level, Webb has about twice the Naval Architecture enrollment of M.I.T. and something less than half that of Michigan. The total number of undergraduates that I am talking about at Webb is sixty. I raise this point of size primarily to put the remarks that follow in context. It is quite possible that some of the unusual routines we follow would be denied to the larger institution but I hasten to add that this is far from a foregone conclusion. Another feature which may set us apart from the norm is the outstanding calibre of the student body. Since Webb offers a full tuition scholarship to every accepted candidate, the competition for entrance is keen. Selection is on the basis of academic merit and personal character. Thus, the incoming freshman class with which I am quite familiar, having interviewed each one personally before the final acceptance decision was made, has an academic profile which can be equaled by very few engineering schools in the entire country.

The history of the practical work term at Webb is interesting. In 1889 when William Webb founded Webb's Academy and Home for Shipbuilders, he was making an educational innovation. Naval architecture in this country had been an art, and a highly successful one as witnessed by the U.S.-built clippers, Liverpool packets and New Bedford whalers. But with the advent of iron ships, the British moved into the position of preeminence. England had the iron mills and the iron masters. But just as importantly they had a group of men, and William Froude in particular, who made the first giant steps toward moving naval architecture from art to science. William Webb, himself, had been brought up through the apprentice system of shipbuilding and ship design. The half model and experience were his design tools, and good ones too. When he retired in 1872, he had built over 130 ships, sail and steam — all of wood. In some of his later steam vessels, he had probably extended the use of wood as a ship construction material to its ultimate limits. But he saw the need from his own experience to establish in this country a school wherein young men could be educated in the emerging sciences of naval architecture and marine engineering, as well as the use of new materials. At the same time, Webb could not completely abandon the apprenticeship approach of his own background. This, I suspect, may have had some influence on his decision to combine the youth of the Academy with the elderly of the Home for Shipbuilders under one roof. Hopefully, in the cool of the evening, some of the lore possessed by the old gaffers would rub off on the youngsters. This is also why practical work experience has been a part of the Webb system from the beginning.

To come up to date, I would like to read directly from our current catalog: "One of the unique features of the Webb Institute educational system is the winter work term. Each year the school closes in mid-December and does not reopen until the second Monday in March. During this period between academic semesters, each student is required to engage in ten weeks of practical work in a shipyard, aboard ship in the engine room, in a design office or in other course-related industries. The practical work period provides a break in the academic routine and most importantly gives the student an opportunity to relate his classroom and laboratory work to actual commercial practice. It solidifies that which he has learned and opens up new engineering vistas for the future. In addition, each student is paid the going rate by his employer and the wages received are normally more than sufficient to cover travel and subsistence costs while away from the Webb campus."

If you will bear with me, I will drop back once more into the past. The words I just read from the 1966 catalog are largely based on current conditions, but I was a little taken aback the other day when I dug out the oldest catalog in the library as part of my research for today. Again I quote:

"A distinctive feature of the course is the summer session of a period of eight weeks, during which every undergraduate is required to work in shipyard, drafting office, aboard ship, in machine shop or in some line closely allied to marine engineering or shipbuilding. Positions are secured by the faculty for the students, but they are sometimes allowed to accept other positions provided the experience to be gained is considered satisfactory. Transportation expenses to the places of employment are borne by the academy. Wages earned above their living expenses become the property of the student. The practical experience thus obtained is of great value to the student and, upon resumption of his studies, enables him to secure a clearer understanding of theoretical subjects."

So, in fifty years, not much is new.

The required work period went from 8 to 10 weeks during World War II. Next year, for a variety of reasons, we will revert to the 8 week requirement. In 1947, when Webb Institute was moved from the Bronx to the present site at Glen Cove, the practical work period was shifted from summer to winter. This yields an unusual, if not unique, academic year schedule. It also brings us to the point where I can discuss the current situation from firsthand, though limited, experience.

Let's look at the schedule for academic year 1967-1968. The first semester opens on Monday, 21 August and ends in mid-December. Examinations are over, marks are posted — the semester is completed with no holiday hiatus and academic continuity is maintained. The second semester begins on the last Monday in February with commencement on 14 June. During the 10 weeks break, every student must spend a minimum of 8 weeks in course-related employment. Interestingly enough, the majority of the students seek employment during the summer interim as well. This is not required, but it is encouraged. Summer work is "in" at Webb and seems to bear only incidental relationship to individual economic need.

The freshman are all required to work in shipyards as helper mechanics, preferably as helper shipfitters or as helper outside machinists since these two trades give the best overviews of the shipbuilding or ship repair processes. We expect them to really work — to get some dirt under their fingernails — not to be tourist trainees. Hopefully, even in two months, if they stay with a single trade, some handiness with the tools will result. Placement is made by the Institute through contact with the yards. We try to give the students some choice of geographic area and have been reasonably successful in meeting their personal desires on location. Last winter we had freshmen scattered from Maine to California — from the Great Lakes to the Gulf. All were paid the going contract wages for the helper rate, ranging from $2 to $3 an hour. With some minor exceptions, this winter practical work session provided exactly what was desired — exposure to shipyards and shipyard processes and, just as importantly, work experience with shipyard mechanics and first line supervisors on the waterfront or in the shops. Since winter work is an integral part of the Webb education philosophy, the freshmen were not complete neophytes when they hit the work site for the first time. They had finished Practical Naval Architecture I, during the first semester, an introductory two hour course planned to familiarize the student with ship and shipyard terms and to explain the purpose and construction of the important parts of the ship. Further academic interplay occurs in the writing of the reports of things seen, things done and things learned, required from every student upon his return to school.

The sophomores are our sailors. All go to sea in merchant ships as cadet engineers. Again, placement is arranged by the Institute, working with the Maritime Administration training officers at the several ports and with the steamship companies. Scheduling is tricky but we were able to place students on everything from the American Mail Orient run to Moore-McCormack's East African route. Here also the student is at least partially prepared for his work. He has been through Marine Engineering I and II and has a general understanding of marine machinery and of the basic physical and thermodynamic arrangements of propulsion and auxiliary machinery. He is required to keep an engineering notebook covering his activities and including sketches of the machinery layout and principal piping systems of the particular ship in which he sailed. These notebooks remind me very much of the one that Ensign Brockett kept for Lieutenant Rickover some years ago.

Characteristically, the Webb students are used on day work rather than watchstanding because of license restrictions. The quality of the work experience depends a great deal on the attitudes and background of the First Engineer. The best experience came from old ships that were short handed with an understanding and possibly harassed "First." In at least one case last year, our sophomores were performing day work repairs and performing them well with a minimum of supervision. As in the case of the freshmen, the people aspects are significant — the contacts wtih the operating personnel, both licensed and unlicensed. What is it like to go to sea? Who are the people that man our ships? What design features do they like and which ones do they not? It is surprising how quickly an operator will launch into a lecture on the do's and don'ts of design once anyone tagged as a naval architect/marine engineer, embryonic or otherwise, falls into his clutches. An early exposure to this phenomenon is certainly educational and has the possibility of beneficially affecting an individual's design philosophy in the long range.

Juniors and seniors can be lumped together since their winter work varies essentially only in complexity. Both classes obtain their own employment, making their own contacts and their own negotiations. This is not too difficult a process since the company recruiters are familiar with the Webb system. Thus when they come on campus in the fall, they are recruiting not only for permanent employment after graduation but also for both winter and summer work. Webb Institute enters into the picture in two ways. The proposed employment must be certified as course-related and each student is required to submit a technical report on his practical work upon his return. We are not at all rigid in the interpretation of what is and is not "course-related." This past winter the projects worked on ranged from economic analyses of Caribbean tanker routes to maintainability and reliability studies of marine boilers for one of the large manufacturers to preliminary design on a new freighter for the Australian trade. Geographically, the seniors were spread from the Pearl Harbor Naval Shipyard to Sulzer Bros. in Switzerland. I don't wish to seem preoccupied with money but to one of my generation, the salary rates are revealing. The juniors averaged something over $500 a month and the seniors were close to $600 per month average. From conversations with both students and employers during the past two months, I have come to the conclusion that, with a few exceptions, the students were worth their hire. And on this score, you might be surprised how well the student can evaluate his own contribution. The best results from both standpoints were attained in heavily loaded organizations with near-term technical problems crying for manpower. I can cite a half dozen such situations in which our youngsters made the studies and came up with the results during the ten weeks span, all with a minimum of supervision. This calls for some technical courage on both sides but it also leads to maximum satisfaction. Conversely, there were one or two make-work cases which led to mutual disenchantment.

As you can see, the Webb system has many of the aspects of the better known work-study cooperative programs in use elsewhere. And, many college engineering students are gainfully employed during their vacation periods. Being new to the educational field, I am not as familiar with the activities at other schools as I would like to be although I have some knowledge from the employer's side of certain highly successful co-op programs such as that at the Portsmouth Naval Shipyard and at the Marine Engineering Laboratory at Annapolis. But without ignoring these other enterprises, I intend to stay on my own ground and the observations which follow will be based on Webb experience.

I think that the term "window to industry" is an apt description of one of the functions of the Webb winter practical work term — *provided* that we are talking about a two-way window. An undergraduate school today has at least three prime customers to try to satisfy — the student himself, industry and the graduate schools. The demands of the three are not always coincident. It is the stated aim of Webb to "provide a basic engineering education of such content, depth and quality that all graduates will be fully prepared to enter directly into the practice of their chosen profession or to go forward into graduate work and research." In meeting this aim, conflict immediately arises in the time allotment between the basic and engineering sciences and the applied and design engineering courses. It is this same conflict, in my opinion, that is at the root of the current arguments regarding four and five year engineering curricula and the first professional degree. I have no intention of opening this question up today, other than to suggest that we need feedback on this subject and on many others associated with engineering education — feedback from industry, from the students themselves and from the graduate schools. The practical work periods, for the juniors and seniors in particular, open up the communication channels between industry and the educational institution. This was brought home to me forcibly early this month at the American Society of Naval Engineers meetings in Washington. I think that I must have spent a good half of my time there listening to winter employers of Webb undergraduates. The remarks were generally most gratifying. For example — three rough quotes from memory:

"You must have excellent courses in strength of materials and structures. We turned your two boys loose on bending moment calculations on two new tanker designs we were working on and they just ate the work up."

"We were designing a new deep submergence search vehicle and put your two juniors to work on arrangement, and weight and balance calculations and they were extremely valuable."

"Your people are self-starters and bears for work. They seem to be able to go back to the fundamentals on a new problem and figure out on their own a method of attack. They seemed to be able to use their academic tools as seniors much better than many of the young graduate engineers we have in our office."

This series of conversations opened my eyes and also pointed to an area in which we may be missing the boat. We get evaluation sheets of the individual students from their immediate supervisors but these are designed to measure personal characteristics and performance. We will still want such information but it seems to me that we can also ask for comments on curriculum and course content. We'll never have a better chance to get close-coupled constructive criticism from our customers. It is quite evident that the undergraduate temporary employee is watched more closely than the newly graduated permanent employee as a general rule. I also have the nagging feeling that the former gets better work assignments in many cases, less dog-work than the man on the permanent payroll. From the other side, there is a definite cord cutting at commencement whereas we still have our academic hooks in the undergraduate. I feel that the formalized practical work device opens the gates to an extremely useful dialogue. We intend to pursue this opportunity.

There is additional useful spin-off from winter work. The financial advantage to some of the less affluent students is obvious. Further, the benefits of 8 months minimum and over a year maximum work experience in industry before graduation accrue to both the student and to the potential employer. It appears that the opportunity for mutual observation during temporary employment may result in better satisfaction on both sides when the time for "permanent" commitment arrives. Job-hopping is at least partially out of the graduate's system. At least 75% of our present seniors are headed for graduate school next fall. They will not be in the job market for another one or two years but the few I have talked to about their long range plans indicate strong ultimate interest in one of the companies for which they worked as undergraduates. Graduate education immediately following attainment of the bachelor's degree is today's normal pattern. This seems to fit the requirement projections of the future but it doesn't help the immediate national needs for engineers of any degree level. I would like to suggest that the employment of junior and senior engineering students can help in the latter case. There are many jobs that they can handle at the technician or junior engineer level, jobs that need to be done. It is just possible that we are overlooking a significant pool of manpower. These youngsters are a lot more competent than we oldsters are ready, willing or able to admit.

I do not propose that all 70,000 juniors and seniors in engineering curricula be placed, and recognize that there are undoubtedly many colleges that have work programs equal to or better than that of Webb. I do propose that more can be done in the area. Which brings me into a position not unlike that of the ensign with no engineering experience who suddenly found himself chief engineer of a destroyer. Fortunately he had a good enlisted chief machinist's mate. There were a few minor casualties over a period of weeks and the chief dutifully reported each one to the young naval officer. There was a standard answer — "Very well, fix it" and the traditional response "Aye aye sir." But in the middle of the mid-watch one night the chief came pounding on the stateroom door — "Sir we lost suction on the cruising feed pump, it flashed, the pump turbine ran away and is all over the floor plates: we had low water in 2 boilers and had to wrap them up and now we're dead in the water." Standard reply from behind the door — "Very well, fix it." A long silence then — "Aye, aye sir — but this time you'll have to tell me how."

Like the ensign, I am at a loss to tell anyone how, although I do know the "how" at Webb. On the surface we appear to be in a special circumstance — a small school with special relationships within a well-defined industrial clientele. But are we too different in size or industry entree from many, many engineering *departments* within the larger institutions? It seems to me that at this level the close contacts with industry and mutuality of interest already exist and can be exploited. I now retract behind the stateroom door of ignorance and say no more.

Today there is increasing interest in the field of ocean engineering and the education required to fit young men for its practice. Since this group has asked me to touch on the subject, I will make a personal observation or two. First, my enthusiasm is minimal for designated undergraduate ocean engineering curricula. In my opinion, ocean engineering — defined as engineering in support of oceanographic research and development and in the ultimate exploitation of the resources of the oceans — is too broad to be considered a discrete undergraduate discipline. By analogy, we would expect to have all-encompassing courses in land engineering covering all the activities in another environment. We don't, and for good reason. I believe that M.I.T. is on the right track in their recently announced ocean engineering graduate course. Here a group of students with recently attained bachelors degrees in a variety of engineering disciplines will be brought together around a core of required courses with wide options for individual pursuit in depth. One thing that they will have in common will be an understanding of the environment and the systems approach to engineering design. The first class, convening next fall, will have about a half dozen students with, as I remember it, an electrical engineer, 2 mechanical engineers, a chemical engineer, a metallurgist, a physicist, and the ubiquitous naval architect/marine engineer from Webb. The end product will be a highly competent *team* — let me emphasize team — that will be most valuable as a group, with differing individual competences, but all designated ocean engineers.

As a member of visiting committee to the department of Naval Architecture and Marine Engineering at M.I.T., I have had an opportunity to review their new program in some detail. I am sure that other institutions are developing or have developed equally useful ocean engineering offerings. I simply am not as familiar with them as I should be. In summary — three personal observations: (1) ocean engineering belongs in the graduate schools (2) multi-discipline team effort approach is indicated (3) understanding of the hostile environment is fundamental. Every entering ocean engineer might well be required for a first laboratory experiment, to stick his head in a bucket of salt water and make the discovery that humans don't have gills!

THE EDUCATION-INDUSTRY INTERFACE

by *Dr. Milton Harris*

Some months ago as I was preparing a talk before a group of about 300 professors of chemistry and chemical engineering, and while I was thinking about the problems of science, technology and education and their role in society in general, I came across a rather interesting statement which, perhaps, emphasizes better than I can the soul-searching and even the bewilderment of the people in science and technology today.

> "The doings of humans are based on confusion and roundabout actions. The impatience of our generation causes us to move too hastily. In the sciences we are prone to sometimes be satisfied with the surface of things. Sometimes we err in the choice of the sciences, sometimes in the way we teach them, sometimes in the way we research them; sometimes we stretch their boundaries prematurely and concern ourselves more about other worlds than about the earth on which we live and which is so wisely adapted to our needs."

Now, this is a rather simple statement on matters that are familiar to everybody, and I'm sure you're beginning to wonder why I chose to read it. Well, the interesting thing about this statement is that it's part of a speech given at the dedication of the first chemistry laboratory at the University of Abo. The University of Abo is the forerunner of what is now the University of Helsinki in Finland, and the speech was given in about 1770!

Now, in a sense we're all asking the same questions today, and you might conclude from this that we've made no progress in the last two hundred years. Actually, I don't think this is so, especially in the field of the physical sciences.

I think one of the reasons why this quotation is so interesting is that that period represented the very beginning of the age when science and technology were beginning to radically affect our lives. It's the period which brought us some fifty years ago to what we now popularly term the period of the science explosion, a period of continual change.

Today we view modern science, engineering and technology as one of mankind's most remarkable intellectual attainments. Everyone recognizes the contribution of science and technology to national security, to economic growth, to health and welfare, and to our general well-being. But, as important as science and technology have been in the development of our country, their future role I'm convinced, is even more important and in a sense even more critical.

You may have noted that several times already in this brief discussion I have used the words "science" and "technology." Science is considered here as the knowledge-generating process; and technology the application of that knowledge. I don't want to get involved today in any philosophical discussion about the obligations of scientists and science to our society. We've had too many polemical discussions on this subject already. Nor do I want to get involved in any discussion of what is pure and what is applied science. There are many definitions. However, a couple of months ago I heard one that really appeals to me and seems to get me out of all these jams. If you haven't heard it, let me repeat it to you:

> If I go into the laboratory and start working on something, that's fundamental research. But if you tell me to do it, that's applied research.

There are those, of course, who feel that science should accomplish something; that the true work of the scientist is not realized until he produces something for the benefit of mankind. This is the well-known Bacon school, which was enunciated several hundred years ago. And there are others who feel equally strongly that scientists' work is just the noble pursuit of truth, which is the Cardinal Newman school. Let me dismiss this whole subject quickly by saying that the basic and applied sciences are inextricably intertwined, and further, useless and helpless without each other. I would think that the sooner our society recognizes this, the faster we'll get on with the job and waste a lot less energy.

All this, of course, brings me back to the topic of the day. I happen to like the title and the reason I think it's well chosen is that from one point of view, interface has a connotation of a resistance to the transfer process. But recently I checked in *Webster's Dictionary,* and there's another definition that says it's a surface forming the common boundary of two bodies or spaces. At the moment I think we have more of the former but I'd like to believe that we're coming to a stage where we're going to deal with interface as the common boundary rather than as the resistance barrier.

My own discussion today is concerned with what we popularly call a growing gap between industry and the university. It's a subject that's been much discussed in the popular and technical press. I have a lot of examples but I just want to cite a few of these:

"BRIGHT STUDENTS SAID TO SHUN BUSINESS"

"JOB-HOPPING HIT BY TECHNICAL HEAD"

"THEY LIKE IT BETTER ON THE CAMPUS"

"THEY DON'T WANT BUSINESS CAREERS"

These discussions take many forms. They include everything from discussion of beatniks in our society to the resistance of the PhD to entering industrial work. Actually, you don't have to limit this to the field of science and technology; it exists in the social sciences and the humanities, and it constitutes a serious problem in all phases of our society.

In the last few years I've had many discussions on this subject with industrial research directors as well as with many academic groups. They were poles apart. My industrial friends said: "These academic fellows have their heads up in the clouds;" and my academic friends would say to me: "Industry doesn't understand research." Now I'm happy to say we're making some real progress here, and mutual understanding is beginning to develop.

What is this problem? Stated simply, it's something like this: some two-thirds or so of all technically trained people, and this is especially true of chemists and chemical engineers, will enter industry. And, further, as many of my academic friends tell me, the best people will go into the academic world. I want to put "best" in quotes, because I am not quite sure what it means and I would like to discuss this later.

Unfortunately, many, if perhaps not most of these people, have not given any thought to what this career might be like prior to actually entering the industrial world. In the extreme case some of them sometimes suffer a traumatic shock. More frequently, a certain amount of disillusionment or disenchantment sets in. This is not true for all, but there is enough to make it a serious problem. I must emphasize that I am referring especially to graduate students.

The result is that we have had a fair amount of turnover during the early employment years. This is not to say that all turnover is bad; some of it may be good. But certainly a lot of it is bad. Rough estimates indicate that a young PhD chemist, chemical engineer, or physicist entering and staying at a company for three years is just getting his feet on the ground and is very unlikely to accomplish much during this period except to begin to understand the process. If he then leaves, the investment loss to the employer is something of the order of $100,000 to $150,000, depending on the nature of the particular work of the company or laboratory. Even worse than the loss of money is what happens to people's attitudes. Many times these young people become cynical, unhappy, and many of them don't recover. Fortunately, to many it is a useful experience and they become much better people.

What is even worse, the attitude of the employer gets soured. One friend who is the vice president and director of research for a large corporation, says he's practically on the verge of not hiring any fresh PhD's out of school. He wants people who have been out of school two or three years; "Let them get their disillusionment elsewhere." I don't agree with him and he'd better examine the process by which they are getting disillusioned.

Now, let me say at once that the principal job of the college or university is to train people in the basic sciences: chemistry, chemical engineering, metallurgy, physics, etc. I don't believe schools can train people to be inventors; I don't think you can make creative people; you can only encourage people. I'm not even sure how well we do in areas that sometimes are called applied science. I used to think that the schools inculcated the students with some feeling that basic research was a noble enterprise, and that applied research was a dirty word. But after an intensive study, I don't believe this happens except perhaps in a few schools. However, they don't do much to prevent this feeling. What really seems to happen is that during the education process, students become sort of idol-oriented.

Now, we can't do much about that, but I think we can do something about what I'm going to call the attitudes and the understanding of this problem on the parts of both the faculties and the students. The proposition is this: The student, especially the graduate student, in his own mind doesn't seem to have a choice. A large proportion feel somehow that if, when they come out of school, and don't get a first-rate academic post or a first-rate fundamental research job, they are becoming second-rate citizens; that they're settling for something less than the best. Unlike our proverbial car rental system this doesn't seem to make them try harder.

One of my proposals is that somehow we must learn how to give the graduate a choice. We must make clear to him that there are many challenges, equally exciting, equally important in our society and equally challenging. They depend on his own interests, his own capability, and his own motivation. In the field of science, engineering and technology there are three principal areas and I want to refer briefly to these.

First, there's the challenge of the academic world. Let me emphasize that we need good teachers, and we need good teachers who also understand research. However, it must be made clear that research in this area must be an appendage of the teaching process and not vice-versa, as it has developed in some areas. Advanced teaching will not proceed without the generation of knowledge and you can't transfer knowledge on a stagnant or a status quo basis. So I support the idea of supporting research in the universities, but again as an appendage to the teaching process. But to take a bright student — he may be the brightest in the class but one who has the pragmatic qualities of a businessman, the instincts of an entrepreneur, the organizational capabilities of a manager — and tell him that he should have a career in the academic world may do an injustice to that young man and a disservice to all of society. In the sense of this discussion, he isn't the "best man" for the academic world.

Second, we have the great challenge of industry. Here the spectrum of needs is so great that industry can accommodate almost every type of interest on the part of the technical man. And I'm happy to say that once a career in industry is properly understood, it can be very rewarding and very satisfying, and I don't mean just in terms of dollars.

Here the opportunities are very great. A few years ago I made a survey of some of these opportunities, and I hope you'll forgive me if I indulge in a little well-justified pride on the part of chemists and chemical engineers. I studied the 125 largest corporations in America as listed in *Fortune* magazine, and was astounded and surprised to find that the directors of research of eighty of them were chemists or chemical engineers. You would expect the director of research of duPont, Dow Chemical or Olin Mathieson to be a chemist, but I think you're going to be surprised when I tell you that the vice president and director of research of General Electric Company is a chemist. This is also true of Bell Laboratories, the United States Steel Company, of every major pharmaceutical company, of nearly every rubber company, oil companies; etc. It is indeed a remarkable challenge to offer to young students coming through our academic science ranks.

The third is in the public sector or what I am going to call "public service," which is principally in government. Here there are many important scientific and technological developments which today can only be carried on by governments. They deal with national security, with health and welfare, air and water pollution, transportation, urban development, and many other areas. As one looks through various government agencies, Departments of Agriculture, Interior, Defense, Atomic Energy, Health, Education and Welfare, Urban Affairs, Transportation — one finds hundreds of other areas involving major scientific and technological developments. To those who are public minded — and many of our younger people are — I think these offer wonderful challenges.

All this I think is so apparent that sometimes we wonder why we have to discuss it. Fortunately I don't think we need a violent revolution. What is needed is a mutual understanding, a sort of partnership on the part of industry, the academic world, and the world of government. In a sense a partnership already exists between the educational world and the world of government, the reason being that most of the money to support education now comes from the Federal Government.

Without digressing, I think it's obvious to most of us that modern universities have a tremendous range of social roles. They must train people to occupy everything from the ivory tower — and we still need ivory towers — to the other extreme of the executive and the manager.

Nonetheless, the thing I want to emphasize is that every individual must decide where to place himself in this spectrum. And this must start, if possible, somewhere during the educational process. It is a joint enterprise involving the student and the faculty with an awful lot of help from the industrial community. But, the spectrum must not be discontinuous, because no one knows where these lines of demarcation break off between academic, institutional, or industrial activities.

At this point, it is important that we understand why we have to give more attention to this entire process, and why we actually have to make these interfaces less resistant.

First, and above all, this country is committed to a certain rate of economic growth. All programs — the support of education, science, national security, health and welfare — cannot succeed if we cannot achieve this economic growth, because many things contribute to economic growth: labor, capital, etc. But economic studies today show that of the long list of things which contribute to economic growth, at the head of the list is the research and development process in the form of innovation of new industries, new products, and new processes.

Secondly it's important that we understand this phenomenon because there is growing evidence that economic strength and technological change, and not war, are going to have the greatest impact on our foreign affairs. It has been my privilege to make several trips this year to Europe in connection with a very politically sensitive problem called the technology gap. I don't want to take time to discuss the political impact of these problems, but you will see, when you deal with these people, that these problems are going to have a much greater effect than where we place our NATO forces in the immediate future.

And finally it's important that everybody understands this problem because the government, which is the chief source of funds for science and education, is going to demand more results from federally supported research and development. This is evident from Lyndon Johnson's remarks at a recent dedication of one of the National Institutes of Health. If any of you followed the hearings of Senator Harris on Government R&D, you can read this through all his discussions. Even more recently, Congressman Daddario has been nudging the National Science Foundation — a hallowed ground of basic research support — to take a look at the field of applied science.

Nowhere is this problem being more widely discussed than in the United Kingdom, where only a few short years ago you could never really talk about applied research.

I have a number of quotations, but do want to read you one by Professor Ewart Jones at Oxford University. This is what he said:

"This country's future is clearly dependent upon our ability to produce goods and ideas which other people want. Industries and universities are deeply involved, since in addition to the flow of ideas, lively academic progress is only possible in a flourishing industrial community, which in turn depends for a vital part of its manpower on the output of institutions of higher learning. But between universities and industry there is in widely varying degrees indifference and unconcern, lack of understanding of aims and motives, and one can suspect, here and there, even severe hostility."

Now, I don't think the problem in this country is quite as severe as it is in England. I don't think there is going to be a need for us to choose up sides, as some people think, between the industrial, governmental, and the academic worlds. Science is healthy in this country, but it's not quite as secure as many people think it is. So, we really ought to take an objective look at it.

What can be done? Well, I think many things are being done; in some cases perhaps not enough of them, or perhaps not fast enough or perhaps without enough understanding of the problems or the importance of the problems.

First and above all, we must realize and understand that these are joint responsibilities, and much is to be gained on the part of the academic world, the industrial world and the world of government by understanding of these problems. No one can sit back anymore and say, "This is your problem."

And second, although I think that while there are many problems here, the major responsibility rests on the shoulders of industry. Enlightened industry is already beginning to recognize this, and is putting forth much effort in this case. I can cite you examples of some very interesting experiments. But nothing will come from this unless industry gets or receives from the academic world guidance, and especially some sympathetic understanding on the part of the faculties.

It is frequently said that the modern university is society's great potential instrument for change. I'm afraid that in the past our universities have not always recognized the challenges in these forthcoming years, just as industry has failed to demonstrate its responsibilities. They've been too preoccupied with the very processes of growing, building bigger medical schools, bigger libraries, bigger everything; no one has sat back and said, "Where have we been and where should we be going?" They are beginning to do this today.

But industry must, above all, demonstrate to the technical man that its work can be challenging, as well as intellectually stimulating. Many suggestions are coming forth and I want to refer briefly to a number of them. Some of them have been tried. They all need greater study in depth. They need reevaluating in light of present needs, and not the needs of five years ago. And we've got to understand what the true purposes of these new experiments are.

One of the programs, and it was referred to elsewhere in this program, is summer jobs for faculty people and students. It is important that the faculty become more knowledgeable about modern industrial research and technology, but we must make proper choices of people for such experiments. In other words we must choose academic people who have pragmatic insights, and who could do well in industry. The wrong choices may do more harm than good.

The reverse of this experiment is also being tried. This involves part-time, or even full-time for a year or so, academic jobs for scientists who are in industry. Again, they must be interested and qualified. The director of the central research laboratory at duPont took a year and went out to the University of California. He's a brilliant scientist as well as industrial researcher and it proved a great experiment. It proved to the academic world that there are great scientists in industry, and that there is a real community of interest. This experiment is being done in a number of areas by enlightened companies; but again, they must be people who can demonstrate the stature of the industrialist and the qualities of the first-rate scientist. This might be called the reverse sabbatical leave. And in future years, I hope that many industries will invest such talent — they always say they don't have the time — they can't part with these good people. But I submit it's one of the greatest investments that they can make.

Another approach is to introduce into textbooks more references to modern chemical technology, so we can accomplish some integration of modern theory and technology.

Another area where I'm encouraging people to do more, is in consultantships. There are very few big companies that don't use academic consultants, but in most cases this is limited strictly to the exchange of technical information. These people could do a lot of wonderful bridging of gaps, if they thought more about our needs.

Finally I want to avoid any misunderstanding. I am not suggesting that the universities start pointing all their effort in science and engineering toward industry. But I am suggesting that we must train people to look at science, technology and engineering, as powerful forces which permeate education, industry, and government; in other words, they really affect every phase of our everyday lives. And depending on his capability, depending on his motivation, and his interests, the student can find an incredible number of challenges in this world. Our job is to give him a choice — to let him know he has a choice.

THE TECHNICAL MAN AND THE INDUSTRIAL WORLD

by *David Allison*

As we grow older, I suspect many of us make the mistake of attributing undue wisdom to the young. I do not mean that we attribute *great* wisdom to them. Certainly we do not regard them as being as wise as we are now. Who so young could possibly be so wise? But I do suspect that we think they are wiser than we were, when we were young.

Not so long ago, I visited a great university on the West Coast, and I talked with a contemporary who, himself, had graduated from that same university about twenty years ago and who now holds an important administrative position there. In the course of our conversation, in talking of the calibre of young people who today pass through those portals, my friend said — with admirable pride in his institution and, I thought, with admirable modesty: "This school is so good . . . and these youngsters are so bright . . . I know I could not be admitted here today."

With this assessment of the young undergraduate, valid as it may be, do we not assume that he knows more than in fact he really does know about what it will be like when he goes to work in industry, or when he joins the faculty of a university, or when he joins the staff of a research laboratory?

A word that comes to mind when considering this problem is "strain" . . . the strain encountered by engineers and scientists in today's industrial environment. I have raised this matter of what the student really does know about the world he is about to enter because this is the cause of one such strain. When he enters the industrial world or the research world, all too often he discovers that it is not at all what he had thought it would be. He becomes uncertain. He worries that he made a wrong choice. And he worries that he will fail. As social scientist Lowell Steel says, he comes with a whole list of questions:

What kind of work will be appreciated in this place?

Will they want me to do what I want to do?

How do I find out?

To what extent can I believe the words I hear?

And when he has been there for a little while, he discovers to his horror and astonishment: "I have no experience *asking* technical questions. My thesis adviser posed my thesis question for me!" And then he asks himself:

Will I be capable of asking major productive questions?

With these worries on his mind, he encounters still others:

What is this thing called a boss? He is not a thesis adviser, or a senior professor. I understand those people, but I do not understand a boss. How do I behave toward him? What is the extent of his influence over me? What are the mechanisms he has to influence my behavior? How much should I take from him?

And soon he begins to ask himself still another series of questions:

How do you talk around this place? What are the do's and don'ts? Can I continue to be a scientist here or an engineer — or am I just an employee now?

And finally he asks himself:

Am I going to achieve my personal goals here? I don't even know yet what I want to be, but will I be able to *be* that here?

In our kind of technical society, it is perfectly understandable that the young man should be confronted with these questions. He is moving from one world, over a great divide, into a quite different world. And, strangely enough, although those two worlds should at least be in touch with one another, they seldom are.

Although they should be exchanging ideas *and people*, they seldom do. Rather, the flow is in just one direction, from the academic world, across the divide, and into the so-called "real" world. Feedback from the industrial to the academic world is largely missing. Our young scientist or engineer hesitates about going at all. "Maybe I won't like it," he tells himself. He delays his jump as long as possible.

The University of Chicago's National Opinion Research Center talked with thousands of undergraduates about their future plans, and found that the typical college undergraduate is more likely to anticipate going to graduate school than is the typical high school student likely to anticipate going to college. I know there are many who lament this trend toward more and more graduate education. There are some half-a-million young people currently pursuing advanced degrees. But in the long run, I believe this trend will help to soften — if not solve — one of the major problems of the technical man. I mean the problem of technological obsolescence — but more about that later.

I think of Jay Stratton's two graphs in connection with this trend toward graduate education. When he was still President of M.I.T., Dr. Stratton pointed out that the retirement curve was growing younger and younger. His second graph showed just the reverse, for this was the curve of years of education, showing that Americans grew older and older, what with college and graduate school and post doctoral study, before leaving school. "When the curves cross," he said, "we will have achieved the Great Society."

I believe that one of the most serious strains the technical man encounters in industry — particularly the man in industrial research — is a strain that is caused by guilt and frustration. Both the guilt and the frustration grow out of the same set of circumstances. Let me try to describe these by way of an example. Let us imagine a young chemist, a PhD, who has worked for five years in an industrial laboratory. Let us grant that he is a very good chemist and that his laboratory is a very good laboratory. One day our young man begins to appraise himself: how has he been doing during these five years? Well, he can look back and count the number of papers he has published. A respectable number. And he can look back and see that he has increased his annual earnings by a respectable amount. So far so good. But then he asks himself: what was it that attracted me to this place five years ago? Have I succeeded in reaching the goal I set for myself? The chances are he is going to be disappointed in himself when he tries to answer these questions. He is going to compare himself with a classmate who did *not* go into industry . . . and who has published *twice as many* papers as he has. Or he will compare himself with another young fellow who works down the hall: this fellow solved a problem last year — it took him months to do it — but today, thanks to that solution, the company is on-stream with its new chemical plant in West Virginia. Anytime he wants to, our sad friend thinks, that chemist down the hall can go down to West Virginia and look at that plant and tell himself: "I helped to build that." What do I have to show, aside from those few papers — they weren't so great anyway — and aside from an occasional assurance from my boss that I've been doing a good job?

The point I am trying to make is that *value, worth, contribution* — things the industrial scientist must be measured by — are often intangible things . . . and defiant of measurement.

Consequently, the scientist himself oscillates between feelings of guilt . . . telling himself that he is not valuable, not worthy, not contributing . . . and feelings of frustration . . . telling himself that his *company* is no good, because it has not exploited — not even *tried* to exploit — any of his ideas.

And the company itself, meanwhile, is going through a similar kind of agony: what are we getting out of research? *Why* do we need to be doing any research at all? I heard the story a while ago of a very large industrial laboratory and the cleavage of suspicion that had grown between that laboratory and top management of the company. The laboratory was not creating the kinds of things top management wanted. When the laboratory proposed something new, and when the idea was carried through development, the product would . . . more often than not . . . fail to establish itself in a market. Usually, this was not the fault of the product, but of management's inability in the marketplace. Still, such failures caused a fear on the part of management toward all developments that the people of the laboratory proposed — a fear that these too would fail. And the people in the laboratory, in turn, resented management. Finally, the ideas stopped flowing altogether. This is the situation today, though the laboratory continues to cost the company about one million dollars per week. What if this laboratory ceased to exist? What effect would it have on the company's competitive position? The man who told me the story and who worked trying to straighten out the problem seems to think that aside from the technical services the laboratory provides, its disappearance would have no effect at all.

This story seems to me to illustrate several failures. Certainly it illustrates a failure in communication. And a lack of mutual respect. But perhaps most of all . . . when we look further into that particular industrial environment . . . we see the illustration of how divergent goals can cause trouble in any industrial organization whose growth comes from science and technology.

For example, what are the goals of the scientists who work in that laboratory . . . or, for that matter, in most industrial laboratories? I believe most industrial scientists want to feel that they are contributing something to *science* and, through their organizations, they want to feel that they are contributing something to *society*. Now . . . what are the goals of the top manager? Certainly one very important goal — if not his primary goal — is to make a profit. He is measured by his ability to achieve this goal and, indeed, he is rewarded accordingly. In turn . . . and perhaps instinctively . . . he measures the worth of the industrial scientist by this same rule: is he profitable or is he not? The danger here is not the threat it poses to the "not profitable" scientist. Rather, the danger is the fact that few scientists — however creative they may be, however profitable they may be — find sufficient satisfaction in their profitability. To know that his discovery is reaping great profits for his company may make the scientist feel good as an employee. He *wants* to know that he is paying his way. But knowledge of profit does not satisfy him as a scientist.

Thus, if he is to feel fulfilled as a scientist, he must know that *his* goals and his *organization's* goals are not pulling him apart. He must know that he can do good science *and* make a contribution to his society through his organization. In short, I believe he must know that his organization's goal goes beyond profit, that his organization has some greater mission. This does not deny the importance of profit, for it recognizes that only through a healthy, profitable organization can that mission be achieved.

But this will not guarantee that our young chemist will be able to achieve his goal, or even that his organization will gain from its investment in him and his colleagues in the research laboratory. And this brings us to the question: how is that investment exploited? How is an industrial research organization *organized* so that there will be something coming out of it? This is what top management wants. And so do the scientists. But how is it done?

Little by little, I think we are learning how *not* to do it. As we saw in the horrible example of the million-dollar-per-week laboratory, and as many companies are learning today, great, profitable ideas do *not* just *explode* out of the laboratory. For one thing, we do not *like* new ideas. We are afraid of them. We are afraid of the scientists who come forth with new ideas. We are afraid that their ideas are going to be unprofitable. So we do what we can to discourage them.

Well, then, how *do* they happen? I recommend to you a study I have recently seen called the "Report of the Ad Hoc Committee on Principles of Research-Engineering Interaction." This report is the work of a dozen or more scientists and engineers who work in the industrial research environment: Ford, General Electric, Arthur D. Little, Koppers, Mellon Institute. The chairman of the committee was Morris Tanenbaum, who is director of research for the Western Electric Company. Tanenbaum and his colleagues looked into the histories of ten important technical developments . . . the development of silicones, the development of Pyroceram glass, the development of superconducting materials. What had made these things happen? In every case but one, these developments had begun with a *recognized need*. Somebody had recognized — and usually it was not a scientist in the research laboratory — that if we had this, we could do that. *Then* the laboratory went to work, helping to produce the new knowledge that would be necessary to make the development successful. This does not say that science is unnecessary. Quite the contrary, it was necessary in every case. But this does say — at least for nine of these ten cases — that the idea did not begin in basic research. Usually, it began in engineering or elsewhere. The one exception, by the way, was the development of polysulfide polymers — the development which has meant the great success of the Thiokol Chemical Corporation. And this exception, according to Edward Fettes, who made the study, was "unquestionably accidental."

Let us look now at that other strain which affects the technical man, this matter of "obsolescence." It begins to occur a little later in his career. Or, rather, I should say that it begins to be *evident* a little later on, for it begins to occur on graduation day. I think this strain is more likely to affect engineers than scientists, although each is concerned about it. We know what it is . . . it is the terrible discovery that one should have at his command a good deal more information than he actually has . . . the discovery, in short, that one is "out of date."

Mr. A. C. Montieth, a vice president of the Westinghouse Electric Corporation and formerly the President of the American Institute of Electrical Engineers, perhaps stated the problem most dramatically — and certainly most bluntly — when he said, "Today's graduate engineer has a half life of about ten years." Harsh as it is, Mr. Montieth's statement is true for most of us. We are out of date. If you are of my generation, having received your technical education prior to 1950, you did *not* study:

Information theory
Feedback control
Modern atomic and nuclear physics
Computer technology
Computer aided design
Solid state physics and molecular engineering

Superconductivity
Plasma physics
Probability theory and its role in engineering decision making.

If you feel "out of date" for not having been taught these subjects — many of which have grown to major technical disciplines since we were students — at least you and I can know that we are not alone, for about one-half of all the engineers in the country today suffer this same deficiency.

We can agree, I believe, that this is a matter for concern. It is a matter that I must be concerned about, if I am to serve the people of the technical community. I must ever be aware that the technical man looks to his technical publications for help: what is this thing called " computer aided design" and what does it mean for me? Tell me what I should know about plasma physics! For most technical men, I suspect, the technical journals are the only continuing source of information on new technological developments. And if I am correct in this assumption, it is a sad commentary, for the technical journals are simply not enough.

I know that you too are concerned about this problem, as men who represent the professional interests of scientists and engineers. But perhaps you feel the same frustration I feel. Perhaps you are asking, "But what can my society do, alone? The problem is simply too big for us to handle." What I shall try to suggest later on is that the problem *can* be dealt with . . . collectively. By the societies, by the journals, by the universities, by the industrial organizations, by the federal government, and by others as well.

Indeed, I believe we must approach a solution by admitting to ourselves, and then convincing others, that we are doing something wrong. Let me see if I can clarify that statement. If this were a society which did not depend so much on science and technology, then I think our error would not be so significant. But this is a technological society. It is a society which looks to technology for solutions to some of its most urgent problems, be they military problems or social problems, global problems or local problems. Whether we are talking about problems of low agricultural productivity in India or high air pollution in New York, whether about efficient boosters to take us to the moon and planets and beyond or simply efficient vehicles to carry us back and forth between the city and the suburbs, whatever the nature of our problem we know that a significant part of its solution must be technological.

To whom do we look for a solution? The engineer who knows one-half of what he needs to know to do modern engineering? Or the young man who may know more modern engineering? Or the young man who may know more modern science, but who has not yet learned to be an engineer? Are we not the victims of a very wasteful system when that system allows its most precious resource . . . its people . . . to rust away? Do we treat out manufacturing equipment in this wasteful way? Or our homes? Is it any wonder that the technical man suffers under a strain, knowing that it is *he* who is rusting? As James Killian has said, obsolescence is a constant occupational hazard to the technical man . . . and this hazard is greater now than ever before, now that the flood of new scientific knowledge is a Niagara-like torrent, with the time between discovery and application growing shorter and shorter.

What are we to do to change this condition? We all know of efforts that are under way to improve the situation, important efforts, including special programs under the sponsorship of the professional societies such as EJC's National Clearing House for Continuing Education . . . and programs created by some of our technological universities, such as M.I.T.'s new Center for Advanced Engineering Study, where a professional man from industry or the academic world can return to school for intensive study — for two weeks, or ten weeks, or for a full year. And joint industry-university programs, such as the program created by Rensselaer Polytechnic Institute and the Long Lines people of AT&T. Here was a situation that is typical of many technically-oriented organizations: AT&T had dozens of technical men in Long Lines who were out of touch with some of the very technologies that the telephone company had grown on during the past fifteen years. Information theory and advanced theories of communication. Superconductivity and other properties of modern materials. Solid state electronics. What does a company do with these men? Does it fire them and replace them with younger people who do have this new knowledge? This course of action may have been taken by some organizations, but fortunately it was not considered in this instance. Or does the company send its people back to school for several weeks — or perhaps for a year? Again, this has been developed at UCLA. AT&T did not elect this approach, but instead worked out a schedule with RPI which enabled its technical people to bring themselves up-to-date over a longer period, with one week at RPI, then two weeks back on the job, then another week at RPI, and so on through the better part of the year.

There is much to commend all of these programs . . . indeed, we find many enthusiastic comments on each of them. But let us grant that these and others that do exist represent only a small invasion on the total problem. For every technical man who is involved in a program of re-education, there must be ten others who are not — who have not been back to school since graduation. Moreover, each of these programs that I have described is a short-term affair, designed to remedy a situation that has been building up within the individual (*and* within his organization *and* within our society) for some long period of time.

If this problem is truly to be solved, if the technical man of forty or fifty is to be as valuable as he might be, then I think we must be far bolder in our solution to the problem. In other words, we have to recognize that the real need is for *continuing* education . . . rather than short, intensive *bursts* of education every ten or fifteen years. We have to make continuing education for technical people *habitual* — as habitual as going to work every Monday morning. I think we must ask ourselves: if John Smith, a good engineer aged 40, is worth $20,000 a year to his company and to his society, despite the fact that he is a bit rusty in modern engineering . . . what then *might* he be worth if he possessed *both* his rich experience in engineering and a strong background in modern science and engineering? If his worth is increased by $10,000 a year . . . or perhaps $20,000 a year . . then is it not sensible to consider some means by which a small allotment of money and time might be invested here in the continuing education of Mr. Smith? For example, a radical idea: supposing we decided to enable him to spend one full day each week in school. One full day, beginning during that first year after graduation and continuing so long thereafter as he wished to continue. In terms of cost, including the cost of time off and the cost of education itself, this radical scheme might cost as much as $2000 to $5000 per year. A lot of money. But what is the return on the investment? If the investment makes him worth half again as much as he is now worth, age 40 and a little rusty, then isn't the investment worthwhile? Wouldn't we do the same if Mr. Smith were a $20,000 fork-lift truck? Indeed, he is the most valuable piece of equipment in the place . . . the only piece of equipment (he and his fellow technical men) which can actually appreciate with age. And yet we seem too often to give more thought to the upkeep of the capital equipment than we do to the brainpower.

Well, this is very nice to think about but is there really anything to be done beyond that? I believe there is, if we will recognize continuing education as a great national opportunity . . . if the professional societies recognize it, if the universities recognize it, if industry recognizes it, and if the federal government both recognizes it and enables something to happen. For example, I think it is unrealistic to expect many corporations to carry the cost of continuing education for their professional people. The technical community, in the United States at least, is too mobile to expect many corporations to be willing to educate their employees only to find those people being lured away by somebody else, perhaps someone who has not made substantial investments of this kind. Further, it is perhaps important that the individual himself carry a substantial part of this investment. After all, it is an investment in himself. And he is likely to derive from it no more than he himself puts into it. But the corporation can contribute — and should contribute, in my opinion — by giving the man opportunity for continuing education, by providing him with a given number of hours each week (working hours) for school. The federal government could encourage this in two ways: by giving the corporation a tax credit for the time allowed employees for school and by giving the individual a tax allowance to offset his investment in education.

The greatest obstacle, it seems to me, is simply ourselves. We fear the new. We resist change. This is the nature of man. I read the other day that the workers in the Soviet Union are now to be able to spend their Saturdays at home. Saturday is no longer a work day in the USSR. I wonder how long that great tradition was battered at before it finally fell. I remember when Saturday was a work day in the United States . . . and I suspect it continues to be so in many parts of this country . . . and I remember the warnings of dire consequences when radical thinkers began to propose that the working Saturday be abolished.

Of course, I am not proposing anything so slothful as a day of fishing. All I propose is a day of school. And, indeed, I will go so far as to propose that it be a day of school for every American who wants to go, whether he is a scientist or engineer or grocery store clerk or dentist or longshoreman. Even my Congressman can go. I wish he would. I am saying, "Let this become a national habit."

In Japan, one of the first things a visitor is impressed by is the vast number of flower shops. Flower shops everywhere. Along the Mediterranean, in Greece and Italy and elsewhere, there is the daily habit of siesta. You close down at three o'clock and go home for a nap. We Americans regard these things . . . the flowers of Japan and the Mediterranean siesta . . . as quaint national customs. We perhaps regard them as excessive. Certainly we would not allow such frivolous customs to spring up in the United States. But there they are . . . and we like to go and observe them, and then return to tell our friends about the quaint behavior of these charming folks in far off lands.

I would like to believe that there will come a day when the visitor to the United States discovers the American's quaint custom of going to school. "Do you know, *everybody* goes to school in that country. Old people. Young people. *Everybody.*" I hope this custom becomes so buried in our culture, so much a part of it, that nobody will be able to remember where it started. Like the flowers of Tokyo and the siesta in Madrid and tea time in London. If Dr. Stratton will forgive me, *that* will be a Great Society.