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BY REG B. BROMILEY, PH.D.

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Human Engineering—Psychophysiology or Engineering?

By Reg B. Bromiley, Ph.D.

THERE are two stages in the production of equipment at which human problems must be considered. They are the design stage and the development stage. At each stage the human engineer's responsibilties and duties are quite different. These stages represent *research* in human engineering and *practice* of human engineering. The title of this article was selected to emphasize the importance of the practitioner — the man who must face the hardware and make decisions.

Because I shall use the terms frequently, it is essential to emphasize the distinction between a research human engineer and a practicing human engineer. The first is a scientist who explores and describes relationships in more or less general terms; the other is a technician who applies the information made available. The research scientist is oriented to consider the system as a whole and thinks in general terms. The practitioner must struggle with the details. The research human engineer should have little or no concern with feasibility, but the practicing human engineer is almost totally concerned with it.

Social, economic, and technological breaks with the past may create operator or maintainer crises. When such crises arise they highlight the importance of human engineering research. The aircraft industry is a case in point. Here, a combination of social, economic, and technological departures from the past have made human engineering research essential. A number of other industrial fields have crises, for example, the computer field with its programing problems.

As far as human engineering research is concerned, it is unavoidable that recognition of the need for it depends upon crises. The shortage of scientists alone prohibits a fundamental, systems-type, evaluation of a vast proportion of our standard equipment and perhaps the pay-off of such an evaluation would not justify it. On the other hand, it is doubtful if one could find an industry where the practitioner would not make valuable contributions, especially in the field of maintenance. But he has another extremely important contribution to make. He is the one who finds the gaps in the available information and, in effect, feeds the research teams their problems. Here I see an analogy with medicine where the clinician does just this: the method is not formal, but his struggles with a problem and his failures cause research effort to swing to that problem.

The type of problem that the practitioner will demand be investigated is

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not likely to involve systems-research, although investigation of his problem may reveal it to be a symptom of a system problem. I would expect that, in general, the practitioner would call for information regarding specific situations. For example, he might ask for information regarding dials and scales, the effect of different degrees of distortion upon intelligibility or legibility, or a nomogram of letter size and height for reading at different distances. In effect, he would require that sufficient data be collected to enable the so-called human engineer handbooks to be comparable in coverage to engineering handbooks. This, we can be assured, will be sufficient to keep research personnel busy between crises!

PRACTICING HUMAN ENGINEER

If either the systems type of research or the more specific (handbook) type is to be effectively implemented, a large group of practitioners is required. Their primary responsibility is the man in man-machine systems. They must work as members of equipment development teams. This proposition raises the question: "What type of critter is this practicing human engineer to be?" I propose that the basic training of the practictioner of human engineering should be in engineering.

The major reason for making this proposal is that fundamentally the human engineer's responsibility as a member of an engineering team is making decisions. He is a member of a team that does things, makes holes in certain places, and puts instruments in those holes. It is a team that wants a certain component but, because of procurement, development and innumerable other reasons, must make do with some other item. It is a group of persons who by the very nature of their job have to say: "This is it."

However, the training of the researchers is that of a scientist. It produces a man who talks in terms of approximations to probabilities, and the more successful his training the more he realizes how approximate his approximations are. If one can be sufficiently objective, few interpersonal exchanges have the comic values that arise when an engineer attempts to persuade a scientist to tell him what he should do. The engineer is not interested in probabilities. He expects the scientist to have evaluated these and to have ended up with a statement that in this situation you do "X." The harder he presses the scientist for an answer, the more the scientist feels he is forced to hedge. Asking the scientist to leave this "ivory tower" and give "yes" or "no" answers is, in effect, asking him to give up the only common item that enables a physicist, physiologist, or psychologist to recognize one another as scientists.

The very nature of the day-to-day human engineering job in a development team is non-scientific. It is the relationship of the practitioner facing the clinical situation and having to make a decision. The knowledge of his own ignorance is his personal cross.

DIFFERENCES IN TRAINING

It is true that some scientists are able to put their training behind them and operate in the decision-making role with considerable ease. Others, however, force their engineering colleagues to occupy the very unfortunate position of a patient whose physician outlines all the possible interpretations of his particular symptoms. It would be a mistake to assume, as many of engineers do, that the inability to answer "yes" or "no" is an indication of lack of conviction. It is the manifestation of a conviction that has been inserted into the scientist during his years of training. Compare the educational cost of this training with that of the engineer. Because the engineer's training is primarily a technical one, methods have been developed whereby in four years a useful professional man can be produced. On the other hand, the biologists have not faced up to the problem of producing a useful professional man without giving two or more years of training beyond the bachelor of science level. I am fully aware that the new Bachelor of Science degree in engineering, while a pearl of great price, is still wet behind the ears. Unfortunately, the same must be said about the biological scientist with his shining Ph.D. degree.

There is a shortage of competent engineers and psychophysiologists; but it is extremely difficult to conceive of the output of biologists with scientific training being markedly increased, because this training is on a personalistic basis. The exception to this statement is the training of physicians. Here, as in engineering, the output of practitioners could be increased rather rapidly. It would appear that on the basis of available machinery for the production of the basic material out of which human engineers may be developed, the engineering profession is at a great advantage.

Having got our basic material, the next problem is either to add the term "human" to the engineer, or engineer to the human type. Here again the engineering training would appear to have the advantage. The amount of highly technical information and mathematical skills required to enable a biologist to appreciate the engineering problems and to contribute as an equal on a development team are vastly more difficult to obtain than is a recognition of the types of human problems raised by various design proposals. Once the practitioner has recognized that a problem exists, there is a great deal of codified information available in the form of handbooks, which will enable him to deal with the routine ones. In fact, many exteremely important aspects of the human engineering of equipment require for their solution nothing more than a statement of the problem. Most of us who work in this field can look back upon very important contributions of which we are rightfully proud. However, in many of these cases, once the problem has been stated the solution is self-evident. For example, consider the extremely valuable work carried out in going through cockpit checks and manipulating of controls while dressed in full flying gear. The real contribution here was the recognition of the problem.

PRESENT REQUIREMENTS

This brings us to the situation that exists at present. A large number of practical human engineers are required in all branches of industry. It is difficult to believe that this need can be filled within a reasonable time either by the output of schools of advanced study in engineering psychology, applied psychophysics and bio-mechanics or by personnel trained in those few industries which now have human engineering sections. This gap in technical training will probably have to be filled by engineers presently employed in conventional engineering jobs.

I am convinced that a great deal can be done by the simple expedient of assigning responsibility within a development team. Those of us who have specialized in this field may have developed a blind spot due to the fact that the first remark that an engineer makes when one explains the nature of human engineering is "But we always consider the operator and maintainer." We tend to discount this remark because of the number of instances where the human has been sacrificed to the machine. By so discounting the avowed responsibility of the engineer for the human and by attempting to relieve him of this responsibility by substituting biologists of divers types, we may have temporarily lost ground. In other situations this very problem has been faced but handled in a different manner. All engineers consider power requirements, yet in a system development program, one engineer is made responsible for the over-all power requirement. Similarly, all engineers consider weight, but it is catastrophic not to have one individual assigned responsibility for the over-all weight commitment. Similarly, if one individual had been assigned full responsibility for the man, it is quite conceivable that the blessing of euthanasia would have been given to many present-day monstrosities.

In the engineering situation the essential element is the selection of the best compromise between performance on one hand and weight, power, complexity, time and cost on the other. The performance requirement has number one priority in all engineering activities, and in order that power, weight and other restrictions may be kept within limits, someone must accept the responsibility that they are not sacrificed for performance. In many cases, man's abilities have been sacrificed for engineering efficiency only because there has been no one to represent him.

As I see it, an intelligent engineer, being given as his primary responsibility the operator and the maintainer, would see that the human requirements got more reasonable treatment when a compromise is called for.

One observation would appear to contradict this argument. It is quite common to find engineers who have considered the operator. Sometimes, despite the best intentions possible, consideration of him by the engineer has resulted in unfortunate conclusions. This, I think, is not an argument against the proposition I am making, for these men have not had a formal statement of their responsibility and, as a result, have philosophized in an engineering manner about how the human being works. In general, they have been ignorant of the existence of codified information in handbooks of human engineering and unaware that there are people in the community who can help them.

From observation of some of these individuals in other situations I am certain that had they been specifically responsible for the human and recognized this as their major contribution to the development, they would have attempted to get expert advice. They do not hesitate to consult experts in engineering fields, either in person or in the literature. If they recognized human engineering as a field and as their responsibility, they would be equally anxious to obtain information.

SUMMARY

I have tried to make the point that the nature of human engineering activities in research and in the practical situation are quite different and require different types of training. Basically, the research aspect requires a scientist, typically one with psychological and physiological training, while the practitioner should have a great deal of training in engineering. I have tried to point out that the nature of scientific training handicaps a human engineer in the practical situation but that the nature of the engineering training is ideal. Finally, because of the shortage of trained human engineers, the vast majority of equipment must be designed and developed without their assistance. The engineer's traditional and avowed responsibility for the human in his system can be capitalized upon. It requires only the designation of the responsibility to a conventionally trained engineer as his primary responsibility.