MACHINE MAN INTERFACE

by

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The interaction between men and the machines they build is of the greatest importance for the future of our race. Whether the world becomes a kind of automated hell, or whether we can build the society of our dreams depends very largely on the men who actually design and build the machines and the systems which are beginning to surround us. Our responsibility under the basic engineering ethic is clearly stated in the oldest definition of engineering, that made by the Institution of Civil Engineers in 1828: *"Engineering is the art of directing the great sources of power in nature to the use and convenience of man."* This is not some abstract responsibility; the question that every designer and builder of machines and systems must ask himself is *"How will my creation affect the men who will use it?"* Man is an essential element in everything which we design and build, whether we are building agricultural machinery to help him, *or* weapon systems to destroy him.

In the past when animals and human beings were the major energy sources the development of tools and machines was slow and took place by successive improvement over generations. Design was by evolution as tools developed to suit the physical and psychological characteristics of the user. Many of our medieval agricultural machines are models of design, perhaps because the builder was often the user.

But with the introduction of power and with the loss of direct contact between designer and user, a change took place. The engineers became far more interested in the physical abilities of their machines than in the interaction with the user. The interface between the man and the machine was often completely neglected. The operator was given a collection of levers, knobs, and handwheels and left to cope with them as best he could.

PHYSIOLOGICAL AND PSYCHOLOGICAL STRESS

One of the characteristics of man—the one that often makes him a superb system element—is his adaptability. He can offset deficiencies in the design of machines by adapting his action to them. Cursing and sweating, with skinned knuckles, consigning the designer to the seventh hell, he makes machines work and work well. But he pays a physiological and psychological price. Man is able to take up the slack, remove the back-lash, adjust for the designer's lack of thought. This was true in machines and systems of the past, ranging from the aircraft, the great power station, and the ship to the kitchen range, and is still true in far too many of the things we build today.

Improvement is taking place not, unfortunately, because engineers have realized their basic ethic, but because the products of their skills have become too powerful and fast-acting for man to continue the role of an adaptive element. When you are flying an aircraft at 1,000 miles per hour, there is no time to reach behind your head to operate a control. This has forced the designers of such systems to re-examine the interfaces between the man and the machine in order to discover how to remove the load from the man, and how those tasks which man must perform can be made easier for him. But their responsibility extends beyond the dramatic situations of the aircraft and the control tower into all the products of our machine civilization.

Machines can damage men in dramatic ways. They can smash him to pulp or burn him to death. But, in the same way that metal will fatigue, crystallize, and fracture by repeated small deformations, so man can be damaged both physiologically and psychologically by continued small stresses. If you have to operate a machine, whether it be a machine tool, an aircraft or a combine, so that you have to make unnatural movements, reach behind you, twist your body, operate levers that test the limits of your strength; when you have to try and read dials which are ineffectively illuminated, poorly lettered, or under conditions of vibration; when you have to do these things eight, ten, twelve hours a day, you are undergoing a continued physiological and psychological stress. It means you are not operating as effectively as you might be, and to degrade the performance of a very expensive system is bad engineering. It is also a source of disease, and not only the obvious physical examples of strained muscles, bruises, kidney damage, and spinal damage.

How can these things be avoided? One of the virtues of the research that has gone into defence systems has been to find what we can do to reduce the load on the human operator in machine systems. There are good examples of this. The incidence of aircraft accidents in the U.S. Air Force immediately after the war due to 'human error' was high. When this was investigated one of the most common causes of such accidents was the operation of the wrong control. For example, there was a quadrant with three control knobs – one controlling pitch, one controlling mixture, and one controlling throttle. They were all round knobs and their

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relative positions varied from one aircraft to another. Now in emergencies men revert to earlier patterns of learned behavior. Pilots changed the mixture when they felt they were changing the throttle and by the time they realized their mistake, it was too late.

As a result of research into this, two measures were introduced which have been adopted by air forces throughout the world.

- One was the standardization of control positions between different aircraft.
- The second was the use of touch and shape coding.

This meant that a throttle was always in the same position in an aircraft and that the knob at the top was always of a certain shape, different controls having differently shaped knobs. As soon as a pilot put his hand on a knob he received reinforcing information as to whether he was right or wrong. These two steps dramatically reduced the incidence of accidents due to 'pilot error' but have yet to be applied to the modern automobile.

THE SYSTEMS APPROACH

This example reflects the use of a systems approach to the problem of man-machine design. Man is a data processor in most systems; he does not supply energy. He operates the controls of a power shovel instead of digging ditches with a spade. He is one element in a system, and his primary function is to process information.

Information about the status of the system and its environment flow into him through his physiological sensors, that is, his eyes, his ears, his sense of touch, his sense of body position. Information flows out of him through the movement of his voluntary muscles. In a complex system it flows into him through his control panel instruments his television monitors, his radar displays, and out of him through the controls which he operates with very little physical energy, perhaps only the touch of a finger. The designer is therefore involved with the interface between man and machine at two points:

- At the display panels, the dials, the meters, all the things the man has to see or hear,
- At the controls through which the man puts information into the machine.

The objective of good engineering design is to speed the flow of information across these interfaces and to minimize error. Therefore the designer must be familiar with the input-output characteristics of the human "black box". He must know what size figures, what illumination, what type of display is needed so that a man can gather information most rapidly from the panels and the environment. He must know the most natural muscle actions so that he can design controls to suit them. He must know the relationship and the compatability between the displays and the controls. He must know the effects of environmental changes on man. A human being who is being vibrated, whether it be on a tractor seat or in a space-ship, cannot see, hear or operate controls as well as in a laboratory or showroom.

This approach is difficult for complex situations because we have very little idea of the transfer function of man the human being is extremely adaptable and therefore non-linear. But it immediately brings out the sort of design errors which none of us will make once we have looked for them, but which are made every day.

Let me talk about one particular area of man - machine design or human factors engineering, that of maintainability, and more particularly maintainability with underskilled users. I need hardly emphasize the situation in which the world is today as far as its population and food supply are concerned. The most critical question that faces our civilization is whether the population curve will ease out because of education and a higher standard of living or whether it will be chopped off by famine and war. Some races refuse to starve — and show more skill in developing weapon systems than agricultural systems.

You are far more aware than I am of the immense steps which have been taken by agronomists and biological scientists in the development of high yielding strains, disease resistant strains, and climatically suited strains of plants and animals. Agricultural engineers, probably more than any other group of engineers, have helped to assure us in North America of a superabundant food supply. But so many products of your skill are completely unsuited to those areas of the world where good engineering design is most needed.

One of the hallmarks of modern engineering is the system approach. This means that every problem must be considered in the context of a whole system and every element must be designed so that it is compatible with the rest of the system. The important question that must be answered is *"What is the object of the system as a whole?"*

If we ask this question we find that we need a significantly different system to achieve a similar purpose in a situation involving the small Indian farmer, the Malayan rice paddy, or the small tropical fisherman, than in one involving a Saskatchewan wheat farmer. It is hopeless to imagine that large and complex machines can or will be introduced into the famine areas of the world in time to stave off the debacle which faces us. *I suggest to you that the most challenging problem for the system and machine designer today is in the design of agricultural machines and systems for the small tropical farmer whose range of skill is quite different from the range of skills in a North American or European farmer.* This is not an invidious comparison. The farmers of Asia are not necessarily unskilled. But they are not skilled in modern technology. They are not skilled in operating and servicing machines any more than the Saskatchewan farmer is skilled in operating and handling water-buffalo. One of the most glaring results of this different background is the tropical farmer's lack of experience in operating and maintaining machines. Most of us would not be much good at maintaining water-buffalo; it is unfair to demand from a peasant farmer that he be familiar with the steps one needs to maintain the tractor and the gasoline powered pump. But in fact we have been faced with another group whose lack of maintenance skills is at least equivalent to that of the Asian farmer. I refer to our

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mine if the percentage breakup of straw into each fraction increased or decreased with an increase of feed rate, indicated that feed rate did not have a significant effect on straw breakup. The data for each length of straw from the different feed rates were then grouped for each combination of grain variety and cylinder type. An analysis of variance of these consolidated data showed that significant differences in the amounts of short and long straw did exist between some lengths when certain combinations of grain and cylinder were examined.

The distribution patterns of straw breakup by each cylinder, when threshing either variety of wheat, were similar (Fig. 1). Differences in the amounts of certain straw lengths were small, although it would appear that the spike tooth cylinder produced more short lengths and fewer long lengths than did the rasp bar cylinder. There were differences, however, between varieties when threshed by either cylinder (Fig. 2). Thatcher wheat straw broke up into more short lengths and less long lengths than did Chinook. These results show that differences in the breakup of straw were attributable to the variety of wheat being threshed rather than to the type of cylinder used.

The amount of straw in the one-to-six-inch lengths represented about 40 to 45 percent of the total of the samples from the tests. This quantity was considered to be part of the shoe loading and would be added to the material less than one inch long and the chaff from which the loose grain must be separated. Wind settings and sieve adjustments must be regulated to provide efficient separation of the variety being threshed. The remaining percentage of the sample represented that portion which passes over on the straw walkers. It is necessary that this straw is adequately spread or chopped so that tillage and seeding operations in the next crop season may proceed without complications caused by an undue amount of unmanageable straw residue.

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own wives. In many instances we have solved this problem quite well. The average refrigerator operates for years with practically no servicing. The designer of equipment for use by untrained personnel already has some backlog of knowledge. However, there remain innumerable points on most modern equipment where the maintenance is difficult even for the skilled man.

It is not the responsibility of the user to insure that a machine does not break down. It is the responsibility of the designer. If it is possible for a machine to become damaged through ineffective maintenance then there is something wrong with the design of the machine. It is true that in many cases we do not know enough to be able to avoid this design failure, but it is a design failure nevertheless. In the past the designer placed the onus on the user. When the user was a sophisticated engineer perhaps he had some justification for this. But when he treats all users as sophisticated engineers, he has no excuse at all.

IN SUMMARY

Every design engineer must ask himself the question: *"How will the products of my skill affect the human beings who interact with them?"* There is a comparatively large body of knowledge developed from research, particularly in the area of military systems, which is applicable to civilian product design and which is not yet being applied. *The overwhelming challenge to the agricultural engineer is to assist in solving the problem of potential famine* and while I can only applaud his success in designing and building the very effective machines for the North American farmer, even if the North American farmer is sometimes bruised and strained by them, *the most important challenge of all is in designing for that vast group of farmers who have different educational backgrounds, different social backgrounds, and infinitely smaller resources than those of us who have been blessed by our western heritage of land and wealth.*

Will our descendants say of us: "There were great engineers in those days. They landed delicate equipment softly on the moon. They sent their space-probes close to Mars. They built 300,000-ton ships crewed by twenty men. But they did not build a small tractor which could be operated for two years by an unskilled farmer without maintenance. So, in the end, all their other accomplishments signified nothing."

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