RESEARCH AND DEVELOPMENT IN HUMAN ENGINEERING

5 October 1948

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Publication No. L49-26

THE INDUSTRIAL COLLEGE OF THE ARMED FORCES

Washington, D. C.

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COLONEL RUTLEDGE: The emphasis which has been placed on research nd development during World War II and since that time has resulted n the procurement of military weapons which have amazing capabilities. his emphasis has given the armies and navies and air forces of those ations which are technologically advanced tremendous advantages over heir adversaries. However, it has resulted in a new problem, which ecomes increasingly important as this equipment becomes more complicated nd the time factor more shortened for the manual operation of the equip- ent concerned. This problem is the development of machines so that the rdinary man will be able to operate them effectively. The Services are ware of this problem and have called upon the psychologists of the country o help them solve it. It is only fitting, therefore, that we have one of hese men to give us a lecture this morning on research in human engineer- ng.

Our speaker this morning, Dr. Marquis, not only is eminently known as psychologist, and is head of the Department of Psychology at the niversity of Michigan; but he is also Chairman of the Human Resources ommittee of the Research and Development Board. It gives me great pleasure o introduce to you this morning Dr. Donald G. Marquis.

DR. MARQUIS: I guess it is no longer necessary to argue that in any eapon or weapon system the human factor is one of the things which have o be taken into account. Even in my short life I can remember when that sed to be a point of contention. But I think we can take it for granted ow and return to the question of how best the human factor in a weapon ystem can be engineered for the total effectiveness of the system, which ncludes the machine and the operator in the total environment in which ney have to work.

At one time perhaps we thought that with the development of push-button idgets and automatic devices, we would be able to eliminate the variability operation and the possibility of mistakes which arise from the fact that ere are human operators for each of these machines. That has not turned t to be the case. When lookouts in certain situations were replaced by dar devices, we merely changed the nature of the visual task of the erator. Instead of looking over the sea with his bare eyes, his task w becomes one of interpreting the signals on the radarscope and integrat- g them with other information. As a matter of fact, the task is one which more complicated and puts a greater demand on the individual.

The general field, then, which concerns the operator in relation t the machine that he is working on, is the field that can broadly be ca human engineering. It is not a new problem. We have always had the p of designing machines so that people could run them, and of setting up which were capable of being carried out by individuals. The problem, was one which was solved by common sense or wisdom or experience, and was no special technical field recognized to deal with this problem.

Perhaps an analogy with the subject of meteorology would make this clear. We have always had weather predictions since people have had rheumatism; and the only difference now is that a scientific and techn field called meteorology has developed to do the job a little better; always perfectly, but in the long run and on the average with much mor nearly accurate predictions.

The technical field which is concerned with the problem of human capabilities and the limits of human work is psychology. Psychologist have recently become more concerned with this general problem because of the needs demonstrated in the experience of the last war. So psych incorporating facts from neighboring fields like physiology, physics, a engineering, is trying to put them together in some kind of interdisci pattern which will give a total attack on the problem of human enginee

The phrase "human engineering" is itself a new phrase. Perhaps it not the best one to describe this general field. Certainly it is used different ways by different people. Let us take a simple example from experience of the last war. It was apparent that we would need a lot pilots. A pilot's job is just one of the two or three thousand specia jobs which are required in the Armed Forces. We could just as well ta radar operators or truck drivers or any other. But at any rate it was recognized that we would need a lot of pilots and we didn't have them. the Air Forces called on a group of specialists to set up procedures t get the right kind of pilots.

Their first conception of the job of fitting the man and the machine together into an effective combination was to select the right persons Accordingly the first task assigned was that of the selection of perso for pilot training. And so a small group of psychologists were assemb and they started to devise a series of tests, both of the pencil and p sort and the mechanical sort, which would provide a measure of an indi aptitude and potential capacities for the job. A large number of test introduced, and they were tried out with varying degrees of success. became apparent very soon that the only way you could tell whether a p test was good was whether those individuals that did well on it then w to become good pilots. All right, what is a good pilot? Well, perhap the long run it is the pilot who survives, or who brings down the larg number of enemy craft if he is a fighter, or who gets more of his bomb

missions done. But we couldn't wait for that kind of criterion, because data on those things are not easily available. So they took the next best measure of who is a good pilot--the person who is graduated from a training course.

But in using that criterion against which to measure the effectiveness of the selection tests the experts very soon discovered that the training itself might stand a second look. There was a certain amount of material in the course which was ordinary book learning. If we were to choose our selection tests against the criterion of the training course, we might be selecting people who could read well or who could do well in a written examination--things which are not required of the pilot in the ordinary course of his duties.

These considerations led the human engineers or psychologists into the question of possible changes or modifications of the training programs. As a result of some of that work, methods of shortening or improving the training programs also came within the scope of the research in human engineering.

As they began looking at the training programs, they began to wonder whether we were training for the right things, whether all the errors and mistakes which were observed in field operations were the result of faulty training or whether perhaps some of them resulted from features of the plane itself which tended to produce mistakes and errors in reading the instruments, errors in reaching for the wrong control, or something of that sort. And so studies were made of the features of the instrument or weapon itself, in this case the plane, which put limits on the kind of operators that we had. It is perfectly true that an airplane is built so that a competent person can fly it; but that doesn't mean that the kind of people who get the job of pilot will all of them under all conditions be able to fly it without any errors, and a single error is apt to be very serious.

So an analysis was made of the possible trouble spots. The simplest way to proceed was just to ask a pilot what sources of difficulty he had found or what errors he had made. For instance, a common error was to misread the altimeter by a thousand feet, because the pointer as it swings around is at the same point. It is perfectly possible to make such an error, and it occurs many times. For example, one pilot coming in and intending to level off at 800 feet misread the altimeter and leveled off at 200 feet below ground level, with a result which fortunately left him able to tell the story. Or in reading the artificial horizon he may get mixed up and get it just backward. This information suggested that it might be wise to design the equipment and machines in a way which would tend to minimize the errors. And so this general process of human engineering got pushed a step further into the field of engineering design of the equipment and the machine.

There are other features which came under study as this problem was pushed further. The general environment in which the operator works, at what altitude it is necessary to introduce oxygen in order to maintain his efficiency, or what temperatures he can tolerate without impaired efficiency, or what noise level, and so on, are features of the physical and physiological environment which have an effect upon the possibility of mistakes or errors.

Similarly there is a psychological environment in which the operator works. This might be thought of as social environment. If he is working with other people, there develops in his interpersonal relations what we sometimes generally call morale; a factor which will have a large effect upon the efficiency with which he does his job. We all know that in a high-morale team, such as in a bomber group or in a submarine group, people seem to be able to do things with greater efficiency, to work longer without fatigue, and so on, than in similar groups in which the tensions among the individuals are a source of annoyance.

And then another problem comes up when you get into large-scale operations, like choosing the thousands of pilots which were necessary. What is the effect upon the total manpower resources of picking out one hundred thousand people for pilot training? If they are all taken from the highest talent level, then will there be enough of that talent level left for the other jobs which require a similarly high degree of intelligence and coordination and responsibility and so on? So we then get into manpower resources and requirements and allocation problems, which require knowledge of the levels of capability of the people in the population, which again is a psychological study of individuals.

From this example perhaps we could now draw out those main features of human engineering which define this field of man-machine problems:

First of all, of course, there is the engineering itself; the design of equipment so that it works and so that it fulfills the criteria of good engineering; that is, it is accurate and doesn't break down, and so forth.

Second, then there are other features of design which are dictated by the requirement that the machine is going to be operated by a certain kind of person, either the average person or a person with certain stated capabilities and potentialities. This, then, is the human phase of engineering, and is sometimes called "human engineering" or "engineering psychology."

For example, the displays on the machine, the indicators, dials, and so forth, can be designed in such a way that they are easily and accurately read, or they can be designed in such a way that under the stresses of operating conditions, with perhaps a little fatigue and a little distraction thrown in, there is a greater chance of error.

A dial which is perfectly satisfactory to an engineer in the sense hat it is absolutely accurate within two percent, that it can be read y anyone who takes the trouble to look at it, may be completely unsat- sfactory in terms of operating conditions in which that dial will fur- ish information to the operator. So methods of getting information, ethods of display, communication equipment, auditory signals, and so orth are important features of design, which have to be looked at care- ully from the standpoint of the person who is going to use them.

Similarly, the controls may be good or bad with reference to operator erformance. The amount of resistance which the operator meets in pushing control must not be too little, because then you get an overthrow. It ust not be too great, because there is then the element of fatigue in ontinued operation. There is an optimal point, which cannot be determined y engineering principles alone. A control may be completely adequate in he sense that if you move it to a certain spot, then the proper result ccurs. But from the standpoint of the operator there may be a big difference. imilarly if the operator has to identify the controls by touch, the shape f the handle of the control is important if you want to be sure he gets old of the right one. Then the arrangement of the different dials and ndicators and controls can be of a sort which tends to promote good operation r not. Another feature is the design of the operation procedures themselves, hat is, the instructions which are given to the operators.

These things can often be determined as the result of experience, rovided someone is checking up. If there are many operational failures, ou begin to wonder why and recognize that something is wrong. That doesn't ell you what is wrong, of course. But it is necessary to introduce these onsiderations at a much earlier period than that of an analysis of flying ccidents or operational failures. So these things belong at the stage f the design itself, following through in the production models and ock-ups and so forth.

An example may make this operational procedure a little more concrete. he remote radar indicators are usually equipped with a bearing cursor n order to make more accurate the readings of bearing. I don't see how nyone could question that the use of the cursor would increase the ccuracy of the reading of the bearing, and it does if the operator has ime to do that and nothing else. But in actual experiments it was found hat the use of the cursor did not increase the accuracy over direct read- ng of the bearing when there were just single flights on the radar ndicator; and when two or three or four flights were being watched at the ame time, the use of the cursor slowed up the operation so much that there ere actually more mistakes.

This is a very quick and brief survey of the kinds of problems whi enter into the design of instruments from the standpoint of the operat who has to use them in a particular system.

The third feature, then, of this total process of man and machine would be the selection of the operators. This is one which is readily recognized as a clear-cut problem. It is one on which the greatest am of work was done during the last war and on which everyone seems to ag that it is necessary and desirable to continue work. I have tried, ho to put it in the context of the larger problem, so that you can see it only one feature of the total problem.

Fourth, the methods of training constitute the next step, because one training technique you may produce a man-machine combination that and by a less adequate training technique you may produce a combinatio which does not work.

One of the crucial problems in the field of training methods now i the use of synthetic trainers. It is crucial because synthetic traine are very expensive, and because the few observations and experiments f the last war did not indicate any very great effectiveness of the synt trainers. The people who were trained on them learned to operate the trainer itself very effectively, but when moved over to the real equip they did not show any clear advantage over people who had not had the course on the synthetic trainer. This is not a final conclusion, beca it may be the result of the particular trainer or particular methods t were used; but it certainly raises a question for research in the eval and redesign of trainers, not to make the trainer any better, but to m the transfer better from the trainer to the actual operation for which is intended.

This is a problem which the psychologists call "transfer of trainin Being trained on one machine, how much does that improve your ability t operate another machine? At the present time research is planned on s of the basic principles of transfer of training in the hope that from that can come a better design of synthetic trainers.

The fifth and last aspect of this total process would be the discov and control of the environmental conditions in order to produce the opt efficiency of operation of the man-machine combination. And here, as I said, we are concerned with lighting, ventilation, temperature, noise, certain special problems which arise from operations under tropical or conditions and those social environmental conditions which we call mora

This then is the problem: this is the task for the human engineer-- produce man-machine combinations in such a way that the most effective operations result.

What kind of research do they do in order to achieve the result? How can you recognize the psychologist working in this field? For one thing, we don't see any big, impressive installations like at an ordnance research laboratory or the David Taylor Model Basin. There are no wind tunnels or other big gadgets. What you see is a bunch of people working at their desks, some of them with calculators totaling up figures which have been collected in laboratory or field observations. You will see someone in another room administering a test to a sample of one hundred individuals pulled in from the field for purposes of purifying and improving the test, and of determining the norms and the distribution of abilities. You will see another group over in a laboratory looking at a mock-up of a cockpit instrument panel and recording information from it or making reactions in accordance with the information.

One feature of this research is that it must always remain close to the operation. If you want to know what the capability of truck drivers is, you go where the truck drivers are and study them. You don't find a laboratory stuck off in the sands of New Mexico where in isolation and secrecy some technique is developed and then presented on a silver platter for the use of the Armed Services. These problems have to be studied in very close connection with operations. You have to know exactly what the jobs are, and that requires observation of the jobs. You have to study the actual people who are called upon to perform these jobs.

Another feature of this research which is a little hard to understand, particularly for people whose training has been in engineering or some of the other fields of knowledge, is that in all cases we are dealing not with certainties but with probabilities. For this purpose it is necessary to make statistical estimates of the probability of this or that outcome.

Now, if you were to call in an engineer to design and build a plane which is capable of carrying ten tons at a cruising speed of 400 miles an hour, you can tell when he has done it. He has delivered the plane to you--you try it out and it either does or does not do what you expect of it. If, however, you call in a psychologist and tell him to give you the specifications for, let us say, an operator for a sonar gear, things are not so clear cut. You first have to put the operator through a long period of training before you try him out; he is able to interpret the sonar signals and do what he is supposed to do. But that is not the whole story. He has to keep doing this over and over again, and the problem is to get an operator who will be able to do his task ninety-nine times out of a hundred without error.

Nobody does this a hundred times out of a hundred correctly because the signals vary in their clearness, and other conditions change. So the problem is one of predicting that this operator will be able to do it at a certain level of proficiency. Sometimes he will do it better and sometimes worse. Some operators will do it better; some operators will do it worse. But you get a total average performance of sonar operators at a

probability level which is adequate for the requirements of that operation This, then, is a statistical problem; the only way it can be dealt with is in terms of probabilities.

Research in human engineering might be divided into three types. I wi call them testing, engineering, and basic research.

Testing is the simplest type. You are given two gadgets and you are asked which one an operator can use the better. So you bring in a sample of ten operators and try them first on this one and then on that one and record the response that they make in the situation. You come out with the conclusion that gadget A is 18 percent better than gadget B, or that the number of errors made on one is a third greater than on the other. That is usually what you want to know.

But all that you have then is a comparison of these two gadgets. As soon as a revised model of the gadget comes along, you have to do the test ing all over again. You don't have any general knowledge which enables you, by studying the characteristics of the gadget, to be able to say with out tests that this one is better than that one. This is the testing type of human engineering research.

There is a second kind of research, which provides specific guides for engineering or the design of equipment. The analysis of performance of equipment provides certain information, for example, that if you turn a dial, it ought to turn in the same direction that the hand turns; otherwise you get confused. Such a finding will work for any dial. Or if an adjustment requires the operator to turn a crank, the best kind of crank for that purpose is one that has a radius of three or four inches and moves at a speed of one or two hundred revolutions per minute. If you know that in one situation, it may be useful in another. So this type of research examines certain features of the design in such a way that recommendations can be made which will be useful in the design of other equipment.

The third kind of research, which we call basic research, is directed not at any gadget or instrument particularly, but tries to get at a funda- mental understanding of the capacities and work potentialities of the human individual. What are the limits of his visual acuity? What types of auditory signals can be distinguished best? What types of movements are most accurately and easily carried out? Such basic research, which is the kind going on in psychology laboratories all the time, is producing a storehouse of knowledge which can then be used in the engineering of particular instruments or equipment or weapons.

An example of basic knowledge which was pulled out of the dusty archives was the use of red light for preserving dark adaptation. It was discovered by some fuzzy old psychologist in the latter part of the nineteenth century. It had never found any practical use of any kind. It was a laboratory curiosity. But when the practical problem came up, that knowledge was available. The curves had already been plotted and it was possible to move quickly into practical application of the use of red light for preserving dark adaptation.

Those, then, are the three kinds of research which you meet in this field--testing, engineering, which is the application of knowledge to the design of instruments; and basic research, which is the discovery or creation of new knowledge.

The interrelations between these three types of research now become apparent. Engineering applications are limited by the amount of basic knowledge; and if all the effort is placed on testing and engineering applications, there is no accumulation of basic knowledge, which is what permits advance in the field. Let me turn, then, in the time that remains, to a very quick review of current programs in the field of human engineering.

In equipment design, the Navy has a laboratory group working at NRL principally concerned with fire control and gunnery problems, and doing very effective work. There is another small group in the Electronics Laboratory of BuShips at San Diego working on sonar and undersea problems. At the Submarine Base at New London another group is working on technical problems of equipment design with especial reference to undersea operations. The Special Devices Center on Long Island has a human engineering section working on the general problem of equipment design, with contracts for basic research let through the Office of Naval Research. That is all for the Navy. The Army has a Quartermaster group working on the design of equipment and equipage which have to be fitted to the individual, and that is all, except for a plan for a new laboratory at Fort Knox under the Surgeon General's Department. The General Research Office of the Army can let contracts with industry or university research groups for such work, but it has not yet proceeded to that stage. In the Air Force there is an outfit at Wright Field in the Aero Medical Laboratory, Psychology Division, which deals principally with problems of cockpit design for better pilot performance. There is other work at the School of Aviation Medicine at Randolph Field, and contracts can be let through the Office of the Air Surgeon. That is the picture. There are twenty scientists in all three Services who are engaged in this work and in addition a couple dozen contracts with universities or other research agencies.

In the field of selection and training the Navy has a small group with perhaps a dozen people in the BuPers dealing with the problem of research on selection and training. In the Office of Naval Research there is a Psychology Section, which lets contracts for basic research in this field. In the Army there is a much larger research group in the Personnel Research Section of AGO dealing with problems of selectio and training. This is, I think, probably the largest research group in this whole field in any of the services. They can let contracts themselves for outside work which is needed. In the Air Force the Training Command has recently been given cognizance over the problem of research in selection and training, and is proceeding to initiate a program in this field.

In the remaining field, morale or the psychological environment in which people work, there was some extremely interesting and stimulating work done during the last war by a troop attitude research unit in the Information and Education Division of the Army. This work was cut off at the end of the war except for a small skeleton staff, which is so swamped with routine operational work that it has not been able to unde take any research since the war. There is a small amount of related work in the AGO Personnel Research Section, where they have gotten into problems of leadership in connection with their problem of officer selec No work is going on in the Navy or Air Force in this field, although potentialities for it exist.

Here, then, is the picture. By recent count there were seventy-eigh professional persons engaged in the three Services in this whole range of work from machine and equipment design to selection, training, and morale. This contrasts with over a thousand who were engaged in this work during the war. But that is not the important contrast. The relevant relation is between the magnitude of the military needs and the level of work.

There are, as I said, two or three thousand different specialized jobs in the Armed Services. Each one of them could conceivably be studied with the same care as pilot selection was studied during the last war. Pilot selection, however, required the work of something like eight hundred scientists and technical specialists. You can see the potential magnitude of the job. If each of these two or three thousand jobs were to be studied in the same way with respect to selecti and training, design of equipment used, and morale conditions, it would an enormous task. Obviously, priorities have to be established for the important and critical jobs. This requires a degree of coordination and staff consideration of these problems which does not exist at the presen time. The organizational setup just does not exist.

There is, however, great possibility from this research. I think it can fairly safely be said that a routine research operation on any one of these two thousand jobs could easily produce an efficiency improvement of 10, 15, or 20 percent and on certain ones much greater. For a critical job that is a very great difference. It is hard to design equipment which through improved design will improve the efficiency 10 or 20 percent. So we face a question whether the research effort in the human factor of the man-machine combination should be expanded as a good bet for improving total efficiency.

There are many limitations on research in this field. One of the most critical ones at present is the shortage of personnel. The fact that there are only eighty professionials working in this field in the Armed Services is not due to the fact that the Table of Organization does not permit more. They just can't be had. Or to put it another way, before there is any talk of expansion of the work in this field, there has to be serious talk about where the people to do it are to come from. This involves a training program primarily. The personnel shortage in this field of technical psychology is by any ordinary basis of estimation more acute than in any other technical field since the war with the exception of nuclear physics, and the universities and industrial companies are feeling it just as sharply as the Military Services. There is no place you can make a raid and get all the people you want, although you could do a better job of raiding if the working conditions for technical scientists were better in the government laboratories.

Another possible limitation on this work would result from taking a shortsighted view of what you wish to accomplish, with emphasis on testing to the exclusion of basic research. I don't want to elaborate on that any further, because I am sure it is obvious.

Another possible limitation concerns the utilization of research results. Five years ago, when such research was begun, there were few officers in the Services who understood well enough what had been done to see that it was put into effect. When a new gadget is devised, the Services have plenty of officers with engineering and technical training who can immediately see the advantages of that gadget. An improved selection technique or improved training technique did not always fare so well and only by the efforts of the last couple of years is there any possibility that the responsible officers of the Armed Services will understand enough about this field so that they can recognize, evaluate, and support the application of the results of research in human engineering.

This, then, represents the current status and some estimates of the needs and potentialities of this field. The situation is much the same, of course, in industrial production as in the Armed Services. Industrial production involves machines and gadgets in the same way that warfare does.

The problem of human engineering for increased production is perhaps even clearer in the industrial field than it is in the military field. When Henry Ford complains that his man-hour productivity is about 50 percent what it was before the war, that is not because his machines are worn out, nor because they are poorly designed. The factor which produc that change is on the human side of the man-machine combination; and he and his production men are sitting around guessing what that factor migh possibly be.

There is one thing that I can say in closing which I think is releva to our consideration. In this general field of the human factor in the man-machine combination we have a big lead on any other country. Intell gence from other countries indicates that except in England there is not even a clear recognition of this problem. While they are aware of the job of improving the quality of their machines, they do not have a large body of trained technical psychologists in any country--England, or Fran or Russia. So, even if they were to try to attack this problem, they wo not have the resources to do it. There is therefore the possibility tha a distinct jump on another country, a potential enemy, could be obtained by concentrated work in the field of human engineering.

COLONEL RUTLEDGE: Dr. Marquis, you mentioned the lack of coordinati among the Services in this matter of planning and programming. You are the Chairman of the Committee on Human Resources over in the Research and Development Board and I thought that was their job. Would you clari that a bit for me?

DR. MARQUIS: The Research and Development Board is set up to review the research programs of the Services. Dr. Hafstad spoke to you about that, didn't he?

COLONEL RUTLEDGE: Yes. He gave us a lecture on the functioning of the Research and Development Board.

DR. MARQUIS: The Board has not done much yet on an official level. The Committee on Human Resources is one of the thirteen or fourteen committees within the Research and Development Board and has cognizance over this field. It has been in existence one year, during which time it has made a very hasty, although serious study of the military and civilian research programs related to needs of national defense. It has prepared a report of the status of research effort as of two months ago, which has perhaps had some informal and extra-legal influence on the Services in suggesting ways in which they might develop their progra But there has been little official action of any sort.

That survey disclosed, among other things, that while the psychologists in the various Services got along together personally and informally very well, with very little interdepartmental or bureaucratic rivalry, and with a great deal of exchange of information at the operating level of research, at the higher echelons there was no coordination. The result was that the assignment of priorities to the programs and the distribution of effort among them was largely haphazard and the resultant of the individual interests of the psychologists or of the officers who happened to be engaged in those programs. It, of course, is a responsibility of the Research and Development Board to look at this and make recommendations on it; I expect that it will be done.

Coordination will be facilitated, of course, by organization within any service of a clear line of command from top staff levels to research at all levels. The Air Force has recently modified its organization of human research to achieve just that. It has a top staff group which will keep aware of all that is going on in the Air Force and of the needs and relations to the other Services. This will make it very easy, of course, to achieve that degree of integration and coordination and distribution of effort which is desired.

QUESTION: Doctor, you spoke rather casually of the advance which research in this field could produce for us. It seems to me that right now, where the international situation makes us especially concerned with the short-term results of research, somebody should be shouting from the housetops and beating the drum very loudly for an expansion of research in this field, particularly in the matter of training and selection of personnel--people to administer, command, and maintain all these super-gadgets that we are working on.

DR. MARQUIS: Well, all I can do is to outline the possible results of such a research program and the difficulties which we would face in establishing it. It requires guidance from a higher level to determine the distribution of effort in this research program as compared with others.

It should also be pointed out that research on training is likely to be the first thing which will be needed in the event of mobilization, because we will immediately start bringing in large numbers of individuals and putting them into training. Research on training takes time; that is, you cannot in a week devise and test and improve a training course. You have to go through the whole training course before you can measure the results of that training. If you want to compare two methods of training, you have to have these two methods set up; the comparison can be made only at the end of the training program. Therefore it is a little late to wait until the big push of training comes before research in training is established.

Some of the considerations you mentioned might perhaps put a little qualification on one of the things I implied, namely, the importance of

basic research. If somebody decides that all our research programs shou have an objective not further than two years or whatever it is, then of course, that is the limit on basic research. However, everything I said is still true. In such a case we won't be much better off in a war two years from now than we were in the last war so far as that storehouse of knowledge is concerned. It may become necessary to channel effort to th application side of human engineering; but if that is the case, we are just standing still so far as doing any better job in this field than we did during the last war.

QUESTION: In that same connection the Training Command of the Air Force recently moved its psychological unit from under the Air Surgeon into the Operational Division. I wonder if that move won't tend to inhi basic research or perhaps limit its ability to do long-range work.

DR. MARQUIS: That is, of course, a possibility. I said that resea in these fields has to have access to operations. That is, it must use the soldier himself as the subject of research, it must use the equipme itself, and it must be in the environment of the military operations. S there is an advantage in having research closely related to the operatin arms of the Services.

I don't know how much danger there is of precluding basic research by moving it into the Training Command. I do know that the danger of cutting out basic research exists in every part of the Military Services because the pressures are always for answers to the problems which are on your desk now. Any officer with the responsibility for making decisi obviously wants help in those particular things which are in his file basket now; and he is going to try to divert the research facilities whi are available to his direction to those immediate problems rather than giving freedom to work on basic problems the relevance of which he perha cannot even see. So I don't know in this particular case what the effec would be, but I do know that the pressure is always in that direction.

In industry and in military operations it is only after executives have become convinced of the value of research that they sort of punish themselves to permit and encourage basic research. Companies like Weste Electric, Bell Telephone, General Electric, U. S. Rubber, and so forth have come to that point. They find eventually that the punishment doesn hurt; that the basic research produces increases in knowledge which in t are capable of application in their operation to the profit of the stock holders and the business in general. But it is a hard lesson to learn.

QUESTION: The Army had a project, running for a couple of years, tha seemed to measure up to some of your criteria on human engineering. Cou you give your idea of how effective you believe the Fort Knox Experiment Unit of UMT is, how closely that measured up to a human engineering expe ment, and how much useful data we have gathered from that project?

DR. MARQUIS: I am afraid that I can't answer that question. Perhaps someone in the room would be willing to give a statement. I have not seen the research report on the Fort Knox experiment.

QUESTION: Your discussion of the subject of human engineering was concerned primarily with the coordination of man and machine. Is there not room for research into the human relationships that are involved? We put individuals in the organization and they have to operate the organization. Is that not an appropriate field for research; and, if so, are the Armed Forces doing anything about it?

DR. MARQUIS: I think that the phase of the problem which you are referring to is one that I meant to describe as the last step in human engineering--the social or psychological environment--in other words, the interpersonal relations of the workers. I think I also meant to imply that that was possibly the difficulty Henry Ford found in the drop of production. There is to my knowledge no research on this going on in the Services now. There are probably one or two small projects, but I don't know about them specifically.

There is contract research being done by universities in basic factors of this problem, contracted for by the Office of Naval Research. Project RAND in the Air Force, I think, has some possible intentions along this line. The General Research Office of the Army, when that gets set up, will have a directive which permits it to contract for research in this area. I am sure it is an important program. It is hard to know how much could be expected from it, because the experiments which have been done have been limited in scope and applied to particular situations.

Let me give you one example. A psychologist with nothing to do for six months went into a textile factory in North Carolina where they were doing some kind of spinning operations which were rather monotonous. They had production records on several groups of workers over a period of a good many months.

This psychologist brought together a group of women workers and gave them a chance to discuss how fast they would like to work. He had a hard time convincing them that the management would let them make that decision; but when he finally did, they discussed it and worked out some kind of a scheme in which they would work hard for the first two hours, then rest fifteen minutes, then work again slowly for an hour, then work fast in the last hour before lunch, and so on. That was the way they thought they could like to do it. He said, "All right. Go ahead and do it." The production increased about 60 percent, and stayed up at that level.

That is an isolated example. I don't know whether it would work again. I don't know whether it would work with a different group of

people or in a different operation. I suspect that something like it w work, but I don't know. But an increase of that level of magnitude is citing enough to make one want to try it out in some other places or to out other techniques of achieving the same thing.

COMMENT: I would like to mention that psychology is not totally neglected in England. Psychologists are used for the purpose of person selection and giving advice on training methods, but not to a large ext in influencing the design of equipment.

DR. MARQUIS: I am very glad you said that, because my remark was o the number of psychologists in Great Britain and not on their quality. We have learned a great deal from British psychologists, and actually t have worked in the design of equipment. The work which Craik and Bartl did during the war in visual displays was a guide to us in the work whi we did when we took it up at a later time. Their work on selection and training has been very effective. Brigadier Stevenson is now here at t University of Chicago, where we have had a chance to learn a great deal from him about some of the things that were done. But the number of psychologists in Great Britain is still pitifully small compared to the magnitude of the task which they would have to undertake if there were expanded research in this field. The number of British psychologists, however, is greater than in any country other than the United States.

CAPTAIN ROWLEY: I have just one brief question, Doctor. Your commi in the Research and Development Board is the Committee on Human Resource I thought you did a magnificent job in adapting the subject we gave you of "Research in Human Engineering" to our needs. But along your own lin of Human Resources, all this technical equipment--electronic gear, super sonic flight equipment, more emphasis on submarines and guided missiles- all these things are complicated, expensive equipments, which take not o one but a number of persons to operate, each one with special training a a relatively high IQ. Is it the province of the Research and Developmer Board, or of Selective Service, or of all three Services combined to determine whether the manpower pool of the country can support the numbe of personnel required for all these intricate operations in case of mobilization, and still leave enough men to do the normal things in the Armed Services? Would you discuss that for a moment?

DR. MARQUIS: The problem certainly exists. You ask where it rests. I presume it rests with the National Security Resources Board and the Munitions Board, which have by directive been given the job of allocatio of manpower.

This job, however, requires a great deal of information about popula resources and the requirements of the Services. In resources we need fa not just by counting bodies but by counting the number of bodies that ha talent or the number of bodies that have good mechanical coordination or

number of bodies that have cortex enough so they can learn such and such a task. We don't have that kind of information. The Bureau of the Census doesn't collect it, the Bureau of Labor Statistics doesn't collect it, and Selective Service doesn't collect it. I don't know what agency is going to collect that kind of information on resources and requirements which would be necessary for any intelligent planning of manpower distribution.

The Committee on Human Resources of the Research and Development Board has recommended that a joint inter-Service program of basic information necessary for a manpower policy be established; that the Services contribute to it; and that agencies like the Bureau of the Census and the Bureau of Labor Statistics be pulled in to help with the technical details. Whether that will be carried out remains to be seen.

The Air Force has some rather definite plans for work on the basic information necessary for manpower planning. The other Services have not made plans for the 1950 budget year yet.

QUESTION: In your discussion of the factors that come under human engineering it appears to me that much of what has been done in the past under safety engineering and the study of safety factors could be incorporated in your subject. Would you comment on where one starts and the other stops?

DR. MARQUIS: I don't think it is necessary or possible to draw a line between them. The problems are very much the same, because they are both concerned with the relation of men and machines. One of them has as its objective the reduction of accidents, and the other one has as its objective increased efficiency and output. Obviously, accidents influence output, so the two are completely intermingled. Therefore safety engineering offers in a sense a pattern for the type of development that we are talking about.

COLONEL RUTLEDGE: Doctor Marquis, we certainly are deeply indebted to you for coming to the Industrial College and giving us a very stimulating and interesting lecture. The faculty and students thank you very much.

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