THE HUMAN FACE OF TECHNOLOGY

Selected Presidential Addresses Given to the Human Factors and Ergonomics Society in Its First Five Decades

Collected and Edited by

Peter A. Hancock
University of Central Florida

PREFACE

The Human Factors and Ergonomics Society (HFES) is now rapidly approaching its fiftieth year of existence. At the time of its founding, human beings had not yet ventured into space and computers were large, room-sized entities requiring squads of people to program, operate, and maintain. The world was just recovering from a disastrous global war, and far-sighted scientists were beginning to explore the opportunities for peaceful exploitation of the technologies that had been developed in the heat of battle (Bush, 1945).

Into this flux came the birth of a new professional organization made up largely of those who sought to create a better postwar world by matching technology to humans rather than the other way around. Reading the classics of that era, such as Chapanis, Garner, and Morgan (1949); Craik (1947, 1948); and Licklider (1960), one can sense the atmosphere of excitement, the air of opportunity, and the burgeoning of hope. In particular, Taylor (1957) proposed that the marriage of engineering and psychology could be more than simply a meeting of different disciplines. He speculated, "in starting to contribute to the design of machines, psychologists have begun theoretically and pragmatically to pull together the psychological and physical sciences. Just how far they can be moved toward one another at the concept level has yet to be seen." (p. 258).

In the intervening decades, the discipline of human factors/ergonomics (HF/E) has begun to come of age (and see Marek & Pokorski, 2004). The flowering of human-computer interaction studies, issues of system usability, specializations in aviation and aerospace research, and problems associated with nuclear power control facilities has each triggered developments critical to the growth and diversity of HF/E. Contemporary areas of interest are now even broader, and a continual concern of HFES – and indeed the science itself – is the constant threat of fractionation and "balkanization" as specific areas get "hot" and move to establish themselves as foci in their own right.

However, there is much more to hold us together than the momentary, pragmatic forces that threaten periodically to tear us apart. The continuing search for a unified theory of human-technology interaction is one that embraces many disciplines. It is a search that asks crucial questions about purpose, upon which the processes of technology are predicated. This question remains as vital for us today as it was for those who envisaged a time of peace emerging from a time of war, now almost five decades ago.

The volume you hold in your virtual hand is a collection of essays derived from the presidential addresses from Human Factors and Ergonomics Society annual meetings. Some are taken from published texts an others have been kindly resurrected and revised by the contributing authors from their notes. The great value of the work lies in three basic elements.

1. It can serve as an introduction to the area for interested laypersons, advanced undergraduates, or graduates who may be searching for a specific research focus.
2. It can be used by practicing professionals to bolster and support the case for their contribution by acting as an information source and introduction to fellow professionals who may have heard of but have not directly encountered human factors/ergonomics.
3. It acts as an archival record of the progress of HF/E across the decades.

Here, the reader can not only enjoy the contributions of each specific individual but, by a pairwise comparison across the respective chapters, grasp the evolution of topics of interest and concern over time. The document, being a virtual entity, is a living one. It is my hope as HFES Historian that as time goes by, I can encourage other presidents of the Society to add their own individual contribution in order to further elaborate upon this individual and developmental theme. And, of course, there is potentially one new chapter each year!

For me personally, Alphonse Chapanis's address, "Words, Words, Words" (the first chapter), was one of the very earliest articles I ever read on human factors, which parenthetically was set in a class given by Stanley Roscoe, another past HFES president. As might be expected, the present selection of addresses covers a wide range of topics.

Chapanis begins by reminding us that much of human factors is concerned with communication and that the understanding of linguistics is exceptionally useful and important in so many practical applications. The following year, Julien Christensen (to date the only two-time HFES president) raised the crucial issue of individual differences, a topic that has come to the fore more and more as the years have passed.

In terms of the breadth of topics, the epitome is perhaps H. MacIlvaine Parsons' observations on "Life and Death." He explained how death often plays an unsuspected but central role in modern life and asked hard questions about the value of life while maintaining that much of the issue pertained to human factors concerns. Richard Pew's "The Ten Best Ways to Embarrass a Human Factors Specialist" presents arguments commonly raised against the importance of human factors. Pew responded by offering practical advice to the human factors professional in how to answer these objections, and his wise advice is as valuable and pertinent to professionals today as it was the day he first presented it.

One of the most successful of all presidential presentations was that given by Douglas Harris concerning his observations on success stories. Eventually made into a useful and popular videotape (*Human Factors Success Stories,* 1984), this presentation provided a number of vignettes in which human factors interventions proved to render great value. Set alongside Steve Casey's important and most readable book *Set Phasers on Stun,* which illustrated vignettes concerning human factors problems, Harris's observations give the complimentary, positive side by emphasizing success.

According to Richard Hornick, dreams can become reality, which eventually result in destiny. However, these dreams can rapidly become nightmares that remind us again of the importance of human factors in how technology exerts its effects. Thomas Sheridan's notes are representative of his career-long interest in questions of automation, and the interested reader can find a much larger exposition of his work in *Humans and Automation,* copublished by HFES (Sheridan, 2002).

The "Everybody Knows" problem was presented by Kenneth Laughery as a warning about the assumptions we all make. He was especially concerned, as we in human factors should always be, about the disconnection between the mind of the designer and actions of the user. It is all too easy for the designer to make assumptions about what the user "must" know. When that assumption is incorrect, as it frequently is, bad things happen. The message is that we have to design things that forgive these human errors and limitations.

Hal Hendrick subsequently made a great appeal to consider the win-win situation of human factors/ergonomics by protesting that good ergonomics practice also makes sound fiscal sense. His aphorism that "good ergonomics is good economics" has become a widely promulgated sound byte that has helped justify ergonomics interventions with the bottom line in mind. Whether good economics itself is good remains very much open to discussion and brings us back again to questions of purpose and intent.

From the financial concerns to personal concerns, Arthur (Dan) Fisk used the example of his mother to remind us of the crucial role of human factors in aging. Following his mother through a normal day, he pointed out the myriad occasions on which HF/E innovations can alleviate and even negate the intrinsic problems of aging. His work at Georgia Tech, alongside Wendy Rogers (also an HFES president) has explored in laudable depth the way in which our own domicile can have a pivotal role in everyday quality of life. These efforts have continued to reinforce the crucial observation that improvements made for older individuals almost inevitably percolate to the advantage of the whole spectrum of users.

David Woods reminded us to take one step back from any problem to understand how we – as scientists, researchers, professionals, and teachers – are always part of an environment in which these events occur. His insightful commentary points to the understanding to be derived from this fundamental observer-observed paradox. Woods was the first to establish his HFES presidential address as a Web-accessible report, setting the precedent for the inclusion of the present work as a Web publication.

Finally, in this edition, William Howell looks to our future and asks what we, as a Society, wish to achieve – it is a suitable valediction to such a diverse set of offerings and yet will represent an important benchmark when the history, yet to be written, has come to pass.

Human factors/ergonomics lies at the very confluence of so many of the diversities of life. True, HF/E is a science, but as contributors to design, those of us in the field should have almost as much concern for art, or at least creativity. Seeking general principles, we should never forget the nuances and subtleties of each individual (and see Cronbach, 1957). Partaking of both engineering and psychology, we have to embrace both objective and subjective aspects of reality. Finally, and most crucially, we are the mediators between people of society and the technology that they cause to have created. If, as it is reasonable to assume, that technology is the most powerful force that shapes our world today, those who arbitrate this intercourse are surely those who exert great power and influence (for either good or bad) as to the direction in which human society proceeds. Our present political conflicts attest to this power, and we must embrace this most daunting of challenges if HF/E is to achieve the vision of those who helped create it, now some fifty years ago. I hope that this living document can help us move in the right direction.

This compilation would not have been possible without the help of many individuals who worked long and hard to get the respective contributions into final form. I am especially indebted to Stephanie Vinat, Danielle Adazima, and Cristina Vega, who spent many hours on this work. Also, I thank the staff of the HFES Communications Department who took our output to create the final electronic version you have before you. Finally, I am most grateful to each of the present contributors who helped to translate this work from a dream to a destiny.

Peter Hancock
Orlando, Florida
March 2005

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WORDS, WORDS, WORDS

Alphonse Chapanis
The Johns Hopkins University

The aim of this paper is to call to attention a very large and important area of human factors engineering that is almost entirely neglected. This area consists of the language and the words that are attached to the tools, machines, systems, and operations with which human factors engineers are concerned. Examples, illustrations, and data are cited to show that changes in the words used in man-machine systems may produce greater improvements in performance than human engineering changes in the machine itself. Argument are made that this province – the language and words of machines – is properly the concern of the human factors engineer, and not of the grammarian, linguist, or the communication theorist. The paper concludes with an outline of some of the kinds of work that needs to be done to fill these important gaps in our knowledge and technology.

INTRODUCTION

In the opening scene of one of Shakespeare's great tragedies, we find the castle Elsinore haunted by a strange and fearsome specter. When news of this apparition is brought to Prince Hamlet, the prince himself decides to take up a watch on the battlements one night. There at midnight he is confronted by a ghost which draws him off to one side and reveals that it is the spirit of Hamlet's recently deceased father. Hamlet's terror turns to horror when the phantom tells him that his father was murdered by his brother, Hamlet's uncle, a man who not only usurped the throne but married the recently widowed queen, Hamlet's mother. Before he disappears, the ghost exhorts the prince to avenge this foul deed. In the days that follow, Hamlet is beside himself with anguish. The king and queen, concerned about his obvious distress, ask the lord chamberlain, Polonius, to see if he can discover the reason for Hamlet's strange behavior. Polonius meets the prince in the lobby and asks him, "What do you read, my lord?" To which Hamlet replies, "Words, words, words."

In this skillfully written exchange Shakespeare cleverly creates the impression of a man who reads, but who doesn't grasp what he reads. I, too, want to talk to you today about words – about words that we all read. I hope that, like Shakespeare, I can also convey unmistakably the idea that we often do not grasp what we read. But there, I am afraid, the comparison ends. Our purposes are different – Shakespeare's and mine. Hamlet didn't understand what he was reading because of his own state of mind – because of the turmoil in the mind of the man who was reading the words. I, on the other hand, want to talk to you about words that we do not understand because of the untidiness in the minds of the people who wrote the words.

A PREVIEW OF THINGS TO COME

The main purpose of this work is to call attention to a very large and important area of human factors engineering that remains almost entirely neglected. This area consists of the language and the words that are attached to the tools, machines, systems, and operations with which we are concerned. Using examples, illustrations, and data, I seek to show how changes in the words that are used in human-machines systems may actually produce greater improvements in performance than human engineering changes in the machine itself. I argue that this province – the words and language of machine systems – is properly the concern of the human factors engineer, and not of the grammarian, the linguist, or the communication theorist. Finally, I will discuss some of the kinds of work that needs to be done to fill these important gaps in our knowledge and technology.

Before I launch into the mainstream of my argument, I want to make it clear that I shall be talking about problems of communication. The problems of communication about which I shall talk, however, are problems that cannot be solved, or even understood, by so-called communication theory. I am not concerned with artificial bits of what some mathematicians choose to call information. I am concerned with transmission of ideas and understanding – of meanings which result in concrete human actions. These have not yet been reduced to the primitive language of the computer.

WHY STUDY WORDS?

Why should we study words? There are many answers to this question. Three, however, appeal to me.

Language Is a Uniquely Human Activity

The first reason why the study of language is so interesting to me is that it is a distinctly human activity. I realize, of course, that in making this statement I may expect shouts of protest from animal psychologists who will call to my attention the language of the bees, the articulations of the great and lesser apes, and so on. Nonetheless, my statement still stands. Human beings are is the only living organisms that use a written, codified, symbolic language to communicate ideas and to transmit the accumulated wealth of culture over enormous distances of time and space. As compared with the richness, depth, and complexity of human language, the communications of infra-human organisms are just so much inconsequential babbling. Let me now remind you that we call our field *human* factors engineering and that we use the adjective *human* deliberately. In a general sense, then, I think the study of language is an appropriate activity for us because we are concerned with human factors and because language is a uniquely human factor.

We Are Surrounded by Words

As human factors engineers, we usually think of ourselves as being primarily preoccupied with machines. I submit that this is wrong. The basic stuff with which we deal is not machines, but words. Like it or not, we are surrounded by words. We use far more words than machines, and, in fact, our principal end product is words. Let's take a minute to survey the size of the problem.

The contents of the world's libraries. What do you think is the total number of different volumes available to the avid reader? This is relatively easy to estimate if we confine ourselves to the United States. In 1958, for example, the Library of Congress held some 11,000,000 different volumes. However, the total number of all its holdings (pamphlets, journals, maps, technical reports, and so on) was 3.5 times the number of its volumes. Thus, we may take as a first approximation that in 1958 the Library of Congress had something on the order of 38,500,000 different *things*. Estimates of the total contents of the world's libraries are somewhat more difficult to arrive at, but Senders (1963) has provided us with some usable figures. He made six different estimates, arrived at by using essentially three different lines of reasoning. We need not be too concerned about the steps in his logic but may note that his six values come out to be within roughly one order of magnitude. Using his most extreme values, it appears that there are most likely between 75,000,000 and 770,000,000 different *things* in all the libraries of the world.

At the present time, new additions to the Library of Congress each year are made at a rate of about 3.1% of its holdings. If we can assume that this same figure holds throughout the world, then approximately 7,000,000 new items are being added to the libraries of the world each year. At this rate the contents of the world's libraries will double in about 22 years.

The periodical literature of the world. In arriving at his estimates, Senders counted journals as volumes and did not consider the articles contained in those journals. There are, however, about 30,000 to 35,000 scientific and technical journals being published throughout the world today and these journals contain between one and two million articles each year (Bourne, 1962). Psychology, with an output of about 12,000 articles in some 500 or 600 journals, contributes a very small fraction of this total. The aerospace sciences, for example, can claim about 1,500 journals with an annual output of perhaps 45,000 articles. The field of electronics and electrical engineering contributes about an equal amount. All of these are rather trivial as compared with such wordy disciplines as chemistry, biology, agriculture, and medicine. Medical articles appear at a rate of nearly a quarter of a million a year in about 9,000 journals.

But enough of these dry statistics. Perhaps by now I have been able to convince you that in our science and technology we are being deluged with a frightening avalanche of words. Brian Shackel has computed that it takes 5% of an average human engineer's working time just to scan systematically the abstracts on ergonomics that are published periodically by the Warren Spring Laboratories in Great Britain. A compulsive, well-versed human engineer would have to read, I suppose, something on the order of 20 to 30 articles, books, theses, and technical reports every day of the year merely to keep abreast of the current literature, much less catch up with things that have been published in the past. This is already a problem of frightening proportions. And the worst is yet to come!

Machines Cannot Be Operated Without Words

The third reason we should be concerned with words is that our modern-day machines literally cannot be operated without them. In the early days of our industrial civilization it was possible for an immigrant worker to learn a machine operation by gestures or by imitation. Those days are gone forever. Can you imagine trying to teach someone to fly a jet aircraft, program a digital computer, or use a height-finding radar, without any written or spoken words at all?

You have heard many times, I know, that a second industrial revolution is largely responsible for the growth of human factors engineering. That revolution is usually traced to the appearance of machines and machine systems which dealt, not with concrete products like glass bottles, steel ingots, and washing machines, but with information – meaningful information which can be understood, handled, and transferred from man to machine and vice versa, only by words. I shall have more specific documentation on this point later. For the time being, let me simply state categorically that words are the proper concern of the human factors engineer because they have become absolutely indispensable in learning to operate, and in operating, the intricate machine systems with which we are all concerned.

SOME WORD PROBLEMS

Having talked about three general reasons why human factors engineers should be concerned with language, let me turn now to some of the problems that words create in our man-machine civilization. My aim at this point is to be detailed and specific, and to document the problems I see with genuine examples from the machine world around us.

The Words of Documents

The foremost, and most widespread word problem in human factors engineering is the language of human engineering itself. Many of the documents we read and write are, to be blunt, atrocious pieces of composition. There is so much verbosity, pomposity, and obscurity in the human engineering literature today that it is a wonder much of it ever gets read at all. The examples one could cite are almost endless. The two which follow are a couple I came across recently. Both, incidentally, were written for military audiences.

> 1. The problem of test data validity demands attention throughout the series of events marking the development, execution, and analysis of a test. Ideally, the problem is recognized during the development of the test plan and test operations are structured accordingly. In "worst case" situations the problem of test data validity assurance remains implicit throughout planning stages and test operations as well. In the worst case, realization of the necessity for data validity arrives after the testing fact and the data, if not useless and incapable of interpretation, are likely to respond only to the utmost analytical artistry to provide trivial conclusions.

2. The concept is that of an appreciative continuum with meaning carried forward in immediate memory from moment to moment – perception being born of perception in such manner that repeated experience with instances of classes of objects and events generate schemes of likenesses and preconceptualizing hypotheses whereby on succeeding occasions the known instances are observed less in their unique character and more as contextual relative – that is, as things incidentally noted as being what they are in the places and at the times they are supposed to be, in the service of purposes deriving out of the past and projecting into the future.

How much information do you suppose these two writers managed to convey to their audiences? There's a curious superstition prevalent about technical writing. Many people believe that difficult or obscure writing is the mark of a learned man. In actual fact the reverse is true. Anyone can be obscure an incoherent. This takes no effort whatsoever. But to write technical material simply – that takes real skill! Moreover, before you can write easily you have to have absolute and complete mastery of your subject matter. That, unfortunately, is what we so commonly lack. Much of what passes for profundity in writing may well be only a reflection of cloudiness in the mind of the writer.

Let me contrast the two pieces of writing above with a beautiful passage written by one of the outstanding scientists of our time. In writing about scientific communication, he says, "When we tell about our work, we explain what we have done and we tell what we have seen. . . ." Just listen to the almost poetic clarity of those words. They were written by Robert Oppenheimer (1963). It may very well be that Oppenheimer writes this way because of what he learned from an illustrious teacher, Paul Dirac, recipient of the Nobel Prize and several other distinguished awards. Oppenheimer recalls that Dirac once said to him, "In physics we try to say things that no one knew before in a way that everyone can understand. . . ."

Speeches like mine are, fortunately, transitory. Within a fraction of a second after I have uttered my words, the sound waves disappear and are gone forever. Written communications, unfortunately, appear as hard copies. Badly written articles, technical reports, and documents stay on as durable and stable monuments of obfuscation that confuse and baffle uncounted numbers of readers for years and years to come. I wonder how many man-hours of reading time could be saved for all the scientists and professional people of the world if we all followed Dirac's dictum and tried to say things in a way that everyone can understand.

I'm afraid, however, that we have here a situation much like that in the delightful story Higham (1957) tells about Dr. Hastings Rashdall, a celebrated authority on Canon law and medieval universities. Although a scholar of substantial renown, Dr. Rashdall's understanding of modern machinery was childlike. One day the front tire of his bicycle went flat, and the venerable dean started pumping up the back one vigorously. When a passerby pointed out the futility of this procedure, the professor is said to have exclaimed, *"What! Do they not communicate?"* Some of our problems of modern-day communication appear to be of this nature. Many of us are pumping out words in great profusion from the back ends of our institutions hoping that somehow the information will penetrate to the people that need it. This, I am afraid, is not good enough. In my opinion, one of the most pressing problems in human engineering today is the need to human engineer the literature of our field. Improving the readability of our written documents is, of course, not a problem unique to the field of human factors engineering. It's everyone's problem. Although there's a lot more one could say about it, I want to turn now to some problems which do belong to us, and to us alone.

Machines and Their Words

One way of defining human factors engineering is to say that we try to design machines and jobs so that people can use the machines, and do the jobs, safely and efficiently. If you can accept this definition or one similar to it, then it is also part of our business to design the instructions that go with jobs, the labels which are attached to machines, and the signs that direct us what to do. Look around carefully, however, and you will soon find many instructions that do not instruct and directions that do not direct. Let me take some specific examples.

Confusion at the elevators. Figure 1 illustrates a problem that arose in a very large building in Baltimore. You see in this figure two elevator doors and some signs between them. Figure 2 focuses more closely on one of those signs. What does this sign direct you to do? In a small study I did on this sign, I discovered that most people think something along these lines: “This must be one of those fancy new elevators that has something automatic. The elevator doesn’t stop at this floor very often. If I want to get the elevator I’d better go up one floor or go down two floors.” And this, in actual fact, is what many people did. When they had trudged either up or down, however, they found exactly the same sign at their destination.

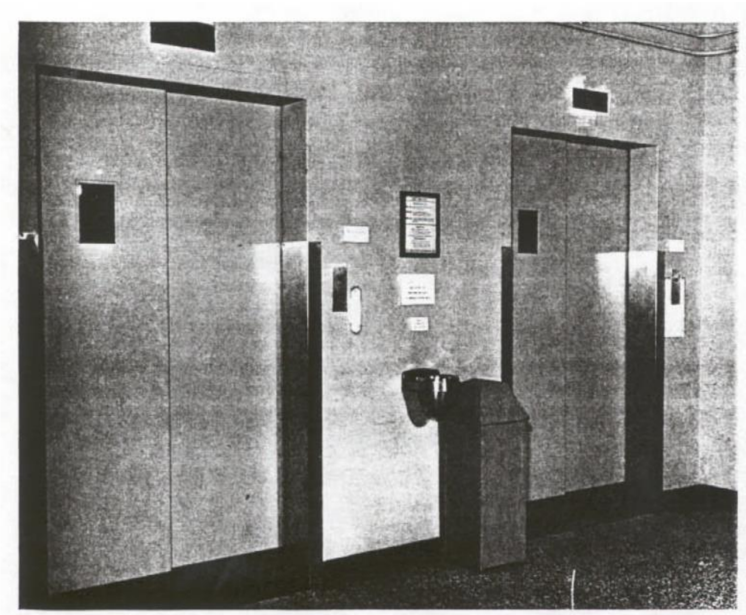


Figure 1. Some elevators in a large building in Baltimore.

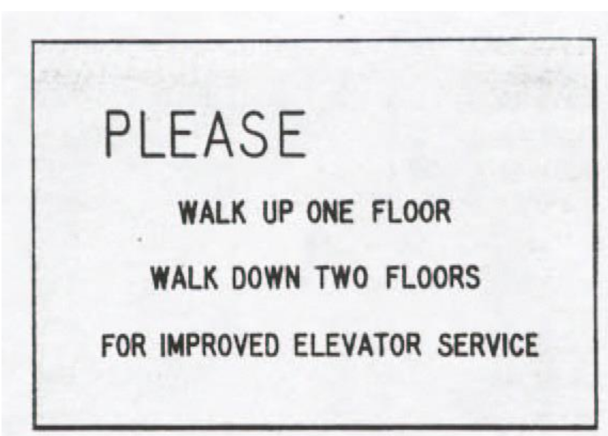


Figure 2. A notice posted between the two elevator doors shown in Fig. 1.

Figure 3 tries to clarify this situation. Let me end my remarks on this case study be telling you that these elevators are located in a very large hospital and that these signs appear in many places throughout the building. Let me tell you also that identical signs appear in at least one other very large public building in the same city.

Figure 3. Some alternative wording for the notice in Fig. 2.

Lamps that do what? My next illustration (Figure 4) is somewhat different. It is a label attached to an expensive AM-FM radio. In the sample of people I tested with this specimen, the first reaction was usually one of bewilderment: What does a long life pilot lamp have to do with staying on a short time? Figure 5 suggests some other wording that might perhaps do a better job.

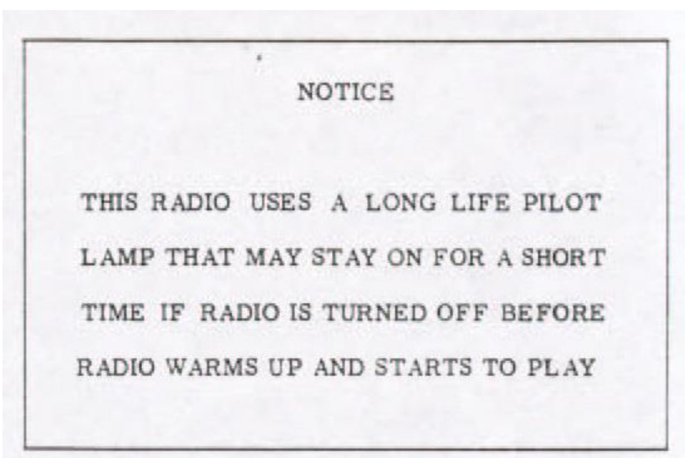
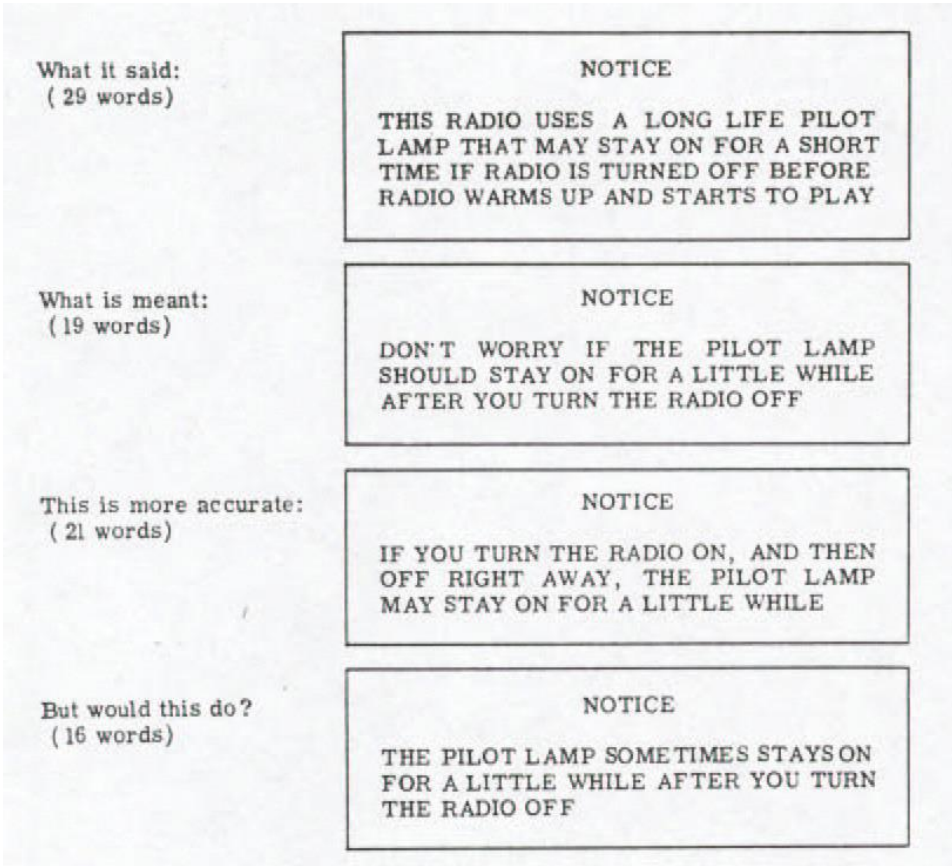


Figure 4. A notice attached to an AM-FM radio.

What paint goes where? My next illustration is the result of a little espionage work done for me by one of my agents. Although I shall describe it only in general terms, the illustration is true enough, I assure you. There is a very large device, part of which might even look like what I show you here as Figure 6. When I say large, I mean that I suppose a man could, if he wanted to, crawl into this container easily. It so happens that parts of this thing need to be carefully shielded against some severe environmental stresses – extreme heat being one of them. Sprays are applied to protect this gadget and these sprays are called finishers.

This thing was designed to be transported to a paint shop with some instructions – part of which appear in Figure 7. Let’s look at one of these instructions: “Finish 198 all over but may have 684B on areas designated . . . with an X." Looks simple enough, doesn't it? But look again. Exactly what is the man in the paint shop supposed to do? Four interpretations I got in a small opinion survey are shown in Figure 8. Perhaps you will understand why this set of instructions caused some consternation. What would you do if you were faced with these words?



What it said: (29 words)	NOTICE THIS RADIO USES A LONG LIFE PILOT LAMP THAT MAY STAY ON FOR A SHORT TIME IF RADIO IS TURNED OFF BEFORE RADIO WARMS UP AND STARTS TO PLAY
What is meant: (19 words)	NOTICE DON'T WORRY IF THE PILOT LAMP SHOULD STAY ON FOR A LITTLE WHILE AFTER YOU TURN THE RADIO OFF
This is more accurate: (21 words)	NOTICE IF YOU TURN THE RADIO ON, AND THEN OFF RIGHT AWAY, THE PILOT LAMP MAY STAY ON FOR A LITTLE WHILE
But would this do? (16 words)	NOTICE THE PILOT LAMP SOMETIMES STAYS ON FOR A LITTLE WHILE AFTER YOU TURN THE RADIO OFF

Figure 5. Some alternative wording for the notice in Fig. 4.

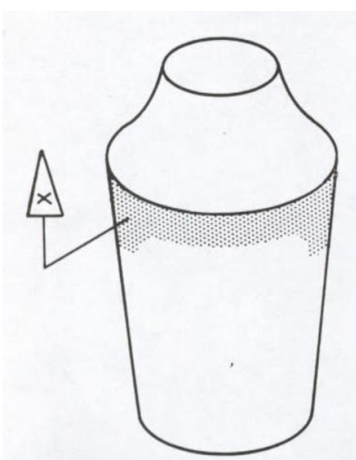


Figure 6. A schematic illustration of a large device to be sprayed with protective finishes.

Translations into common speech. When I was at the U.S. Army Electronic Proving Ground in Fort Hauchuca, Arizona, recently, I saw a number of instruction manuals written for various pieces of electronic equipment. Most of these were, in my opinion, well beyond the audience for which they were intended. The soldiers' solution to this difficulty was something simple and effective: They translated the instructions to meet their needs. Let me give you an example. The instructions for one item contained this sentence: "WARNING: The batteries in the AN/MSQ-55 could be a lethal source of electrical power under certain conditions."

On the equipment itself, however, next to the terminals there was a slip of paper on which someone had printed in large red letters: "LOOK OUT! THIS CAN KILL YOU!"

What a marvelous job of translation this is! Some unknown soldier had cut through the insipid statement that the "batteries . . . could be a lethal source of electrical power under certain conditions" and had extracted the heart of the idea: "This can kill you." He used just four words, each a single syllable, blunt, clear, and to the point.

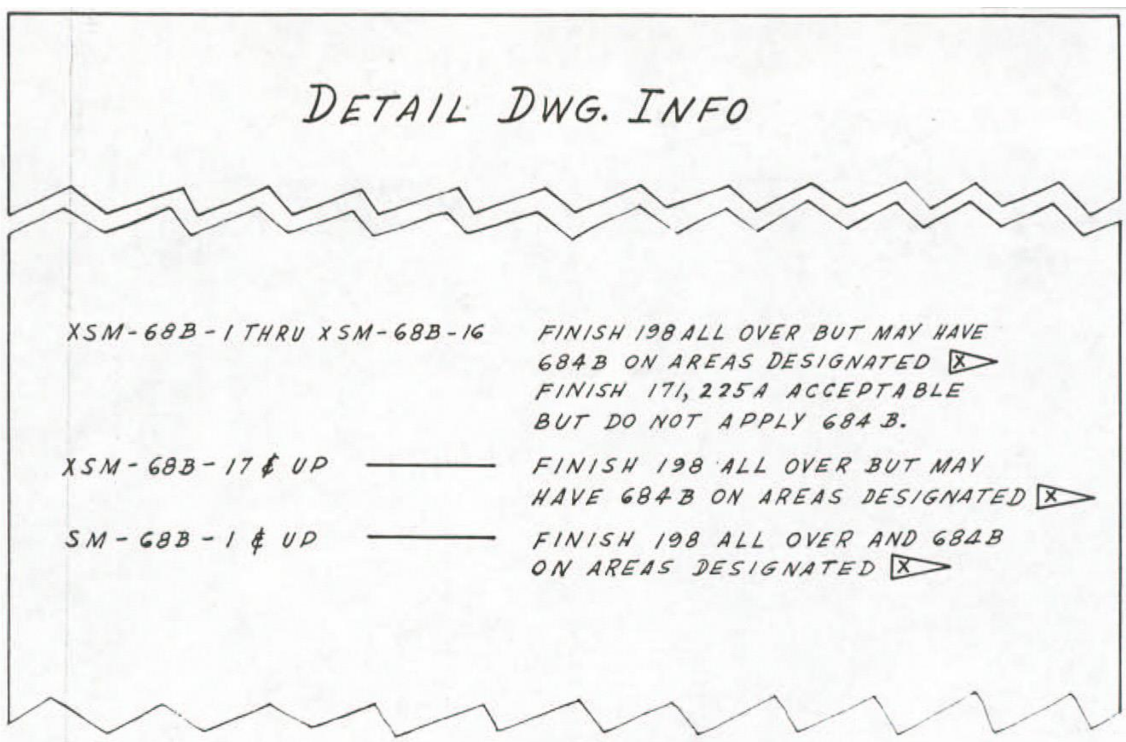
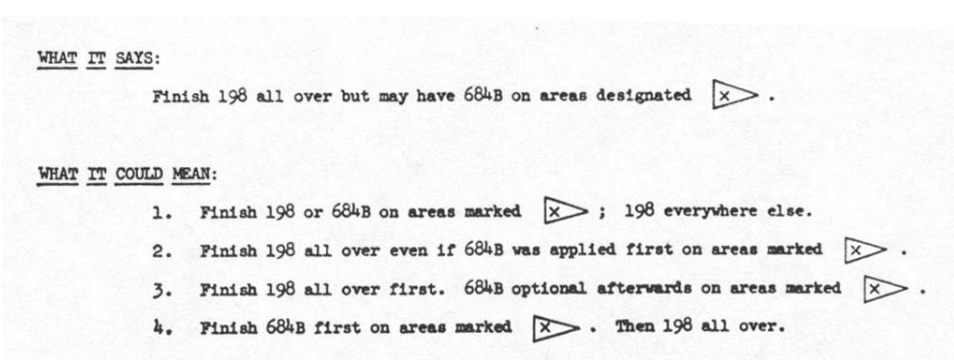


Figure 7. The designer's instructions for the device illustrated in Fig. 6.



WHAT IT SAYS:

Finish 198 all over but may have 684B on areas designated .

WHAT IT COULD MEAN:

1. Finish 198 or 684B on areas marked ; 198 everywhere else.
2. Finish 198 all over even if 684B was applied first on areas marked .
3. Finish 198 all over first. 684B optional afterwards on areas marked .
4. Finish 684B first on areas marked . Then 198 all over.

Figure 8. Some interpretations of the instructions illustrated in Fig. 7.

With regard to Figure 8, the designer intended the men in the paint shop to take the action indicated by alternative 4.

The designer's instructions for calibrating another piece of electronic gear started out with a sentence of some 30 words. In the trailer which housed the equipment, I found a sheet of paper fastened to the device with a piece of adhesive tape. Penciled on the sheet of paper in large bold letters were some instructions which began this way: "1. Turn the big black knob OFF." Here again some anonymous soldiers had taken the designer's instruction and had translated it into beautifully clear and basic English – each word a monosyllable – each word within the vocabulary of a first- or second-grade child.

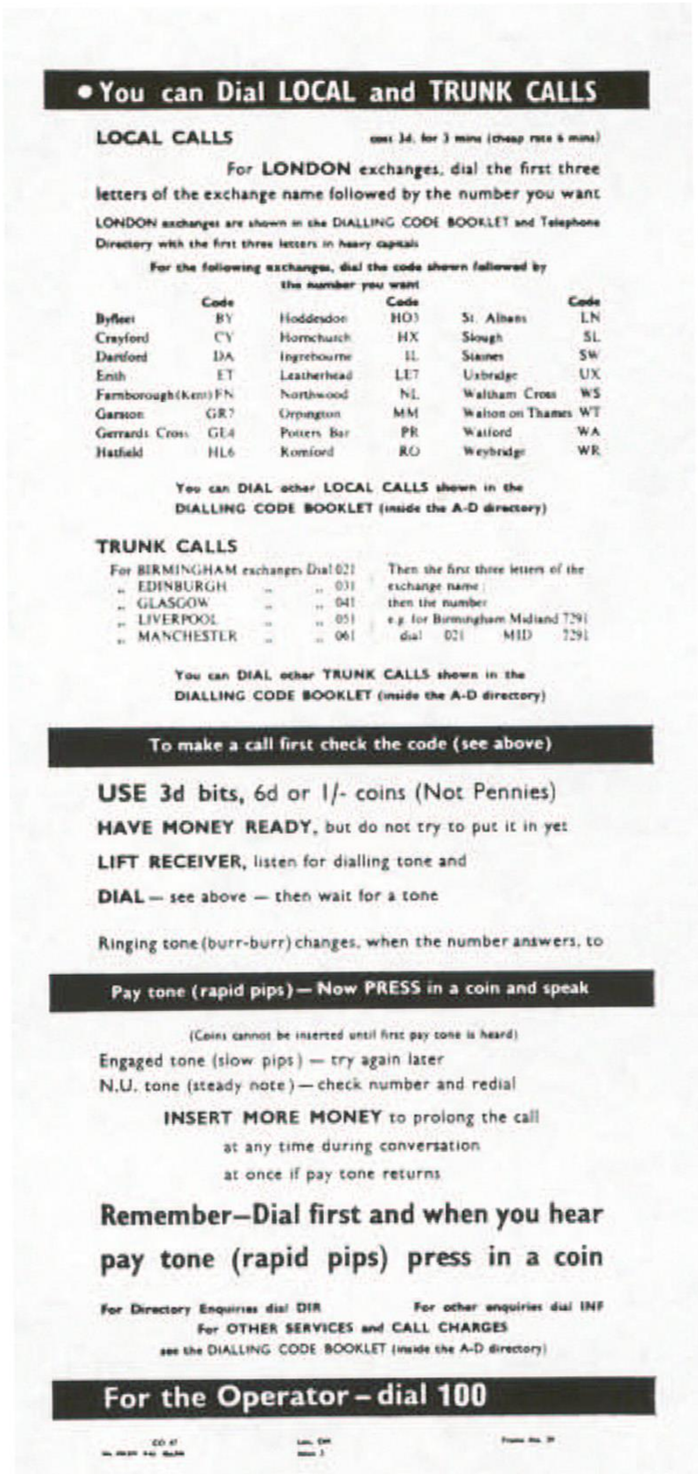
I think examples like these contain a sharp lesson for all of us – a lesson we should not and cannot ignore. Obviously, I am not suggesting that we always write in a style suitable for first- and second-grade children. What I am suggesting, however, is that there may be many times when we should write as simply as we know how. Don't forget that what you and I consider to be a simple style of writing may well be extremely difficult for a large segment of our reading public. Let me remind you that, according to the National EducationAssociation, in 1960 the median adult in the United States had completed only 11 years of schooling. When you write for high school graduates you are already writing for a select minority of our adult population.

Research on instructions. If, as good human engineers, you turn to the literature to see what research can tell you, you find pitifully little. Klare's recent book, *The Measurement of Readability,* (1963) is an excellent summary of the current status of this field. Yet among the 482 items in his bibliography there are, at most, only three items which are even indirectly concerned with the kind of thing I have been talking about today. Most readability research is, unfortunately, directed toward the readability of prose material, especially that in textbooks. None of it asks the practical question: What kind of specific human action will a person take when he reads this instruction?

The only study I have been able to find which bears directly on our problem is one by Conrad (1962) – an article published after Klare's bibliography was compiled. In introducing his study, Conrad reports that a boy in Britain was discovered frozen to death. The reason a search party had not been sent out sooner was that neither the boy's mother nor any of her neighbors knew how to use the public telephone at the end of the street. Perhaps you will understand how this could happen when you see the instructions that are placed next to the telephones (Figure 9).

Conrad was impressed by the difficulty of interpreting a set of instructions which came with a new private telephone network installed in his laboratory. His experiment was concerned with only one operation, that of transferring a call from outside the building to another person inside the building without going through the operator in the office. Four matched groups of 20 subjects each were used. Group A (Figure 10) was asked to transfer a call using the printed instruction provided by the British Post Office. As you see, only about 20% of the subjects were able to do this correctly.

Since it was conceivable that the printing itself was difficult to read, Conrad had the instruction retyped in very large, clear type and with more spacing between the lines. Group B received these reprinted instructions and, as you see from Figure 10, there was indeed a small increase in the number of people who could perform the task. Group C, however, received a shortened and rewritten version of the instructions, while Group D received instructions containing the same number of words as the original but with certain key sentences rearranged. Both sets of new instructions resulted in a marked increase in the number of people who could do the task correctly. Note, too, that the increase in performance brought about by the revision in the instructions is far greater than that resulting from mechanical changes in typography.



• You can Dial LOCAL and TRUNK CALLS

LOCAL CALLS cost 3d. for 3 mins (cheap rate 6 mins)

For **LONDON** exchanges, dial the first three letters of the exchange name followed by the number you want

LONDON exchanges are shown in the DIALLING CODE BOOKLET and Telephone Directory with the first three letters in heavy capitals

For the following exchanges, dial the code shown followed by the number you want

	Code		Code		Code
Byfleet	BY	Hoddesdon	HO3	St. Albans	LN
Crayford	CY	Hornchurch	HX	Slough	SL
Dartford	DA	Ingrebourne	IL	Staines	SW
Erith	ET	Leatherhead	LE7	Uxbridge	UX
Farnborough (Kent)	FN	Northwood	NL	Waltham Cross	WS
Garston	GR7	Orpington	MM	Walton on Thames	WT
Gerrards Cross	GE4	Potters Bar	PR	Watford	WA
Hatfield	HL6	Romford	RO	Weybridge	WR

You can DIAL other LOCAL CALLS shown in the DIALLING CODE BOOKLET (inside the A-D directory)

TRUNK CALLS

For BIRMINGHAM exchanges	Dial 021	Then the first three letters of the exchange name; then the number e.g. for Birmingham Midland 7291 dial 021 MID 7291
„ EDINBURGH „	„ 031	
„ GLASGOW „	„ 041	
„ LIVERPOOL „	„ 051	
„ MANCHESTER „	„ 061	

You can DIAL other TRUNK CALLS shown in the DIALLING CODE BOOKLET (inside the A-D directory)

To make a call first check the code (see above)

USE 3d bits, 6d or 1/- coins (Not Pennies)

HAVE MONEY READY, but do not try to put it in yet

LIFT RECEIVER, listen for dialling tone and

DIAL — see above — then wait for a tone

Ringing tone (burr-burr) changes, when the number answers, to

Pay tone (rapid pips) — Now PRESS in a coin and speak

(Coins cannot be inserted until first pay tone is heard)

Engaged tone (slow pips) — try again later

N.U. tone (steady note) — check number and redial

INSERT MORE MONEY to prolong the call

at any time during conversation

at once if pay tone returns

Remember—Dial first and when you hear pay tone (rapid pips) press in a coin

For Directory Enquiries dial DIR   For other enquiries dial INF

For OTHER SERVICES and CALL CHARGES

see the DIALLING CODE BOOKLET (inside the A-D directory)

For the Operator – dial 100

Figure 9. Instructions posted alongside pay telephones in Great Britain.

Insufficient instructions. It is possible, of course, for instructions to be bad not because they are obscure or confusing but because they are too brief. Figure 11 shows the back end of a fairly common type of accurate electronic counter. Notice that there are eight electrical terminals on the upper end of the panel. Numbers 1 and 2 are labeled “TIME”, numbers 3 and 4 “EVENTS”, numbers 5 and 6 “OUTPUT”, and numbers 7 and 8 “RESET.” Now look at the instructions printed on the lower part of the panel.

These, incidentally are the only instructions printed on the counter. You see that one fairly short, clear sentence says: "To measure intervals of time, connect terminal 1 to terminal 2." If one followed these instructions precisely, would he be measuring intervals of time? Not at all. In fact, if you connect these two terminals with a jumper wire, plug the counter in to a wall outlet, and flip the main switch (on the front side of the counter and so not shown here) ON, nothing happens except that the counter tubes light up. Clearly something more is necessary.

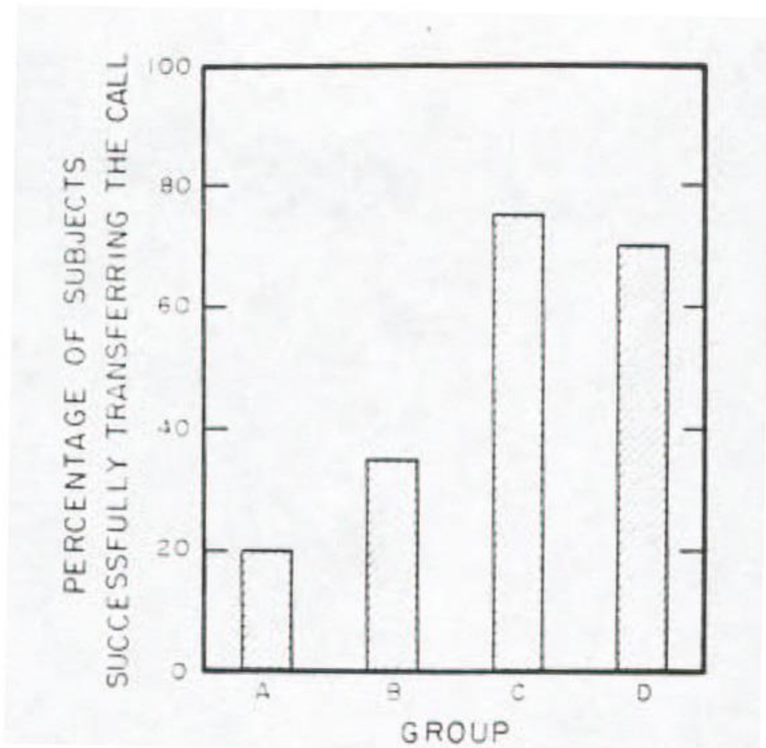


Figure 10. Results of Conrad's experiment on the design of information for a small telephone system.

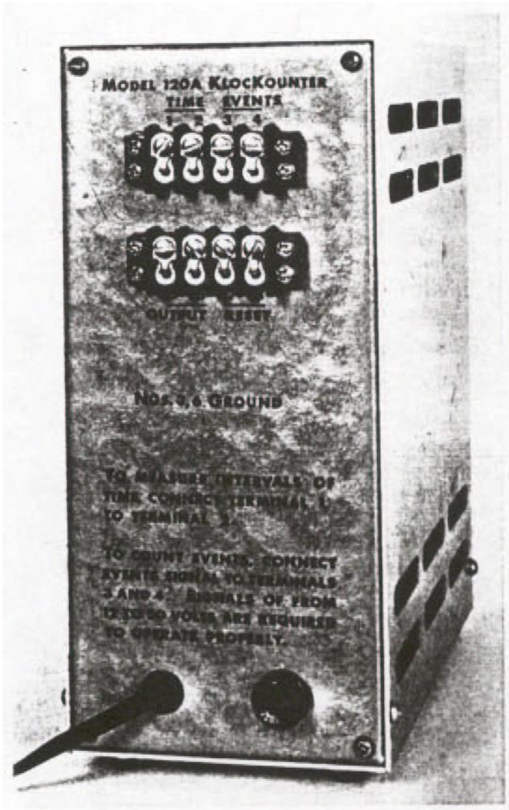


Figure 11. The back end of an accurate electronic counter.

It turns out that intervals of time can be measured in three distinct ways. The simplest way of using this device is to plug it into an electrical outlet and have it measure time continuously, just as an ordinary electric clock measures time in your home. To use the counter in this simple way, however, you must also connect terminal 7 to terminal 8, a fact which is cleverly omitted from the instructions.

In actual practice psychologists, or human engineers, would almost never want to use the counter in the simple way described above. Most commonly they would want to measure the length of time that a circuit has been closed (as in reaction time studies, for example). To use the counter in this way, it turns out that one must actually remove the shorting wire from terminals 1 and 2 and connect the circuit to be timed across these same two terminals. Notice that in this case one must actually do the reverse of what the instructions say. Finally, if one wants to measure the length of time that a circuit is open, he must connect a shoring wire across terminals 1 and 2, and connect the circuit to be timed between terminals 1 and 6.

Although I shall not dwell on this point, I will mention in passing that the instructions for counting events (shown in Figure 11) are also incomplete. I think you will agree that the set of instructions illustrated in Figure 11 is clear enough as it stands, that is, the words themselves are clear. But I think you will also agree that these instructions are woefully inadequate in terms of their primary purpose, namely, that of instructing or informing the user about what he is supposed to do.

The Babel of Tongues

I want now to turn to just one more kind of problem in man-machine system design. It took World War II, the United Nations, NATO, and the balance-of-payments deficit, to bring the United States out of its isolation and into the community of nations that make up our world. This entrance into the larger affairs of the world has led to another language problem – and one about which human factors engineers have done virtually nothing.

Americans are notoriously illiterate in languages other than their own. They never had to be otherwise – until now. But when American arms, planes, tractors, trucks, and digital computers started appearing in such places as Greece, Turkey, India, Japan, Indonesia, and Korea, we suddenly discovered that not everyone in the world speaks English – American English, that is. The fact of the matter is that our world contains a bewildering assortment of languages. No one really knows how many different tongues there are, but realistic estimates place that number at about 3,000! If we concentrate only on the major languages of the world, we find that 130 are used by more than 5,000,000 (Anonymous, 1964). Sixty percent of the people on the face of the earth speak some language other than the five official languages of the United Nations – English, French, Russian, Spanish, and Mandarin Chinese. To suggest how important these language problems have become, let me recall for you a bit of history.

The World War I Lafayette Escadrille. Before the United States entered World WarI, a group of spirited and chivalrous young Americans, captivated by the glamour of the new war in the air, volunteered to form an American flying unit within the French Air Service. This unit, later called the *Lafayette Escadrille,* was officially authorized on March 14, 1916. Before the United States finally entered World War I on April 6, 1917, over 200 volunteers had joined the Lafayette Escadrille.

The adventures of the first group of Americans to enter into this service make fascinating reading even today, for, as you know, their exploits form the basis of a distinguished and proud chapter in the history of American aviation. In addition to the romance, the excitement, and the awful premonitions of what this new form of warfare would eventually mean to the world, there are some useful lessons to be learned from a look backward at this bit of history. Here is a small part of a first-person account written by James Norman Hall in 1918:

> *But my chief concern, in anticipation, had been this: how were English-speaking eleves-pilotes to overcome the linguistic handicap? My uneasiness was set at rest on this first morning, when I saw how neatly most of the difficulties were overcome. Many of the Americans had [little?] knowledge of French other than that which they had acquired since entering the French service, and this, as I have already hinted, had not great utilitarian value. An interpreter had been provided for them through the generosity and kindness of the Franco-American Committee in Paris; but it was impossible for him to be everywhere at once, and much was left to their own quickness of understanding and to the ingenuity of the moniteurs. The latter, being French, were eloquent with their gestures. With the additional aid of a few English phrases which they had acquired from the Americans, [and] the simplest kind of French, they had little difficulty in making their instructions clear*.

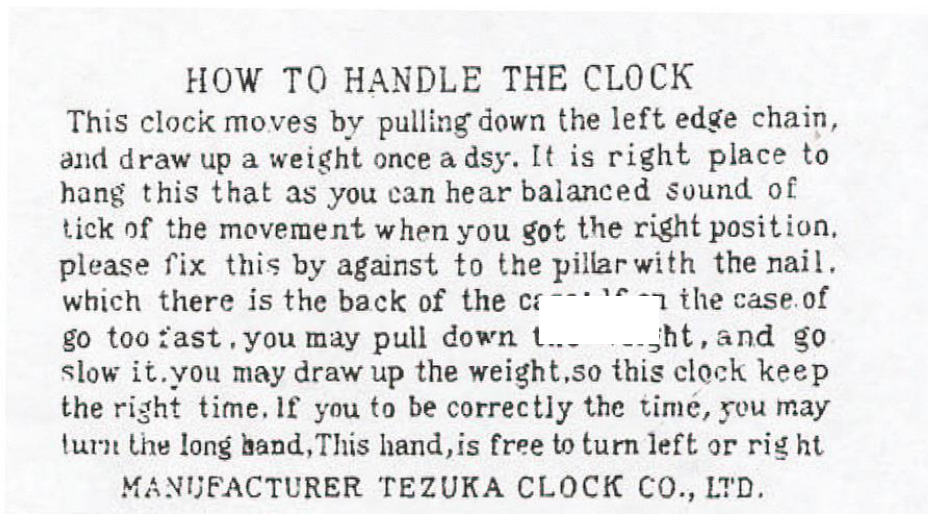
NATO *experience in Canada.* Now contrast this World War I experience with that of the Royal Canadian Air Force (RCAF) less than 40 years later. In 1950, Canada agreed to provide aircrew training for North Atlantic Treaty Organization (NATO) member countries as part of her contribution to NATO. Between 1950 and 1970 more than 7,000 aircrew from eleven NATO countries were trained under this program. Here is one of the major findings of this experience as reported by Sloan (1962):

> *The fact that all training in Canada was conducted in the English language created special problems for some NATO groups. In addition to RAF students, trainees included Dutch, Danes, and Norwegians who had little difficulty with English; Belgian, French and Italian who had some degree of difficulty; and Portuguese, Greeks, and Turks to whom the English language represented serious problems. Prior to the opening of the RCAF NATO Language School in 1953, language was a major cause of failure at FTS [Flying Training School] for some groups. At the language school trainees were held for periods of from three to twenty weeks of intensive training in English until their proficiency was considered satisfactory for FTS training. Some trainees were repatriated directly from language school because of lack of aptitude or lack of progress in English. The school therefore served both a training and a screening function*.

Let me say this another way: Instead of being the rather trivial matter it was in 1916, mastery of the language of instruction has now become the most important single determiner of success in flying school.

Some translation problems. Perhaps you will say that the problem of foreign languages is easily handled by translating the relevant material into the user's own language. The results of this simple expedient, however, are often far from satisfactory. (See Figure 12.) The example given here is highly amusing because we can see at once the absurdities in the translation. Let me assure you, however, that the amusement works both ways. Some of the instructions that we translate into French, German, Hindi, or Swahili are equally amusing. Unfortunately, to understand the humor of the translation requires a familiarity with the target language which neither you nor I have.

Let me add that I have collected stories of airplanes that have crashed, of trucks that were ruined, and of tractors that never could be used because we Americans could not communicate effectively with the people who were using, or trying to use, the machines that we produced. When you recall that American long-range jet aircraft are being used by almost every major airline of the non-communist world, you will appreciate that we do indeed have here a language problem of major proportions.



HOW TO HANDLE THE CLOCK

This clock moves by pulling down the left edge chain, and draw up a weight once a dsy. It is right place to hang this that as you can hear balanced sound of tick of the movement when you got the right position, please fix this by against to the pillar with the nail. which there is the back of the c[illegible] the case of go too fast, you may pull down t[illegible]ht, and go slow it. you may draw up the weight, so this clock keep the right time. If you to be correctly the time, you may turn the long hand, This hand, is free to turn left or right

MANUFACTURER TEZUKA CLOCK CO., LTD.

Figure 12. Instructions provided with a clock manufactured in Japan.

Summary

In drawing this section to a close, I find that I have been able to use only a fraction of all the illustrations, examples, and data that I have accumulated preparing this work. I haven't told you about the instructions for a do-it-yourself kit that even college engineers couldn't understand. Nor have I told you about the difficulties that foreign visitors had with the signs in our New York subway system. Or the million-dollar blunder that was traced to the precise, or imprecise, definition of a single word. Or the bizarre language problems that arise in computer programming. But I hope that I have at least been able to impress upon you that language problems are prevalent in human-machine systems, that they are serious, and that they have largely been ignored. I turn now to some of the things which I think need to be done to remedy the situation.

A PROGRAM OF RESEARCH ON LANGUAGE

Trying to forecast the direction in which research will go is about as difficult as trying to forecast accurately what the weather will be like in Washington a week from now. Making statements about the way research *should go,* on the other hand, is much safer. Even so, let me assure you that I approach this with considerable inner feelings of trepidation. As I've worked in this area and studied the situation, I have become more and more impressed by the multiplicity of the problems and the scarcity of the answers. There's so much that needs to be done, it's hard to know where to begin.

One way of limiting the field of inquiry, however, is to make it clear at the start that my present interests focus on the purely practical problems of words and language that communicate meanings in human-machine systems. There is already much good work being done on language by grammarians, linguists, psychologists, cultural anthropologists, and communication theorists. By and large, however, this work strikes me as being so theoretical, or so [word missing?]oriented, that it contributes virtually nothing to the down-to-earth situations we face in machine design. To be blunt, it doesn't lead to design recommendations one can put in a human-engineering handbook or guide.

Don't misunderstand me. I believe strongly in basic research. I believe that basic research, like motherhood, holds the key to the eventual preservation and salvation of the human race. But there are times when we have to deal with problems that are here, right now, and that need to be solved today. They cannot wait for basic research. When 1,000,000 extra students show up on the doorsteps of the schools and colleges of this country, they have to be dealt with right now. It may be reassuring to know that lots of people are doing basic research on improved methods of education, but that, unfortunately, doesn't solve the problem of the kids who are hammering on the door outside.

Our language problems, I think, have this urgency. I'm delighted to know that there are people doing basic research on phonemes, bits, redundancy, semantics, pragmatics, and syntactics. But we've got a job to do. Somebody has to write that instruction manual today. We have to install that highway sign this afternoon. This label has to go on that dishwasher right now because it has to be out on the floor ready for sale tomorrow. And the Thai, Philippine, Japanese, Hindu, German, French, and Ethiopian pilots have just arrived to get training on the DC-8 and the 707 jets which their airlines bought yesterday. This is the first reason I think human factors engineers need to get into this business. Somebody has to tackle the immediate, messy problems of the real world right now. That is what engineers, human or otherwise, typically do so well.

The second reason why I think we need to get into this kind of work is that most of our problems cannot be solved by conventional methods of linguistic analysis. Instead, we need to attack these problems with the methods which we human factors engineers already know so well and use so often in our work – the critical-incident technique, methods of task analysis, and the method of experiment.

Quality Control Over the Language of Documents

I have already said that the language of our documents is everyone's problem. Because it is so universal, we already know a lot about what makes technical writing good or bad. Insofar as human factors engineering is concerned, I think the proper line of attack should be not so much in starting new research along these lines, but rather in applying what we do know. We need, in short, to institute better control over the quality of our documents.

There are a number of specific things one could do, of course. First, one could insist on a more exact definition of the target audience for each of our reports. Something that does need to be studied in this connection is the precise level and style of writing that is most efficient, most comfortable, and most acceptable to the target audiences we try to reach. The bulk of the available research on readability has been done with schoolchildren in mind. Our readers are quite different and we have practically no data on how one writes best for them. Once we had the answer to this question, contracting officers, technical directors, and editors might then insist that the language of a report be appropriate for its audience. In enforcing this insistence, I think it would be a worthwhile adventure to see many reports summarily returned to their sources with curt notes saying: "Report rejected. Too windy, too hard to read, too long. Final payment on this contract is being held up until readable report is received." Such steps would, I am sure, be highly unpopular at first. But I wonder if the long-term gain for all of us wouldn't be worth the short-term strain on some of us.

Critical-Incident Studies of Language Difficulties

The critical-incident method is a tried-and-tested technique for locating and identifying difficulties in human-machine systems. You are all familiar, I know, with the classic studies in this area which have done so much to advance our field. In preparing this work, I myself used a kind of critical-incident approach. However, my methods have been far less than systematic and my data much too scanty to dignify them with the title of research.

As a first research step into this area, therefore, I would like to see some careful and extensive critical-incident studies of language problems encountered in human-machine systems. Exactly what kinds of difficulties do people have with the words and language of human-machine systems? How extensive and widespread are these difficulties? Where should we direct other research efforts? I feel confident that this is a ripe field waiting idly to be harvested.

Criteria of Intelligibility

In his book *The Measurement of Readability*, Klare lists some 40 different formulas or techniques that have been proposed at one time or another to assess the readability of text. Unfortunately, none of them is particularly appropriate for most of the word problems we have. In the first place, the principal criteria used in validating many of the current readability formulas are: (a) speed of reading, (b) comprehension of text material as measured by tests of recall or retention, and (c) judgments of difficulty. Our interest, however, is not so much in these things as it is in the intelligibility or the understandability of what is said. It is for this reason that I deliberately say that we need formulas or techniques for measuring the intelligibility of text, rather than its readability.

A second difficulty with many current readability formulas is that they require large samples of words – as many as 1,000. Our samples of language are often short. In addition, many readability formulas depend on such things as the average length of sentences, the proportion of difficult words in the sample, or the number of affixes or suffixes in a sentence. Formulas based on counts of this type just won't work with many of our instructions. Let me illustrate.

There's nothing really difficult about any of the words in the elevator sign (Figure 2) I showed you earlier. The real problem arose because 13 short and simple words were arranged in such an order that the meaning of the ensemble was distorted. Recall also the example I gave you of the notice about the pilot lamp on the AM-FM radio (Figure 4). Twenty-two of the 29 words are monosyllables – easy words like this: *a, long,* and *off, up, play,* and so on. Three of the remaining seven words are *radio*[?] – certainly a commonplace word these days. The remaining four words are *uses, pilot, turned,* and *before.* You will agree, I am sure, that there isn't a hard word in the collection. But the combination is almost completely unintelligible to the average person. None of the conventional readability formulas helps us in cases like these.

Instructions built up on the basis of task analysis. As I see it, we need to have research done to discover formulas and methods for assessing the intelligibility of short declarative and imperative sentences. I am not certain in what direction we should search for these criteria, but I strongly suspect that the methods of task analysis which we have used to such great success in the design of human-machine systems may be of use to us here. My idea is that rather than starting with words, we need to start by asking what specific human actions we want to result from a set of instructions and in what order we want these actions to occur. Then we need to compose the instructions piece by piece so that they will produce those actions and in the correct order. Building up a set of instructions in this way would, I think, clearly have avoided the obscurity of the directions written for the men in the paint shop (Figure 7).

Rules for structuring short sentences. In composing instructions we need to follow certain rules of construction. What I have in mind is something like that which Miller (1962) referred to, all too briefly, as the constituent structure of a sentence. We cannot really understand a sentence until we can make an unambiguous flow diagram of it. We need to know precisely what the subject of the sentence is, what the verb is, what adjectives modify which nouns, precisely what adverbs modify what, and so on. Let me illustrate with a specific example: Long strings of four or more nouns, one right after the other, are one of the most common faults in military and technical writing today. The trouble with such sequences is that it is usually hard for the reader to figure out which of the words are supposed to be adjectives, and which are supposed to subjects or objects. The writer, of course, doesn't have this difficulty, because when he wrote the sequence he knew exactly what he had in mind. The reader, unfortunately, doesn't come to the sample of writing with the writer's set, or frame of mind. Look at a portion of the first passage I quoted earlier: ". . . the problem of test data validity assurance remains . . ." A reader coming across this for the first time is brought up short. Exactly what is the object of this prepositional phrase, what is the subject of the verb remains, and which of the remaining nouns are supposed to be read as adjectives? For example, should we read this as:

a. the problem of test,

b. the problem of . . . data,

c. the problem of . . . validity, or

d. the problem of . . . assurance?

To continue, do we read this as:

a. the problem . . . remains,

b. test . . . remains,

c. data . . . remains,

d. validity . . . remains, or

e. assurance remains?

So long as questions like these arise in the reader's mind, there will be misinterpretations. Rules for avoiding pitfalls of this kind need to be discovered, tested, and codified. Or, to give this a more positive accent, we need to devise rules for composing instructions so that the flow of words matches the flow diagram of the actions (or thought processes) that we want to be taken in response to the words.

Experimental validation of principles. Next, the rules, whatever they are, need to be validated experimentally by testing them with the behavior of people, not the judgments or opinions of linguists or grammarians. What kinds of sentence structure lead to wrong actions? What kinds of sequences of words take more time to read? How are regressive eye movements and fixations in reading related to the particular arrangement of words and phrases in a sentence? These are questions for which there are virtually no experimental answers. The merest glimpse of the rich rewards that await us here, however, is suggested by a small study reported by Miller (1962). He compared the matching of simple declarative sentences with their passive forms, negative forms, and passive negative forms. On the average, simple passive sentences, like "The small boy was warned by John," took 25% more time than their corresponding active forms, "John warned the small boy." This will come as no surprise to anyone, I'm sure, but note that military writing is full of passive sentences. In fact, you usually have to look hard to find a simple active sentence in the typical military technical report.

Still, this work of Miller's is only a beginning. We need to have a lot more experimental work done with more complicated sentences. What happens when you start adding adjectives, adverbs, prepositional phrases, and clauses in various places? Above all, these questions need to be tested in terms of their effects on the behavior of ordinary people.

Along these same lines we need to test our highway signs, labels, and instructions, not with engineers, copywriters, or advertising men, but with drivers, housewives, and electricians. In this business, the empirical test of what people do with words is the one that has most often been neglected.

Checklists for Rating Manuals

Equipment evaluations usually conclude that, among other things, there are deficiencies in the instruction manual, operating manual, or maintenance manual that is attached to the equipment. It's almost a universal finding. Yet we have no good checklists, or guides, for rating manuals. There are checklists which purport to do this, I know, but all those which I have seen are almost entirely concerned with the format and mechanical details of arrangement. I have yet to see a checklist which places any emphasis on the content and understandability of the material. The need here, I think, is great. We need criteria for evaluating manuals, methods for testing them, and guides for preparing them.

Words Versus Other Symbolic Forms of Conveying Information

There is an old Chinese proverb which says "One picture is worth more than ten thousand words." I'm not sure whether this conversion factor is correct, but I think it would be worthwhile knowing approximately how much we do gain from pictures and other forms of symbols. Traffic signs in Europe don't say "Slippery when wet." They show a picture of a car skidding in a most impressive way. How much is a picture worth? When should we use pictures rather than words? What should be the mixture of pictures and words that will give us the most understandable and most readable combination? These are only a few of the questions that lie unanswered in this area. The answers, when they come, might very well help us in the solution of some of our cross-cultural language-machine problems.

New Word Lists for Many Languages

The Thorndike-Lorge word lists are already so well known and have been used so often in experimental and applied work that I scarcely need to describe them. Lists of this kind enable us to estimate more exactly the difficulty of words that are used in ordinary writing, in instruction manuals, in directions, and so on. Recall, however, that these lists were made years ago and that they were prepared for general vocabularies. We need to have these lists brought up to date and extended.

More important than merely bringing the lists up to date, however, is the need for preparing special lists for special purposes. As I see it, we need special lists for special fields; for example, electronics, human factors engineering, or psychology, and we need lists for special audiences, audiences differentiated according to nationality, educational level, intelligence, and areas of training and skills. Many of our word problems arise, I am sure, because we cannot be sure whether certain words are, or are not, likely to be within the range of comprehension of the average citizen, soldier, maintenance technician, or engineer. Thorndike did his original work with an army of student helpers over a period of years. With the digital computers we have today, compiling lists of this kind should be vastly simpler. The rewards of such work would, I think, be great.

A Language for One World

When we come to foreign languages and the problems of designing languages for machines to be used by persons of diverse nationalities, the problems loom so large that they seem almost insurmountable. One tends immediately to think of all kinds of grandiose, and impractical, schemes like constructing a universal language. Nonetheless, there are some practical beginnings that need urgently to be made. Perhaps this would be an area in which American human factors engineers might engage in cooperative research with some of their foreign colleagues.

Let me tell you an interesting fact. In preparing his book on readability, Klare could find almost nothing on the readability of languages. This is virtually a completely unexplored area. To put it another way, almost anything one did here would be interesting and worthwhile. We need new ideas, new methods, and new solutions to the language problems that arise when a person of one nationality has to learn to use, and to operate, a complex machine produced in some other country. I feel absolutely confident, however, that no one here will challenge me when I say: There must be a better way to do it!

CONCLUSION

In conclusion, there is another characteristic of words that I have entirely neglected in everything I have considered here. This is the remarkable capacity words have to excite our emotions and to produce affective reactions within us. Words make us glad; they make us sad; and they make us mad. They may make our hearts sing or make us weep with joy, love, or patriotism. Conversely, words may frustrate us, drive us to despair, and incite us to kill ourselves or each other. These affective and emotional concomitants of words also have their implications for human factors engineering – but that's the topic for another lecture. In addition to whatever intellectual content my words here have had, I hope that they have also been able at least to interest you, perhaps to amuse you, and hopefully even to excite you. If, by some stroke of good fortune, my language has been esthetically satisfying to you I will feel richly rewarded for having written these words, words, words.

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INDIVIDUALS AND US

Julien M. Christensen
Aerospace Medical Research Laboratories

For I dipped into the future, as far as human eye could see,
Saw the Vision of the world, and all the wonders that would be;
Saw the heavens filled with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales;
Heard the heavens fill with shouting, and there rained a ghastly dew
From the Nation's airy navies grappling in the central blue;
Eye, to which all order festers, all things here are out of joint.
Science moves, but slowly, slowly, creeping on from point to point;
Yet I doubt not through the ages one increasing purpose runs,
And the thoughts of men are widened with the process of the suns.
Tennyson – "Locksley Hall"

If I had the prescience of a Tennyson, my remarks today on the topic of "individuality" might have a measure of validity that they currently lack. If I had experimental data, perhaps my remarks on this same topic would have a measure of objectivity that they now lack. But I have no data; I have no mathematical function (except a very simple one), and when I have finished you may well conclude that I lacked even significant purpose. However, I believe that there is a problem in society to which our Society, the Human Factors Society, should address itself immediately. If I'm wrong, please tell me so that I will waste no more time thinking about it, but if I am right then let's join together in trying to help solve it.

I make no claim to having discovered this problem. In fact my first formal reference to it came only 4 years ago when I wrote in our Society's journal,

> *While he (man) may control more machines, more power, perhaps even more people, etc., do not these same elements with which he is interacting also exert greater control over him, essentially reducing individual freedom of choice and action? Such considerations are perhaps beyond the immediate or, at least, current responsibilities of the systems engineer. Yet for the systems engineer to ignore these interactions would patently violate the ultimate objective of his profession* (Christensen, 1962).

Two very wise men in rather different fields had something to say on individuality and creativity. Hobson (1926) in his "Free Thought in the Social Sciences," states "The creative spirit is one and indivisible. It cannot live and work under servitude or external control," and Einstein, in an address that he gave at the California Institute of Technology in 1931, stated:

> *It is not enough that you should understand about applied science in order that your work may increase man's blessings. Concern for man himself and his fate must always form the chief interest in all technical endeavors, concern for the great unsolved problems of the organization of labor and the distribution of good[?] –in order that the creations of our mind shall be a blessing and not a curse to Mankind. Never forget this in the midst of your diagrams and equations.*

In addition, I recall some remarks from a convocation on "the ethical use of knowledge," which was held a few years ago at Baldwin-Wallace College. Dr. Dryden (1960), the late Deputy Director of NASA, stated at that convocation that there are three aspects to life: the materialistic, the intellectual, and the spiritual. He warned of the dangers implicit in exaggeration of any one of the three, pointing out that an

. . . overexaggeration of the materialistic produces a sensual, primitive man, an overexaggeration of the intellectual and egotistical, selfish, soulless egghead who makes reason a God, and an overexaggeration of the spiritual . . . a religious fanatic dominated by instinct and emotion.

I acknowledge additional indebtedness to my first instructor in psychology who once wrote this simple equation on the blackboard:

B = HE (Behavior is a function of heredity and environment.)

I am of the opinion that this formula has significant implications for each member of our Society. Whether or not you are a psychologist is completely and totally irrelevant. Let us examine this equation.

B = HE

Of all the members of the animal kingdom it is man who most extensively and persistently modifies his environment. With rare exceptions most animals seek a more suitable natural environment when the one that they currently inhabit becomes too hot, too cold, too dry, etc. Man modifies his environment and, incidentally, thereby modifies his behavior and his heredity. As Caspari (1960) has put it, “The adaptive value of a particular gene, i.e., its probability of being transmitted to the next generation, depends on the environment. Consequently, the composition of the gene pool will depend on the environment, and will change when the environment changes.” (How many of you in this audience have ever considered the fact that through your work on systems you are determining to some degree the nature of the genetic pool of future generations?)

Elsewhere I have developed the thesis that as man has progressed from his earliest beginning through the Primitive Ages, the Industrial Revolution, etc., he has exerted more and more control over his environment *and thus over his behavior* (Christensen, 1964). In addition, Caspari suggests that environment also affects behavior indirectly by determining to some degree which genes shall be passed on to succeeding generations and which shall disappear. (The employment of more direct methods of controlling the genetic pool is, of course, available through birth control and it appears that direct intervention in the basic genetic structure of the individual will someday be possible.)

Surely no one in this audience will deny that scientists, engineers, and systems designers have a direct and special influence on the environment of modern human. I believe that no one here will deny that if these individuals are influential in the structuring of the environment then to some degree (and I believe a very significant degree) they are determining man’s behavior. Now in our By-Laws I find that our Society has as its aims the increase and diffusion of “. . . knowledge of man in relation to machines and his environment . . . and to promote the application of this knowledge to design of systems and devices of all kinds.” Thus, we have openly declared that we intend to play a significant role in structuring the environment and have at least implied that we will play a role in determining, to some currently unknown extent, the behavior.

“Well,” you say, “what is so bad about that?” Nothing is bad about that if we are aware of, and remain ever sensitive to, this rather awesome responsibility that we have assumed. For we are in the position of being able to control significant segments of behavior by directly influencing the design of the cultural aspects of the environment! My concern, however, is that we, as a profession, might become so engrossed with standards of design, measures of efficiency, the exact meeting of exact requirements, etc., that we, like others before us, will neglect important but unofficial requirements dealing with individuality and the possibilities for creativity that exist among those who operate and maintain cultural systems. We may already occasionally have been guilty of systems designs that are so deterministic that systems effectiveness has been reduced rather than enhanced because there was no provision or allowance for the expression of individuality and creativity in that system. Let us do all that we can to promote an environment that is responsive to the unique, perhaps even idiosyncratic, characteristics of the individual.

We are expanding our influence at an accelerating rate from the civilian systems, so we must be even more sensitive to this need to preserve individuality and creativity.

I realize that I am proposing an extremely difficult task. Pressure to conform, to standardize, and to lose individuality pervade all organizations. It is true in the political realm, in our unions, in our social organization, in our schools, and I fear, even in our homes.

Now those of you who know me know that I have strongly favored the "*systems approach*." And I still do. But this or any other systematic approach to design could eventually prove to be sterile and degrading if in pursuing it we don't make provision for differences among individuals, for their individual hopes and aspirations, for their individual needs, and for their individual potential for creativity. With the advent of modern technology it is not too difficult to envisage a society in which every basic need is met, yet in which the expression of individuality and creativity is seriously stifled or completely expunged.

This Society and its members must resist trends that tend[?] to diminish individuality and creativity. Perhaps one can have too much of a good thing, e.g., security. I recall a recent quotation from a University of Dayton publication:

> *Were it not for insecurity, the human race probably would never have advanced beyond the mentality of the caveman. Insecurity in some form is behind most of the progress mankind has made. Curiosity and ambition are strong driving forces in human nature, but the tension of insecurity is frequently needed to prod men into action. If necessity is the mother of invention, insecurity is surely its father* (Bulletin of the University of Dayton, 1964).

Kierkegaard put it somewhat more succinctly when he said, *"To venture causes anxiety, but not to venture is to lose oneself"* (May, 1949). A variety of organizations are worried about "society," "social problems," etc. Let us devote more of our attention to the individual – the elemental particle of society. Perhaps many of the organizational problems will then solve themselves.

It is often said that individuals today don't feel as responsible for their acts as did individuals of yesterday. Perhaps they really aren't! If you design an environment that markedly limits the control that individuals can exert on that environment, then more assuredly, you are at least jointly responsible for the consequences.

In a related vein, I fear that the use of statistical analysis (or, perhaps more accurately, the misuse of statistical analysis) has tended to foster the subversion of individuality. Instead of being used to accentuate and highlight our differences, our individuality, our creativity, statistical measures of dispersion are usually employed to show what design or what situation will accommodate those encompassed by the mean plus or minus two standard deviations! I'm concerned not only about that middle 95% of the population which is being lumped into one amorphous mass, but also about that 2 ½% at each end of the distribution which often is completely ignored. I want the artifactual elements of our society designed so as to be adaptable to anyone and everyone who may have legitimate access to them. I view with joy such things as the work on adaptive control systems, the programmed instructional schemes, that adapt themselves to the changing requirements of the individual learner, and, yes, even something as seemingly modest (but in reality as noble) as a completely adjustable chair!

However, I view with alarm the unrestrained and unquestioned acceptance of the idea that what is best for the majority is best for all, whether it concerns design or some other aspect of our lives. I hope that some day, for example, enlightened managers and union leaders will agree on a labor contract that is not the same for all the workers of a particular union. If an individual worker wants to trade some pay for an extra week's vacation, I'd like to see him allowed to do so. If a competent individual wishes to continue working after he has reached retirement age, why shouldn't he? (Solutions to the programming difficulties associated with such a variety of individual desires should yield to confrontations by a team of programmers and a big computer.) I understand, for example, that our good friend Dr. Dorenberger of Bell Aircraft has been forced to resign because he is 70 years old. If you know this gentleman, then you know that he is one of the truly outstanding individuals in the aerospace business. You know also that at 70 he has the stamina and energy of someone half his age. What a tragedy to apply an arbitrary retirement rule to such a man. In so doing, we fail to recognize him as an individual. We may even have done worse – we may be destroying him. It has happened to others.

Fortunately, I perceive in the very young an eagerness to retain their individuality and creativity. Unfortunately, once they start to become acculturated, there exist enormous pressures to divest them of this treasure. I recall reading somewhere that while the average small child asks 400 questions a day (most mothers will consider this a very conservative estimate!), this measure of inquisitiveness is reduced to only 50 by the time the child is an adult. Don't decry the fact that the young rebel against us. The length of young men's hair, for example, may be their way of showing their disdain for much of what our generation stands for. (Incidentally, if we really want them to cut their hair probably all that we need to do is let ours grow!)

POSSIBLE CONTRIBUTIONS TO A SOLUTION

In asking you to give more consideration to the problems associated with design for the individual, I don't believe that I am posing an insoluble problem nor do I believe that we need to yield significant amounts of the advantages that we have gained from standardization in order to achieve such goals. Let me suggest some ideas.

As I have already stated, I enthusiastically endorse the work being done on adaptive control systems and adaptive teaching machines. They represent clear examples of "mass-produced, standardized items" that take intelligent account of the individual differences among the users. The more complex of these devices rely on computers to store and analyze the operator's input and then present the problem to him in terms most compatible with his state at that moment. (Note that computers will be our servants and not our masters if only we insist on it.)

Since each of you contributes in some way to the design of systems, permit me to quote from a book by Dr. John Gardner (1963), the new Secretary for Health, Education and Welfare: "Too often in the past we have designed systems to meet all kinds of exacting requirements except the requirement that they contribute to the fulfillment and growth of the participants." Let us not nurture these tendencies. Let us be alert for design opportunities in our systems that will stimulate the expression of individuality, flexibility, and creativity. In so doing you will be enhancing, not degrading, systems effectiveness by allowing more of man's truly unique and greatest resources to be tapped. Again to Gardner (1963): *"We must learn to make technology serve man not only in the end product but in the doing."* (my italics)

To the extent that you do not provide for the emergence of these nobler characteristics, you will have degraded you system's operators and your system. If we cannot ennoble the job of the garbage man, for example, then I suggest in all seriousness that each person should have to attend to his own!

Although rather foreign to the interests of many of us, I wish that some team of union and management specialists would make a sincere effort to tailor their contract more in accordance with the individuality of the workers while still retaining a balance of fair and equal money for equal work – the same amount of money is not necessarily the same amount of reward to two individuals. One individual might very much have preferred to exchange money for an additional week's vacation, a larger paid-up insurance policy, or some other form of compensation.

Vast improvements could be made in education for individuality and creativity, and we can help by designing instructional devices, laboratories, and buildings that maintain the maximum degree of flexibility and provide an environment that encourages the expression of creativity. It is discouraging to note that in many schools essentially the same techniques are used to teach the student with an IQ of 160 as are used with the student who has an IQ of one-half of that. This is patently unfair to both of these students. In others, instead of trying to find better and more interesting methods of teaching those subjects that offer immediate and later enrichment of the student's life, surrender is made by diverting him to a vocational school, often only to hasten his subservience to a machine by learning skills that probably will have to be relearned when he gets in a "real job" situation. As Gardner (1963) put it, "Our educational purposes must be seen in the broader framework of our convictions concerning the worth of the individual and the importance of the individual fulfillment." Our schools must be more than tool sheds, as Gardner says.

We should support more research on assessment of the abilities and prediction of success or failure *of the individual* in various fields of endeavor. Even the best measures of ability are far from satisfactory for making predictions of the likelihood that an individual will succeed or fail in a specific job. Some will suggest that this is because the criteria are invalid. All right then, let's get to work on methods for making them more valid. We must promote studies in such poorly understood areas as motivation and means of enhancing it by providing a stimulating environment.

More thorough examinations should be made of the characteristics of inheritance, home, school, and job that stimulate creativity. No thinking person wants complete equality in anything except opportunity. But in a democracy each individual has a right to expect an environment that will provide him an opportunity to develop his individual, distinctive talents to the utmost.

I can't conceive of a scientist or engineer being against the space program, although many are. In addition to the material progress that will result from this challenge, does it not lift your spirits just to live in an era when we are breaking the chains that have fettered us to this speck of dust for almost 2,000,000 years? And, as has been pointed out by many, the studies associated with manned space programs will have direct and significant payoff in the social and biological sciences as well as in the physical sciences.

We must extend our ideas to other nations and associate closely with other organizations, such as the Ergonomics Research Society, that believe essentially as we do. There are no independent nations or societies any more – the environment and resultant behavior of the people of one affect those of another.

Finally, I feel that we should constantly review our requirements for membership. We should encourage, regardless of background, those who display a sincere desire to devote their talents to the development of an environment that enriches men's lives. We may have unduly and unwisely restricted ourselves to those who can show that they can contribute to an understanding of human beings as effective (in its narrowest sense) members of a human-machine complex. We must nurture our interdisciplinary point of view. We must never forget that the human will never be completely understood from the vantage point of any single discipline or any single facet be primarily material, spiritual, or intellectual. Herein lies our strength; we must exploit it.

I am for the measurement, description, prediction, and control of human behavior. But I am concerned as to where that *control* will reside. Obviously, I want as much of that control as possible to reside with the individual. And, equally obviously, I want the members of our Society to be in the front ranks of those who recognize the threat of modern civilization to individuality and creativity and who will join together to do something about it. It's a tough problem and those who solve it will have to overcome the subtle but powerful forces at work in modern systems to stifle individuality and creativity. But when you consider the beauty and even utility of the goal, is it not worth all that we can do to attain it? Obviously, I feel that it is. I hope that a significant number of you do also.

Since I began with a quotation from Tennyson, perhaps I should conclude with one – this one from his "Ulysses."

. . . and tho'
We are not now that strength which in old days moved heaven and earth;
That which we are, we are;
One equal temper of heroic hearts,
Made weak by time and fate, but strong in will
To strive, to seek, to find, and not to yield.

I hope that we will strive, seek, find, and never yield in our search to provide humans an environment in which an important element in the effectiveness of responses is the satisfaction that they derive from making them.

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LIFE AND DEATH

Henry M. Parsons
Riverside Research Institute

A "systems study of mankind" should incorporate analyses of the cost/effectiveness of life and human factors analyses of death. Various methods have been adopted for placing a dollar value on human life. Human factors studies can attempt to prevent loss of life in vehicular accidents, incorporate the number of lives saved as a criterion of the benefits of improvements in defense systems, examine the nature of behavior governed by deterrence, and investigate some of the complexities of population control. Systematic investigation might also be conducted into the parameters of death. An ecological projection suggests that a nuclear war may occur to counteract the disequilibrium of nature resulting from technology, including the population explosion.

INTRODUCTION

Four years ago I came across an appeal in *Science* for a "systems analysis of man and his environment." Entitled "Save the World," this appeal (Wolfle, 1965) by the executive officer of the American Association for the Advancement of Science contained the following key sentence: "If it be assumed – as it must be – that we will succeed in stemming population growth and preventing nuclear catastrophe, our expected success on these problems makes it time for an analysis on a global scale of the whole set of environmental problems, a systems study of mankind in relation to his planet."

It occurred to me at the time that according to this viewpoint the world's future was literally a matter of life and death. However, I questioned the assumption of mankind's success, at least the way Wolfle phrased it. I also said to myself, "Here's a human factors problem."

The tradition has been growing in the Human Factors Society that Presidential Addresses adopt a philosophical vein, if only by indicating new horizons toward which human factors research and practice should march. In pondering this tradition, I recalled the *Science* editorial. I speculated that life and death are indeed human factors and could properly provide the theme for my presentation.

Certainly no one can deny that death and the threat of death play a major if not central role in modern life. In Viet Nam, on TV, Biafra, on the streets, and even on Martha's Vineyard, death intrudes on us daily. The threat of death and the excitement and avoidance behavior this threat generates are even more intrusive than death itself. Death is threatened by terrorists in Brazil, by the Cosa Nostra in the United States, by Soviet troops in Prague, by starvation in Calcutta, by plane hijackers everywhere. Robbery replaces burglary in crime popularity polls. The astronauts make it to the moon and back, while innumerable millions watch them with the same fascination that once gripped thousands in the Coliseum. The Safeguard antiballistic missile system is debated in terms of the total number of deaths threatened by ICBMs on the one side or the other. The commander of the *Pueblo* says he surrendered his ship to save the lives of his crewmen. Subordinates buy guns to defend themselves from those in the central city. Hearts are transplanted to forestall death. A mighty ecclesiastical institution is rent over the issues of life and death in the womb. The draft, with its threat of death in Viet Nam, has helped transform a generation into rebels of many kinds – and some of the fallout is visible in the hirsute embellishments on the faces of my friends here.

George Bernard Shaw (1959) had a point when he wrote: "Nothing is ever done in this world until men are ready to kill each other if it is not done."

Yet death and its reciprocal have encountered little systematic analysis as general phenomena. Except for religious preaching about immortality, there seems to be an aversion to discussing the termination of life – another example, perhaps, of the avoidance behavior that death generates. Only poets, philosophers, and playwrights face this universal phenomenon in human terms and they have produced more popular quotations about death and life than about any other topic, even love (Stevenson, 1935).

Or at least that was the case until more recent years. In today's culture, where sex and making money occupy so much of our attention, death does encounter some real competition as a topic. In any event, the humanist has strongly resisted any inclination to examine life and death systematically. In the value system, death is a subject to be shrouded in amorphousness. And though he lives in a plutocracy, he particularly resents the evaluation of life in dollars.

ECONOMIC EVALUATION OF LIFE

Yet to undertake Wolfle's systems analysis of humankind, surely one would have to incorporate a study of life's cost-effectiveness or cost-benefit ratio. The dollar cost of human life has been variously assessed – from 30 pieces of silver almost 2,000 years ago to insurance policies and court judgments widely ranging in value today. One method of determining the economic value of an individual life has been to total a person's lifetime earnings, or the earnings the deceased would have acquired had he survived (Rice & Cooper, 1967). Another more operational method involves keeping alive a terminal patient in a hospital, though in vegetable-like state; the amount he or she or relatives can afford presumably represents the value of that life at that point.

In a different approach, the life-assessor makes comparisons as well as, or in place of, absolute evaluations. For example, it must have occurred to many that the billions spent in trying to kill off the Viet Cong and North Vietnamese at a rate of so much per enemy death could have been better allocated to rewards for desertion or to bounties on the lives of leaders. Possibly the CIA has been doing something like this. The most intriguing comparison analysis I have seen comes from Morgan Jul, secretary of the FOA/WHO/UNICEF Protein Advisory Group at United Nations Headquarters and formerly director of the Danish Meat Research Institute (1969):

The author has made some rough estimates of the world effort to prevent loss of human lives in various fields – or, to put it bluntly, what is the value of a human life? An estimate of the research and development effort may be calculated in terms of dollars spent for death prevented from each cause:

Space Exploration	$1,000,000,000
Civil Aviation	1,000,000
Automobile Accidents	1,000
Malnutrition	1

The comparative approach has most often zeroed in on the cost of sending men to the moon. In a luncheon talk before the Highway Research board in 1969, Alvin M. Weinberg, Director of Oak Ridge National Library, estimated that the $40 billion spent on Apollo would save 110,000,000 American lives in a nuclear war if the money were spent on shelters. Let us hypothesize that the total Apollo project expenditures, if there had been no need to bring astronauts back alive, would have been lower by about 20%, or $8 billion to preserve the lives of 16 human beings (disregarding the value of the scientific data their return assured), or one-half billion dollars per person. Even if some of the above assumptions are altered, the lives of Apollo astronauts are the most valuable ever protected by American taxpayers. Further, on the basis of Weinberg's figures, $8 billion in shelters would save 22 million lives, at $363.63 per individual. The value ratio of an ordinary citizen's life to an astronaut's life is about 1:1,375,000.

To discuss the Apollo project in these terms will certainly seem repugnant to many, especially humanists, and in no sense am I advising that the Apollo shots should have been designed as kamikaze-like missions. The idea that they might have been, however, has occurred to others, for example, Boule (1965) and an anonymous author in *The Flying Physician*. The basic question still bedevils NASA in another form: Should there be a space rescue system?

Probably the most impressive source of an Apollo-inspired comparative approach to the economic value of life was Walter Orr Roberts when he was president of the AAAS (1968):

> *We plan to walk on the moon, and with exquisite concern for the lives of the two or four astronauts who will walk there, we spend hundred of millions of dollars to assure their safe return. But we find it impossible to marshal the human ingenuity to give food or shelter to the uncounted millions of souls who will die of sheer starvation or exposure*.

Another comparative approach is the trade-off analysis. What should be foregone in desirable features of our culture to prevent deaths? In a paper at a National Academy of Engineering Symposium in 1969, Martin Wohl of the Ford Motor Company stated the problem succinctly:

> . . . *It is hardly sensible to adopt a policy that attests that "lives and limbs" are priceless. No matter how final one's death or loss of vital parts may be, neither can be regarded as priceless. To argue the contrary, for example, would be to argue that people would be willing to sacrifice their homes, recreation, food, clothing, traveling – in a word, everything – in order to reduce traffic safety hazards and guarantee their chance of survival and non-injury*.

A different trade-off approach is to weigh the loss of income incurred by some segment of the population, such as those in the cigarette industry who would suffer if cigarette sales were reduced or forbidden, against lives to be lost, such as those succumbing to smoking.

HUMAN FACTORS

Analysis of the economic value of the human lives and of the economic losses incurred by deaths does have tangential significance for the field of human factors, since we too engage sometimes in cost-effectiveness studies. But they are primarily the province of economists. How might life and death figure more directly in human factors research and practice? I find a number of ways, most of them concerned with technology and its products, the legitimate home of human factors enterprise.

One will have been apparent to you already: the prevention of fatal (and otherwise injurious) accidents, especially in transportation, and more especially in motor-vehicle transportation. Human factors people have already moved into this field, in human engineering, simulation, and training. I should like to see them compare human engineering, training, and selection for their relative advantages. I should like to see them protect the pedestrian. We need more Naders. One of the ironies of the human factors world is that not human factors but law produced Ralph Nader. Lawyers are our social engineers, and it seems they can also become human factors engineers. Above all, I should like to see human factors people try to get a handle on the motivational variables in driver behavior that lead to life or death decisions on the highway – such as those, for example, responsible for what I call "caution" behavior.

In recent years human factors people have also been entering hospital and health systems. Human factors techniques may raise the chances of survival of hospital patients and applicants for admission. Medical instrumentation cries for human engineering attention. I do not see much likelihood of human factors involvement in the most dramatic human-machine situation in medicine, namely, the determination as to who shall live and who shall die, to which patients life-saving devices should be assigned when there are too few of these for all. Yet this is a selection of personnel.

Another human factors area is military systems – notably those designed for defense. The number of lives saved through human factors improvements in an air defense system, for example, has always seemed to me a valid criterion, among others, of the effectiveness of the improvements, just as the total of lives saved seems like a good criterion of the effectiveness of the system (provided, of course, you are in favor of human life). I first verbalized to myself this criterion almost two decades ago when I worked at Columbia University's Electronics Research Laboratories on the human engineering of some air defense semi-automatic equipment. The work seemed terribly important. Just think, one might be helping to save a million lives by reducing the number of effective enemy bombers by one or two! When I went to the System Development Corporation to continue developing system training for the SAGE system, the same kind of thought sustained me, although I don't recall any widespread use of "lives saved" as a criterion of system effectiveness. Perhaps if more attention had ever been paid to it, efforts to increase system effectiveness, if only by a few percentage points, would have attracted wider interests – since each percentage point might mean a million fewer deaths in a nuclear war.

In addition to trying to limit the death total in war, human factors people might well engage in attempting to prevent war itself. I think particularly of the concept of deterrence, which is so central to the strategy of the Soviet Union and ourselves. Deterrence means influencing the adversary's behavior – the development and use of his technology – through one's own behavior in relation to one's own technology. Surely these are human-machine relationships, with enormous import. Assumptions with life-and-death significance are being made about human behavior, particularly behavior to be influenced by the threat of death, multiple deaths, in competition with other influences in a complex organizational context. What is known about such behavior? How valid are assumptions of rationality? What values will variables in motivational mechanisms acquire and maintain, under a range of circumstances, and what contingencies will result in what action? To answer such questions requires an extension of human factors knowledge onto motivational mechanisms in human behavior, probably drawing on research from operant conditioning. But why shouldn't human factors research and applications be thus extended?

As an example, it might be concluded that one way to avert the use of destructive technology on a massive scale would be for rival powers to demonstrate this use jointly on a limited, controlled scale, giving it maximum publicity. In other words, the United States and the Soviet Union might together destroy some simulated metropolis with a nuclear explosion while the world watches on TV. Would such an undertaking augment a mutual deterrence, that is, mutual avoidance of initiating hostilities? Might not the balance of terror be maintained by mutually renewing the terror?

Human factors people might well get involved in population control. Population growth is outstripping the development of new food resources and apparently will continue to do so. More and more human beings are moving further and further along the nourishment continuum toward starvation. It has been estimated that 417 persons die in the world every hour from malnutrition and its effects. In spite of this attrition, demographic estimates of the world's population in the year 2000 are as high as even 7 billion. Even if the final figure is a billion or two lower, the planet will be crowded, and more so in the year 2100. Nor is the problem simply one of food supply. Man does not live by bread alone. Humans call on many other resources which will also be in short supply. Furthermore, as numbers increase, so will human waste products and those of the industries satisfying collective wants.

The population problem is a complex one. The IUD and the pill were developed without benefit of human engineering know-how, but there remains a formidable problem in training, that is, in persuading women to use them and men to support their use. Beyond these devices, moreover, there remain difficult questions of preferred family size and of alternatives to woman's role as a mother. Widespread distribution and use of contraceptives are not the only way to reduce birth rates, and it has even been argued that "family planning" programs will not bring birth rates down to levels that will halt population growth (Davis, 1967), even when the programs are successful.

It should be realized that high birth rates are not the only cause of the population explosion. Decreasing mortality has made its contribution. "There are two biological checks upon a rapid increase in number," Dorn (1962) has pointed out, "a high mortality has resulted in the past from war, disease, and famine.[close quote here?] Man has achieved some success in controlling two of these regulators, disease and famine. Mortality has dropped and the population grown. I shall come back to this theme in a few moments, after looking at one more potential human factors venture.

To enable people to adopt a more systematic view of the subject, human factors research and analysis might be directed toward defining the parameters of death. By parameters are meant those aspects of death which influence the behaviors of those who survive. Certainly the parameters of death and their interactions will have to be better understood if a systems analysis of humankind is to achieve results. What are some of these parameters?

One is the amount of pain accompanying death. Related to it is the manner of dying – by disease, famine, “old age,” accident, war, murder, suicide. Even though the ultimate outcome is the same, people seem to have preferences. (Further, the manner of dying may be prosaic or rather special.) Another parameter is the duration between certainty of death and death itself, death’s suddenness. A fourth is an individual’s subjective probability that death will result from certain conditions – the uncertainty of the event, so well expressed in “when there’s life, there’s hope.” The point in time during a person’s lifespan when death occurs constitutes another parameter. It may be shortly after birth, for example, or at the start of adulthood, or in mid-life, or in senescence. The significance of death varies according to when it happens during life.

Reaction to death varies according to who dies, and where. There are gradients of individual importance and geographical or cultural location. I first fully realized this when I became a newspaper reporter in New York City and was occasionally assigned to a police beat. There had to be a dozen deaths in a fire in Harlem to get the same space as one on Park Avenue. A dozen deaths in a Park Avenue fire are something else again.

The number who die under the same circumstances is an important parameter. In impact, it interacts with identity, location, and cultural affinity, as well as cause and suddenness. If a thousand human beings starve to death during 24 hours in Calcutta, who in New York knows or cares? Yet if the same number should starve to death in New York or be killed in Calcutta in an earthquake, it is another story. More U.S. citizens die each week in automobile accidents than are killed in Viet Nam. Which get the headlines?

Our century has seen genocide in Russia, in Germany, in Indonesia, in Africa. One’s reaction in each instance depends on who one is

The last parameter I shall mention is not a trivial one. People react to the possibility of death according to what they confront as alternatives. “Better dead than Red” is an example. So is the convers.

These parameters are not novel, but to my knowledge they have not been measured, nor have their interactions been fully explored. The parameters of the threat of death are equally interesting and uninvestigated. As I have already noted, we tend to avoid systematic analysis of the subject, so we are left in ignorance about matters of life and death.

A PROJECTION

I will conclude with some observations about something else we find aversive and avoid, partly because in our culture “life” as such is valued so positively. Those who find the topic of death too lugubrious should read no further.

Let me refer back to Wolfle’s statement that we “must” assume “we will succeed in stemming population growth and preventing nuclear catastrophe.” As I said at the outset, this assumption may be questioned. The very systems analysis Wolfe proposed might reject it! The analysis might lead instead to the following hypothesis:

1. Population levels cannot be held in check by limiting fertility, that is, by reducing birth rates to the required levels. The alternative, as we have seen earlier, is to increase mortality.

2. Nuclear catastrophe cannot be prevented.

3. However, nuclear war would reduce population levels in such a way that population control would no longer be a problem. Fallout, fire, flood, and famine would decimate both agricultural and urban populations in all lands.

4. If the Earth is a closed ecological system, it is likely that this is the way things will go to arrive at the balance of nature. The only uncertainty lies in the character of the cataclysm. Some other population-destroying event may occur that would fulfill the same function and at the same time eliminate the possibility of nuclear war.

5. However, nuclear war is the most probable event, because a process which assures it is already operating. The strategy of deterrence depends in part on the adversary's conviction that we would employ the deterrent. Yet continued growth of uncertainty in this country about the employment of this strategy, and even hostility to such a strategy, may weaken the adversary's conviction to the point that the deterrent is no longer effective. If at the same time a similar "softening" does not develop in the adversary, a process of progressive imbalance occurs, leading to war.

6. Like the population explosion, other unsolved and possibly unsolvable problems, such as water and air pollution, will be resolved by the cataclysm through the destruction of the technology that created them.

The ecological projection I have outlined derives its strength in large part from the first hypothesis, to which I am inclined to subscribe, that population cannot be held in check. The prospect is grim, yet neither unique nor hopeless. Man is just now learning, in our time, that sometimes life must perish for life to survive. For example, the belief has grown that some forest fires should be permitted to burn or even be prescribed rather than suppressed, to prevent more devastating fires or unwanted changes in the composition of the forest. Man has also discovered he has, in the past, destroyed much of his environment. For example, it is thought that through his agricultural practices in past millennia, man has changed much of Egypt, Libya, the Sahara, Arabia, and Tibet from forest and cultivated fields to desert (Bouillenne, 1962).

Please note that my ecological projection does not include the destruction of civilization. Culture is exceedingly tenacious and seems to survive when only a few people and their artifacts survive. Despite enormous destruction, habitats are rebuilt, as attested by Normandy's St Lo and Leningrad after World War II. Nor is my projection founded on religious or moral beliefs that Armageddon is at hand.

According to the projection, death on a very large scale over a relatively short period of time is inevitable on this planet. Only one circumstance might stand in its way. If it is widely enough appreciated that on our present course the holocaust is inevitable, the reaction of mankind may be strong enough to prevent it.

THE TEN BEST WAYS TO EMBARRASS A HUMAN FACTORS SPECIALIST

Richard W. Pew
Bolt Beranek and Newman Inc.

For the past several years, I have been collecting a list. The list represents all the frequently well-intentioned, but usually critical, comments that we encounter when we try to introduce human factors work into new design environments. So far, I've gotten up to ten, but when the reader sees how it goes, I am sure he will want to add to my list.

While I hope the reader finds this set of comments entertaining and that many of his own sensitivities are reflected in it, my main purpose is to try to communicate why I believe we have matured as a discipline to the point where we don't need to be embarrassed by them anymore or take a defensive posture.

Human factors is nothing more than the application of common sense.

There are basically three different ways to deal with this comment. First, it can be argued that it is true – a certain amount of the work in human factors reflects the application of common sense. Nevertheless, somehow without the input of human factors specialists, this kind of common sense seems too often to be overlooked. Everyone has his own favorite examples of this phenomenon. Over the street intersections in many parts of Canada, you will see a sign next to the stoplight, which says "Advanced Green When Flashing." I puzzled for several stoplights and had to observe the behavior of the vehicles at such intersections carefully before I understood the meaning of this sign. It could be better expressed as "Left Turn on Flashing Green".

A second and perhaps more critical example concerned the design of a snowblower which was the subject matter of a personal liability lawsuit. One issue in the case concerned the hazards of getting a hand caught in the impeller blades. A warning label was placed on the handlebars where it could be seen by anyone operating the machine, which said something like, "Do Not Leave the Operating Position without Disengaging the Impeller Clutch." As the reader is probably aware, the principle of operation of a snowblower depends on the high-speed revolution of an impeller, which throws the snow out the chute. On this particular machine, the clutch engagement lever controlling the impeller was mounted at the side of the machine right next to the chute. It required the user to leave the back of the machine (a violation of the warning label), walk around to the side, and place his hand in a position right next to the chute in order to disengage the very clutch referred to in the label. The potential hazard is obvious.

The second perspective for dealing with this issue argues that almost everything is common sense when you view it with hindsight. I am reminded of the quote offered by Chapanis (1966):

> *Outside of the proven impossible, there probably can be found . . . no field where so much inventive seed has been sown with so little return as in the attempts of man to fly successfully through the air. It may be truly said that, so far as the hope of a commercial solution of the problem is concerned, man is today no nearer fulfillment than he was ages ago when he first dreamed of flying through the air. . . . A calm survey of certain natural phenomena leads the engineer to pronounce all confident prophecies at this time for future success as wholly unwarranted, if not absurd.*

This quotation was authored by Rear Admiral Melville, then engineer-in-chief of the United States Navy in 1901, 2 years before the first successful flight at Kitty Hawk.

It is certainly true that, after the fact, it is easy to make almost any result appear to be common sense. It takes study and sometimes experimentation to predict what will be common sense and to put those predictions on a quantitative basis. The goal of much human factors work is to predict what will become common sense after the fact.

Finally, it is not all that difficult to find examples in which the human factors principle to be applied is not common sense at all. One example that always surprised me was the effect of requiring simultaneous performance of tasks having different initial levels of difficulty. I would expect that the more difficult of the two tasks would suffer more on the introduction of a second task, but in fact, it is the easy task whose performance degrades in comparison with the single task control performance.

A second example, first reported to me by Dr. Irwin Pollack, is the idea that, in a noisy environment, you can hear speech better if you put your fingers in your ears. The technical reason for this result is that the fingers in the ears provide selective filtering of the signals from the outside; admitting frequencies in the speech range better than frequencies outside that range. I doubt that anyone would argue that this is simply an application of common sense.

Yes, some human factors principles are common sense, and others become common sense with hindsight, but in all of these cases, it takes a professional to understand how and when such commonsense knowledge applies.

The human factors consultant I hired didn't tell me anything I could not have thought of myself.

This assertion could be regarded as a corollary of the commonsense issue. The individual who made it is very good at understanding a good idea after it is presented to him. For purposes of this discussion, I would like to take it as a comment on the level of quality control within our discipline. There are good and bad consultants in every field. We must continue to be concerned about the issue of quality control. At its October 1978 council meeting, the Executive Council of the Human Factors Society spent more than an hour discussing how to come to grips with the evaluation of the quality of our specialists.

There is currently much discussion nationwide about licensing professionals, and such licensing requirements are being imposed by state legislatures today in many disciplines. We need to take the initiative to do it ourselves, to meet our own needs before licensing standards unacceptable to us are imposed by the legislative powers. I think you will begin to see proposals of this kind from the 1979 Executive Council.

The research you people do is too abstract to be useful to me.

I have frequently heard the criticism that the journal *Human Factors* is too researchy. I don't think you should expect everything you read in the journal to be useful to you immediately. One purpose of a journal is to advance the state of knowledge in the field. This is a gradual process.

The individual who makes this comment needs to understand that it takes time to see researchpay off. Let me take two examples of some of the more abstract work that has been developed in our field.

Work began 20 years ago on engineering models for manual control of vehicles. These models are being used actively today for pre-simulation analysis of vehicle handling qualities, both in aircraft and automotive applications.

Signal detection theory has not only changed considerably our view of sensory measurement, but has recently become the basis for a very practical standard evaluation protocol for examining the usefulness of radiographic imagery by the National Cancer Institute.

I actually believe human factors specialists are in a better position to produce *useful* research than your average university academic. There is no better research than that which grows out of practical needs. The problem now is the opposite. Usual sources of support, particularly the Department of Defense, are directing their resources to short-sighted applied development projects rather than longer term research activity.

Of course, as a matter of fact, we need *both* competent research motivated by practical questions and careful case studies which systematically explore the range of parameters that would support improved design directly.

That's a great concept for improving performance, but you just can't build it that way.

This is, indeed, a frequent criticism of the psychologist or physiologist working in an engineering environment. But let the engineer be patient with us. A human factors specialist worth his salt will learn rapidly what the engineering design and cost constraints are. Our field depends on the ability to make trade-offs between human factors issues on the one hand and design and cost constraints on the other.

The engineer will also want to be careful when he uses this gambit that he is not exposing his own flank. Human factors specialists can often say, "That's a fine design, but an operator just won't use it that way." Too often this expression is used as a stock phrase to close off discussion. Don't let the designer close off his options too soon.

Human factors input is not important. People are so adaptive they learn to overlook the deficiencies of a system that is hard to use.

While I have heard this point argued many times, I should not have to belabor it with this audience. It is well known that compatible designs are more resistant to the errors induced by time stress or workload stress. It is well known that the most important contributor to safety is design that meets good human factors principles in the first place. It is true that people are adaptable and that, after experience with a system, they have great difficulty reporting on its shortcomings, but that does not mean that their efficiency and effectiveness are not reduced.

The education of a human factors specialist is not complete if he or she has not been exposed to the classic story of an ingenious experiment reportedly conducted at the Bell Telephone Laboratories during World War II.

The telephone company was concerned about ways to save copper, and one use of copper was in the cable connecting the telephone handset to the tabletop set. The experimental question was, "How long does a telephone cord need to be?" The investigators identified a series of test telephones around the laboratory. Each night, they went to those telephones and reduced the length of the line cord by one inch and replaced the telephone in its normal position on the desk. They then designated a special telephone operator to receive complaints about the telephones. Day by day, the line cords got shorter, and one by one, their users began to complain to the special operator. When the line cord had reached a given length, about half of the participants had complained, and this process continued until the line cord was only a few inches long. There remained one person who still had not complained. The investigators decided to check up on him. One of them visited his office while the second called him on the telephone. Sure enough, when the telephone rang, he leaned over his desk so that his ear could reach the handset, and he answered the phone in a very awkward manner indeed. When asked later if there was anything funny about his telephone, he said, "Oh, the line cord is a little short, but that doesn't concern me."

As I said, people are very adaptable, but that doesn't justify a poor design.

The handbooks never have recommendations for the conditions I need.

I think this statement is frequently true and can be very discouraging to the practicing designer. In other fields, this problem is solved by teaching theory and models that will predict the specific case of interest. In a few areas, we can do that too, but in many areas, we must be satisfied with concepts and principles and call on our experience and knowledge to understand how and when they apply. This criticism carries with it the implication that we must do more laboratory and field testing than is required in some other disciplines, and this brings us to the next two issues.

The study you propose will take six months – I need an answer tomorrow.

(Or Its Corollary)

The study you propose will cost $100,000 – the budget for my whole project is only $50,000.

There is never enough time or resources to solve a practical problem the way you think you ought to solve it. The best answer to this issue is to anticipate the problem and develop in-house expertise ahead of time. Particularly in the consumer product industry, the characteristics of the issues to be addressed do not change drastically from one model to another. It is practical to use the resources required to undertake a series of generic studies to address issues that it is clear will be continuing issues for a particular kind of product. Begin the work early that will have a payoff for the next design effort in that particular product line.

There is one other message here. There is a strong drive among human factors specialists, especially those who obtained their experimental design training in psychology, to insist on complete symmetric factorial designs. These are costly, time consuming, and grow to unmanageable size as the designer tries to add that one last interesting variable. Many times factorial designs are used as a substitute for careful thought and analysis of exactly what data are needed to solve the problem. It is the analysis that calls on all the specialist's knowledge and experience. The goal should be to obtain results of *practical* importance to design. In such cases, statistical significance, while important, will be a natural fallout. Sometimes you will only have the time and resources to do a crude experiment that aids your intuition and supports your background and experience. Sometimes you will have no opportunity to experiment at all. After you have screamed at management for giving you inadequate resources, and management continues to demand an answer, pause for a moment and ask yourself, "Would I rather have someone else making this decision?"

After I get this system working, then I'll look into human factors questions, if I have any time left.

This assertion is all too often offered. We are plagued with being left out, with getting in after the major decisions have been made, or being offered the role of pervade[?] of checklists and performancesign-offs. My own belief is that getting in early, we can have orders of magnitude influence on system performance. But when getting in late, our influence is reduced to percentage points. Getting in early depends on management, and that leads me to the next issue.

You have converted me, now can I convince my boss that human factors work is important?

In seeking an answer to this issue, think about the goals of human factors work.

1. *Improving the productivity and efficiency of performance*; any time you can reduce the time or increase the accuracy of performance, you have reduced manpower requirements and thereby costs.

2. *Reducing personnel selection and training requirements*; minimizing the selection criteria you must impose, and the training effort required for development of adequate personnel can be directly translated into dollar savings.

3. *Improving the safety of a product*; safety has large indirect payoffs in terms of reduced legal liability. The costs of exposure to personal liability cases involving negligence in design have become a real dollar cost to most major industrial organizations.

4. *Promoting consumer acceptance*; acceptance has become a major source of motivation for improved human factors in design.

More and more systems are being sold as complete packages, with application design as an integral part of the system itself. Under these conditions, the human factors aspects of the design become an integral part of its competitive advantages.

The toughest part of convincing management is to create a reputation when you are just beginning. If your group is relatively new and inexperienced, chances are you have been confronted with a number of possible problems on which to work. For your first efforts, my advice is to select among all the problems you are offered, not the most challenging or most interesting, but the one on which you think you can have the most impact with the smallest risk. Solve it, and then sit back and accumulate the credit. It doesn't take very long before potential customers are beating down your door with their problems.

So much for the ten potential embarrassments. I hope I have convinced you that you need not be defensive about them. In my view, we are currently in a phase where human factors work is receiving unprecedented acceptance. Military budgets for human resources research and development continue to rise. More organizations are initiating human factors programs. Professor Chapanis, at our annual council meeting, reported his first inquiry from a labor union in this country. Several Western European countries have introduced legislation mandating the use of ergonomic principles in the design of the workplace. One large industrial organization has reported to me that they believe their future lies in a corporate commitment to improved human factors design of their products. In the group with whom I am affiliated at the Social Security Administration, there has been a turnaround in the last 2 years from disinterested skepticism to an insistent demand for human factors results they can use.

In short, I have never been more enthusiastic about my profession and its potential for serving as one interface between technology and society. I hope you share my enthusiasm!

HUMAN FACTORS SUCCESS STORIES

Douglas H. Harris
Anacapa Sciences, Inc.

INTRODUCTION

As participants in the 28th Annual Meeting of the Human Factors Society, we are all concerned with the influence of human characteristics on engineering and design processes. We know that success in our endeavors depends on how well we understand human factors and how well we translate that understanding into the development of products, entertainment, systems, facilities, environments, organizations, and procedures.

We also know that success can take a variety of forms and can be attained to varying degrees depending on our objective, the way we measure our progress, and the stage of the development process that we address. These three dimensions of success – objectives, measures, and stages – provide the framework within which I will tell you some human factors success stories

OBJECTIVES AND MEASURES

Five major categories of human factors objectives are listed in the table[?] below. Two measures typically employed to assess results are also shown for each category objective.

Performance enhancement encompasses the greatest amount of human factors attention and diversity. Much of our effort is directed toward facilitating human performance through the way displays, procedures, and controls are designed and related to each other. One strategy is to improve the performance of a baseline system by increasing the speed and accuracy of human performance. Another strategy is to define human performance criteria and to design to meet them.

Resource conservation is often the objective of human factors effort when resources are limited or when resource reduction is desirable. For example, the objective might be to reduce aircrew workload so that missions can be completed successfully with a smaller crew. Another example is the design of vehicles so they can be satisfactorily maintained by persons with limited technical skills.

Acceptance is typically linked to one or more of the other four objectives, and is typically assessed means of user preferences and opinions. As users of products become more sophisticated and demanding, human factors become more important. Furthermore, adequate design from the point of view of operability may not be sufficient to gain user acceptance. The designer may be required also to address user perceptions of product attributes such as quality, value, and durability.

Cost reduction and corollary improvements in productivity provide a fertile area for human factors research and engineering. For example, the nuclear industry learned from Three Mile Island and other less publicized catastrophes that dealing with human factors by “common sense” alone was a costly mistake. A less dramatic but equally great potential for cost reduction is the cumulative impact of small reductions in the cost of operations. For example, a cost savings of $1 billion is only a four % reduction in the army’s $25 billion annual maintenance bill.

Promotion of human welfare is generally equated to safety and to the associated reduction of accidents, injuries, and disabilities. There can be little doubt about the great importance of this objective to individuals and groups within our society. But also included in this category are reductions in the frustrations and increases in the quality of life in our increasingly complex society. Comprehensible instructions, adequate feedback, comfortable body support, informative displays, and manageable controls all help.

STAGES OF SUCCESS

Since engineering is a process, the attainment of human factors objectives depends upon a progression of intermediate successes. In this sense, success can be attained to varying degrees as each of the five activities shown in the figure[?] below is satisfactorily completed. A major human factors success story is produced by successes at each stage and by the ultimate attainment of one or more of the human factors objectives discussed earlier.

User requirements drive the developmental process. Consequently, appropriate observations, interviews, and analyses must be completed to define and describe user needs, and to delineate the behavioral information that must be obtained and applied. Applicable behavioral information can be found in reports, journals, texts, handbooks, and computer files. When needed information is not available, it must be generated through experimentation, extrapolation, analysis, and expert judgment.

The transformation of behavioral information into design specifications continues to be more art than science. This is not necessarily bad since sufficient latitude should be allowed to nurture design creativity. Intermediate success at this point is defined by design features that satisfy user requirements and adhere to appropriate human factors principles. However, because it is not realistic to assume that we can get everything right the first time, provisions must be made for testing to identify needed modifications. Tests might consist of observations, simulations, experiments, failure analyses, and opinion measurements.

The final stage is implementation. This stage is critical because if the results of the developmental effort are not used, no matter how magnificent they might be, there is no human factors success story.

Success Stories

The following success stories were contributed by the Human Factors Society members listed[?] at the end of the paper. In each story, successes were achieved at each of the five stages of development and, in addition, one or more of the five human factors objectives was met. Of course, these successes were seldom achieved by human factors specialists alone. Most successes were team efforts in which human factors specialists made major contributions.

In compiling these stories there was no attempt to be exhaustive or representative. Since some interesting and important stories took place many years ago, there was also no attempt to be current. The stories serve only to illustrate the variety of contributions that our profession has been making to performance enhancement, resource conservation, acceptance, cost reduction, and human welfare.

Please note that the space limitations of the proceedings document precluded presenting here the many illustrations employed in the address.

Advanced aircraft flight deck design. A crew-centered approach was employed in designing the flight deck for the new Boeing 757 and 767 commercial aircraft. Design simplicity, equipment redundancy, and automated features were emphasized. Workload studies verified that these design efforts paid off in resource conservation, and that these aircraft could be safely operated with a crew of two rather than three pilots. Subsequent assessments of in-flight operational workload confirmed the validity of the earlier human factors analyses and simulations. Emphasis was also given to the design of color CRT displays for the flight deck. Louis D. Silverstein received the Society’s 1983 Alexander C. Williams Award for this contribution to the flight deck design.

Aircraft altimeter improvements. A new altimeter configuration was defined and developed for the Douglas DC-10 commercial aircraft, and for the new MD-80 aircraft. The altimeter has been one of the most error-producing displays in aircraft cockpits. The new snap-action, counter-pointer altimeter has substantially increased the accuracy of altitude readings.

Improved aerial refueling operators station. To initiate aircraft refueling, the boom operator on the aerial tanker “flies” the boom into the receiver aircraft’s receptacle. As a result of experimental studies of the side-stick controller, boom handling qualities, and visual envelope requirements, major improvements were achieved in KC-10 operator effectiveness over that of previous aircraft. In addition, workspace layout studies produced a more comfortable and convenient operator station.

Development of computer-generated maps. One of the greatest problems faced in military operations is that of maintaining geographic orientation. The greatest hope for solving this problem for pilots, tank commanders, and others is a world-wide digital map database and computer-generated maps. Human factors specialists have resolved many of the perceptual and cognitive issues in the display of maps from digital data. Furthermore, they have supported the development of a functioning digital map system. The adaptive display features of the system greatly aid the maintenance of geographic orientation during operations, facilitate tactical decision making, and provide for more effective mission planning.

Safe aircraft evacuation. Human factors played an important role in the design, testing, and certification of the slide-raft evacuation system for the Douglas DC-10 commercial aircraft. The effectiveness of this system has been demonstrated in several incidents and accidents. Particularly noteworthy was an incident at Los Angeles in which a fully loaded aircraft was forced to abort a take-off. The aircraft ran off the runway, sheared a landing gear, and caught on fire. All of the passengers, most of whom were elderly, evacuated safely.

Fire escape stockings. Human factors efforts in Switzerland and Japan have resulted in a safe and efficient way to escape from fires in buildings. The system consists of a woven fireproof stocking. If inside a building, the stocking is contained within a fire-brick tube. If outside, the stocking rolls down the outside of the building in the event of fire. To escape from fire, a person simply steps into the stocking and slides down to safety.

Textured paths for the blind. Human factors principles have been applied in Japan to facilitate the movement, with safety and confidence, of blind persons on streets and in subways. Textured paths are provided for guidance around obstacles and at crosswalks.

Industrial gas monitor improvements. Gas monitors are designed to assure maintenance workers that there is sufficient oxygen to breathe and that no explosive gases are present in an area. Existing monitors were found to have problems such as inadequate alarms, awkward packaging, obscure operating procedures, and inconvenient cable wrap. In addition, usage was inconsistent. Human factors analysis and engineering led to a new concept in gas monitor design, overcoming the various problems enumerated. The result was a product that served the user well in aesthetics, perception, communication, and operation. As a commercial product, the new gas monitor was highly successful.

An improved work vest for dredge operators. The safety work vests worn for dredge operations were found to interfere with work tasks, build up heat next to the body, and provide little utility when the wearer was not in the water. The vests were redesigned to overcome these deficiencies. Pads were reshaped to provide more arm space; ribs were added to the pads to aid air circulation, a second strap was added for safety, and a pocket was added for utility. Laboratory and field tests were very positive. The manufacturer has incorporated the human factors features into a new work vest for the dredge and offshore industry.

Component assembly reliability. The discovery of an error in the assembly of rack-and-panel connectors for a critical major system served as the starting point for two success stories. The first was the human factors fix that was made to assure that the error would not occur again. The second was the validation it provided for the Technique for Human Error Rate Predication (THERP) used in human reliability analysis. A sample of major systems was disassembled to check for any similar errors. The findings of this check compared well to what was predicted by THERP.

*Test equipment improvements***.** A difficult area for the application of human factors methods is in the procurement of test equipment. This equipment often consists of off-the-shelf, rack-and-stack assemblies put together with little concern for operability. An example is the thermal-vacuum chamber used for testing electronic subassemblies. The poor design of this equipment led to the overheating and scrapping of a very expensive assembly. Analyses found 79 design deficiencies in the display-control unit of the tester, with 12 considered to be major. Inadequate displays, ambiguous control, and other deficiencies were corrected in all units. In addition to the error-free performance that followed, a lesson was learned by company executives. One commented, “It was tragic that we had to burn up an expensive flight-qualified box before we could appreciate the value of human engineering.”

Fabrication of integrated circuits. Twenty years ago the process of making large-scale integrated circuits was transformed from the laboratory to the production line. Human factors specialists contributed significantly to enhancing production capabilities and yields. At an early stage, task analyses identified critical performance requirements. Then, new tools and procedures were designed to increase productivity. New wafer carries reduced handling errors by 80%. New handling tools reduced wafer damage and breakage by 68%. New alignment marks, based on minimum separable visual acuity, increased photomask alignment speed by 35% and accuracy by 66%.

Better control of oil-field services. The Treatment Monitor Vehicle (TMV) is a new concept for monitoring and controlling oil- and gas-well cementing and stimulation treatments. The TMV was designed from the inside out. Vehicle dimensions, workplace layout, operator-computer dialog, viewing rays, and external storage and hookup were all dictated by operator requirements. Thirteen vehicles are now in use throughout the United States and Canada, providing a major advance in the quality and technical application of these oil-field services. As a consequence, the company that has developed and now operates the TMV has increased its share of the market for the larger, more complex and profitable treatment jobs.

Cost-effective control-panel enhancement. Most operational power plant–control rooms were designed with little, if any, attention to human factors. Because they were hardwired to last for more than 40 years, the problem was how to enhance their operability without expensive changes. Study showed that dramatic improvements could be achieved by systematically reviewing the information needs of the operator and reshaping surfaces of existing panels to better reflect these needs. For example, functional grouping was delineated and labeled, control color coded, and off-normal conditions highlighted with color on displays. These approaches now serve current world-wide efforts to enhance operability of nuclear power plant–control rooms.

Development of an emergency response information system. To overcome the type of catastrophe that occurred at Three Mile Island, a system was developed to support the management of emergencies within a nuclear power plant. The system collected, stored, and processed plant parameter data, and generated displays for plant operators. Human factors design support and testing were an important part of system development. Human factors efforts focused on display content, off-normal detection provisions, display format and techniques display characteristics, illumination, signals, and accessibility of instruments and equipment. Field tests revealed that the emergency response information system was very useful during the management of emergencies, and most useful during major critical emergencies of the type faced at Three Mile Island.

Audio distribution system for 1984 Olympics. The IBM Audio Distribution System was designed and implemented by human factors people. Its design was based upon behavioral research. The system allows users to send messages to anybody in the world and[?] to receive messages from anybody in the world using push-button telephones as terminals. The system provides editing, filing, retrieval, distribution, and control functions. For the Olympics, the challenge was to adapt the system for 15,000 Olympians who had [no?] opportunity to be trained, who spoke many different languages, and who had little or no experience using computers.

*Maintenance performance system for the army***.** The army teaches soldiers some basic maintenance skills in school; however, the bulk of maintenance skill must be learned on the job. To enhance learning on the job, human factors specialists developed a computer-based maintenance performance system. The system maintains a skills profile for every mechanic in a battalion, establishes and monitors a certification program, measures the efficiency and quality of maintenance in the battalion, specifies training priorities, and provides information for maintenance improvements. During the past year the system has been used by three army battalions at Fort Carson, Colorado, with very favorable results. One battalion, which had received poor evaluations for maintenance prior to having the system, improved significantly after the system was installed. The battalion went on to be evaluated as the best in maintenance support of any unit completing field exercises at the National Training Center at Fort Irwin, California.

Versatile keyboard for the personal computer. The objective was to design a small keyboard that could be used easily for diverse functions (typing, numeric input, menu selection) for the various applications of the HP 150 personal computer. The objective was met by functional grouping of keys, color coding, enhancing contrast ratios of characters and symbols, and using a stepped sculptured shape to minimize finger travel and provide keyboard adjustability. Customer and sales feedback on the keyboard has been extremely favorable; the keyboard will become standard on all Hewlett-Packard computer products.

Display pager operability. A prototype display pager required 3,000 words of instruction to operate, and produced excessive operation errors and user frustration. A new display-control design was developed through the application of human factors principles. The resulting design required only 150 words of written instruction, and reduced errors and system failures significantly. Ultimately, the product achieved broad market success. The OPTRIX display pager was also selected by *Fortune* magazine as one of the 10 best products of 1980.

A more effective toothbrush. The commercial success of the REACH toothbrush can be traced directly to the thorough human factors work completed during its design. Features resulting from the painstaking human factors methodology include bi-level bristles, compact head, angled neck, and multigrip handle. Special versions of the toothbrush have now been developed for special segments of the population. The toothbrush is a clinical as well as commercial success. The REACH toothbrush was found consistently more effective in plaque removal compared with the standard-design brush. Also, the REACH toothbrush won a design award in the *23rd Annual Design Review*.

Development of the disc camera. The successful disc system of photographic products came from one of the most extensive new product development programs in the history of Eastman Kodak Company. Human factors efforts played a very important part in this program. Proceeding from the concept of photographic space – the lighting conditions and distances at which amateur photographers take pictures – disc photography was designed to accommodate this space and other user requirements as well. The result of numerous human factors efforts was a camera that provided expanded capability and increased user convenience. The payoff to the amateur photographer includes halving the number of unexposed pictures, reducing the number of blurred pictures, shrinking the number of blank frames by a factor of four, and increasing by 25% the number of pictures rated excellent.

Sports car seating comfort. Drivers of the 1984 Pontiac Fiero will experience a new generation of car seating. Human factors analyses led to improved lumbar and thigh support, greater adaptability, and a more comfortable seat configuration. These advances in body support and comfort, along with other improvements in interior accommodations, have contributed to the appeal of this new automobile.

Reduction of rear-end car crashes. Starting September 1, 1985, all new automobiles sold in this country will be required to have a center high-mounted lamp stop (CHMLS). This new ruling is expected to prevent about 500,000 rear-end crashes annually on the nation's highways, significantly reducing deaths and injuries and providing an estimated new dollar benefit of $196,000,000. According to a representative of the national Highway Traffic Safety Administration, this product of human factors work may be the most significant accident avoidance countermeasure ever produced. General Motors plans to incorporate this change in its 1985 model cars, 1 year before the deadline of compliance.

Increased on-the-road detection of drunk drivers. About 25,000 people are killed in this country each year by drunk drivers. In an attempt to enhance the enforcement of laws prohibiting driving while intoxicated (DWI), and to further the deterrence of drunk driving, a drunk-driver detection guide was developed for use by police officers. Human factors research identified and validated important visual cues. These were listed on a pocket-size plastic card along with associated DWI probability values and probability rules for multiple cues. A national field test conducted over a 15-month period involving 466 patrol officers showed that the guide increased the DWI arrest rate by 12%.

Investigative techniques for law enforcement. Law enforcement officers have traditionally been better at collecting information than analyzing it. Human factors specialists developed a logical framework for criminal investigations and designed a series of graphic procedures for integrating information collected during investigation. At the present time these techniques and procedures are employed by law-enforcement agencies throughout the United States, Canada, Australia, and Great Britain. During the past 12 years, more than 300 training courses have been conducted for investigators, analysts, attorneys, agents, security officers, and judges from over 1,000 agencies. Special training has been provided to the Federal Bureau of Investigation, Scotland Yard, Royal Canadian Mounted Police, Drug Enforcement

Administration, Customs Service, Department of Labor, and many other federal, state, county, and municipal agencies.

CONCLUSION

I hope you are as impressed as I am with the size, nature, and variety of the human factors contributions contained in this sample of success stories. As impressive as they are, however, these contributions represent just a token of what is possible in the future. The present momentum of our profession, if maintained, can benefit ourselves, our society, and the world in ways we have not as yet imagined.

DREAMS, DESIGN, AND DESTINY

Richard J. Hornick

Hughes Ground System Group

DREAMS

In 1985, an intrepid British sailor made his fourth attempt at a solo crossing of the Atlantic. According to a *Los Angeles Times* news item ("Sailor Is No Match," 1985), the 65-year-old man set out from Campbletown, Scotland, in a five-foot boat, the *Marmaduke Jinks IV*. Almost immediately, his outboard engine lost power. So he hoisted sail, but his boat drifted backward and he fell asleep. When he woke up, he didn't know where he was. He used an emergency hand flare and was rescued by the Coast Guard after having traveled four miles – the wrong way! As an aside, the article states that one of his previous attempts to cross the Atlantic was in 1984, when he set out from England in a barrel. When he boarded it, it capsized!

Who knows what the sailor's dreams consisted of. Does it matter, though whether he was motivated by a dream of innovation and accomplishment, or one of simple notoriety? In either event, he certainly did not surround himself with a high-technology system.

How universal it is for humans early in life to dream many marvelous things. Not only are our nocturnal dreams so often filled with hopes and happy times, but in those years our waking state is also replete with aspirations to be someone heroic, or courageous, inventive, artistic, of high stature and recognition, of great wealth, with great wisdom, or some combination thereof. Somewhere along the way, we also learn to strive for competitive goals – to be the fastest, the first, the most, the greatest, etc. And, generally, we wish our destinies to be fulfilled within the context of ever more sophisticated and comfortable support systems.

With humankind's gift for creativeness, many impressive dreams have been realized. Certainly these include rapid travel by jet aircraft; food processing and preparation; environmental control, such as air conditioning; medical advances; television; satellite communications; and so many others that we now take for granted. Could Columbus, on setting sail for the New World in three small vessels, ever have conceived of hydroplanes or surface-effect ships? Could the settlers of the western United States, who wagon-traveled at an average of four miles per day, picture a jet aircraft, carrying hundreds of persons above them, capable of flying those four miles in only 24 seconds? More wondrous, perhaps, has been our ability to harness the energy of the atom for power generation and to explore the universe in manned spacecraft. Our dreams, then, do result in marvelous destinies.

I was privileged to have two grandfathers who shared their dreams of technology with me. As we'd listen to a football game or boxing match on the radio, both stated with certainty that someday people would watch the images of such events in their homes. One of them even predicted that the units would not require an antenna or a power cord – that we'd be able to carry around portable units "without wires of any kind." You can imagine the incredulous looks they received from my "wiser" relatives!

Each also spoke of manned space flight as something they knew that my generation would see. Perhaps they had read the Apollo-predictive novel of Jules Verne. No matter, because those dreams were such that each believed that eventual design would offer a destiny that they might not witness, but that we would.

DREAMS TO NIGHTMARES

Unfortunately, it is true that our dreams contain elements of fear or predicted disaster. In the ancient myth of Icarus, did not his father, Daedalus, while desiring a successful flight for Icarus, fear the potential disaster of flying either too close to the sea or the sun? In dreaming of the potential benefits of a nuclear power technology, did we not have some misgivings about the strangely intriguing atom? In wishing to explore the universe, have we not, in our movies, expressed fears of the unknown and the hazards of technological limits? While crossing a high suspension bridge, have we had a momentary thought of collapse reminiscent of other bridge disasters?

It is my belief that when we learn of failures and disasters, we wonder about the causes and also think that if somehow we had been involved in the design or decision-making process, the tragedy would not have occurred. Why else would we express such indignation at an illogical management process, the faultiness of a design, the basis for a decision, or the paucity of protective measures or safety margins?

I submit that there are currently two prime causes for the events that turn design dreams into nightmares. One is attitudinal; the other is organizational.

Analyses of our failures often reveal an *attitude of complacency or indifference* that almost guarantees that human error will be introduced during concept definition, in analysis, in design, during production, in maintenance, in training, in operational manuals, during tests, and/or, ultimately, during operation. Probably most significantly damaging and dangerous is when such an attitude exists within high levels of management that presides over those processes prior to consumer use.

The second cause for design disasters, I believe, is that of *organization diffusion of responsibility*. Even where management has a positive attitude toward design excellence, the ultimate user or operator may suffer because each element of an organization assumed that proper procedures were being performed by some other organizational entity. I bow to the organization development and management experts among us, but I would guess that such diffusion of responsibility comes from the following factors.

1. *Size* where the sheer numbers of people would suggest to any one individual that “somebody must be doing it.”

2. *Top-heavy management structure* in which there are “too many chiefs and not enough Indians,” so that the job is not done in sufficient technical or scientific depth.

3. *Bureaucratic environment* wherein paperwork is pushed in order to meet milestones or other on-paper requirements, irrespective of quality.

Nightmares of recent vintage include, among so many others, the Three Mile Island accident, the Chernobyl disaster, the collapse of the Kansas City Hyatt-Regency Hotel walkways, the gas poisoning of thousands in Bhopal, the mid-air collision over Los Angeles, and the explosion of the Space Shuttle *Challenger*. Let’s review only a few of these to examine the attitudinal and organizational factors involved.

Hyatt-Regency Hotel

Table 1 summarizes the collapse of the Kansas City Hyatt-Regency walkways, the significant factors, and some of the known effects. Initially, the collapse was suspected to have been caused by too many people moving on the walkways in rhythm while listening to an orchestra below. In fact, however, there was a design mistake and a failure to analyze what seemed to be a minor change in a detail of the support design.

Table 1: Kansas City Hyatt-Regency Hotel Walkway Collapse, July 17, 1981

Event

Collapse of crowded walkways in lobby

Factors	*Effects*
Heavy walkway load	114 killed, 200 injured[placement of entries unclear]
Rhythmic motions of people	Emotional impact on survivors
Initial marginal design	Negative publicity/reputation

Failure to perform calculations	Cost of reconstruction
Failure to analyze design	Litigation for gross negligence in design and analyses
Failure to perform analyses	Over $3 billion in lawsuits filed
Requested by owner	Potential loss of engineering licenses

It was necessary to connect second-, third-, and fourth-floor levels across the lobby to enhance pedestrian flow. Plans called for suspending the walkways (like bridges, but from the ceiling), with the third level hanging independently and the second- and fourth-floor levels being suspended together. Suspension rods were to pass directly through I-beam supports with washers/bolts holding the second- and fourth-level beams (the rods presumably being strong enough to support the total load – but just barely, as later analysis revealed). Recognizing the challenge of threading the upper bolt to the fourth-level support, the design was changed to offset a lower support rod as shown in Figure 1[?]. The resulting change in load-bearing points went undetected. This was human error in design, and human failure to perform appropriate[?] was exacerbated by the fact that such analyses were not performed even when, after partial roof collapse during construction, the owner had asked for them.

Three Mile Island

Given the immense amount of data published in every kind of news and information medium, Table 2 is only a brief summary of that nuclear accident, which approached core meltdown. Both the President's Commission (Kemeny et al., 1979) and the Nuclear Regulatory Commission (NRC) Special Inquiry Group (Rogovin and Frampton, 1980) cited neglect of human factors engineering in most of the key technical problems contributing to the accident. Reading those accounts clearly reveals the technical flaws and the organizational diffusion of responsibility, and suggests an almost cavalier system-design attitude on the part of major elements in the nuclear power industry.

Table 2: Three Mile Island Accident, March 28, 1979

Event

Loss of coolant, turbine and reactor trip, radioactive coolant spill, serious core damage

Factors	*Effects*
Inadequate training	Partial core meltdown[placement of entries unclear]
Incorrect operator decisions	Loss of revenue
Confusing operator procedures	Public distrust
Poor information presentation	Generation of new regulations
Bad control-room design	Requirements for evacuation plans
Confusing alarm system	Recognition of regional dangers
Incorrect maintenance	Pressure for major reorganization
Mismanagement	Loss of orders for new reactors
Emphasis on continued power generation	Impact on closures of other plants
Bureaucratic functioning	
Diffusion of responsibility	
Minimal human factors at NRC	

A common attitude that existed was disregard for human factors through ignorance or intent. When seven members of the Human Factors Society (Charles Hopkins, Robert Makcie, Harold Price, Robert Simillie, Harry Snyder, Robert Sugarman, and I) served on the Society's contract to develop a long-range, comprehensive human factors plan for the NRC in 1981, too often did we hear the expression so indicative of that attitude – "it's just common sense." As you might well imagine, we had our favorite rejoinder of that vacuous expression. Some examples of design deficiencies that we found appear in Figures 2 through 6[?]. Indeed, if human factors design is merely "common sense" then these photographs would not exist. To most of us, such a travesty of quality design, is perhaps, not unfamiliar. But those are only a few examples. I have seen the word *pump* designated four different ways on the same control panel – PUMP, PP, PMP, and PU – even where there was adequate space available so as not to require abbreviation at all. Another panel contained the color red to signify three different states – emergency, warning/marginal, and normal/go!

Unfortunately, there is not much to suggest that this attitude has changed significantly, or that human factors within the NRC has a potent role, or that the nuclear industry is hungry for our participation. Some believe that the status of human factors is nearly as bad as it was before TMI. Perhaps so, or perhaps it is a bit better. However, one can conclude that the general nuclear power community is couching a cavalier attitude in the (false?) comfort of risk-assessment statistics.

Chernobyl, USSR

By any standard, the most catastrophic nuclear power plant accident is that summarized in Table 3. Less has been published formally in the United States about the intimate causes of the disaster, though much has been presented in newspaper accounts as well as at the International Atomic Energy Agency meeting held in Vienna in August 1986 (American Nuclear Society, 1986).

Table 3: Chernobyl Disaster, April 26, 1986

Events

Fire, rupture of containment, explosion, massive release of radioactive elements, massive evacuation, serious core meltdown

Factors	*Effects*
Breaches of discipline	Approximately 30 near-term deaths[placement of entries OK?]
Violation of operational procedures	Estimates of 5,000 to 45,000 deaths over the next 70 years
Unauthorized experiments	
Inadequate management/supervision	Direct economic loss of $2.7 billion
Improper safety measures	Water table and farmland contamination
Operator errors	Installation of new automatic shutdown systems in all plants
Control difficulty	
Design errors and lack of foreseeable use	Recognition of worldwide effects
Bureaucratic environment	International notification agreements
Diffusion of responsibility (?)	Firings/criminal charges against bureau officials

It is rather interesting that a *Los Angeles Times* review of Soviet newspapers and periodicals published in the last several years *prior* to Chernobyl identified many instances that resulted in criticism of the lack of quality control, shortcomings in reactor construction, routine violations of safety regulations, and " . . . crude violations committed by leaders of certain ministries, departments and their subordinate organizations in planning, building, and operation production" (Stein, 1986). Apparently, a less than fully responsible attitude existed in some parts of the Soviet nuclear power community. Perhaps Kremlin pressure to hasten reactor construction as a response to the oil shortages in the early 1980's led to such attitudes. Certainly, there was diffusion of organizational responsibility and communication at the time of the Chernobyl accident.

***Space Shuttle* Challenger**

I believe that no report has been as critical of management carelessness, bureaucratic interactions, disregard for safety, and flaws in the decision-making process as that of the Presidential Commission on the *Challenger* explosion (U.S. Government, 1986). Table 4 presents the commission's major points.

Table 4: Space Shuttle *Challenger* Disaster, January 23, 1986

Event

Launch of vehicle in cold weather with reused booster elements, leak in solid booster, sudden explosion 73 seconds into flight, loss of life

Factors	*Effects*
Serious flaws in decision-making process	Loss of life to seven astronauts[placement of entries unclear]

Loss of credibility in space program	Emotional trauma to key personnel
Waving launch constraints at expense of flight safety	
Lack of external communication of problems	Major NASA policy shifts at Marshall Space Flight Center
	Delay in further launches
Pressure on Thiokol to reverse “hold” recommendation	Redesign of booster seals
	Litigation
Response of Thiokol to please NASA	
Ignoring design problems in “O” ring	
Poor maintenance procedures	
Disdain of technical inputs	
Complacent attitude	
“Silent Safety Program”	
Distilled safety responsibility	

One item bears elaboration – the “Silent Safety Program” – a chapter so titled in the report. It was determined that the chief engineer at NASA headquarters had overall responsibility for safety, reliability, and quality assurance and had a staff of 20 people, only two of whom spent 10% and 25%, respectively, of their time in these areas. Further, the safety programs at the Johnson, Marshall, and Kennedy Space Flight Centers were judged to be in ineffective authority/responsibility organizational positions, with lack of independence in the management structure. Lastly, the critical teleconference calls between Marshall and Thiokol did not include a single safety, reliability, or quality-assurance engineer.

Obviously, upper management has pointed lessons to learn with respect to the nightmares that can result from complacency about human safety, design limits, and organizational location of responsibility.

DREAMS AND MIND-SETS

Henry Petroski’s book, *To Engineer Is Human* (1985), should be required reading for any of us. Beyond giving examples of specific design failures and disasters, he presents a mind-set possessed by too many in the engineering community. Table 5 is a list of thematic statements from his book.

Does this list properly portray Pertorski’s innermost philosophy? It is hard to tell, for he does not *advocate* overly extravagant design departures in lieu of departures based on some combination of (bad) experiences and established successes. Indeed, he acknowledges the tragic cost of mistakes, the value of (post facto) failure analyses, the need for including many elements in trade-off studies, and the consequences of over-reliance on computer-based design decisions and the accuracy of their databases.

Nonetheless, I can’t help but believe that subscribing to that body of tenets can only lead to an attitude that is cavalier and/or an organizational philosophy leading to diffusion of the responsibility for human factors and system safety. While it is true that they often disregard, treat with disdain, underfund, or otherwise denigrate certain design-support disciplines (such as our own) in favor of flair, style, competitive schedule, political expediency, and other driving factors – real or imagined.

Each of Petroski’s statements may seem innocuous by itself. They seem almost to be truisms. Even so, each statement can and should be countered.

In childhood, falling down may be part of growing up. But do we need the falls of hundreds of “London Bridges,” Tacoma Narrows bridges, and Hyatt walkways? Do we need DC-10’s to plummet, commercial and private aircraft to collide and devastate a neighborhood, nuclear plants to release radioactive fallout, and other such falls to wake us to the critical importance of human factors in design, analysis, production, installation, maintenance, training, and operation of our products?

If failure teaches us more than does success, should not the failures be anticipated in *preliminary* (rather than post facto) hazard analyses, and then more safely assessed during test and evaluation *before* release to the market?

Is it really true that design engineers are unable to take into account the human equation for their system calculations? Much of our human factors data is soundly empirical and quantifiable. How often are those data used? Are not design engineers often urged and rewarded by program managers to get on with the design and to minimize costs?

However, isn't it also true that some human factors practitioners are not persistent enough to change that course? When we have a supportive management, it is our even greater obligation to identify, document, and recommend effective changes based on established criteria. I believe that we have sometimes failed to do that . . . and that is *our* fault.

WAKING UP

What happens when our design dreams take on the destiny of tragedy? Our courts of law are filled with liability litigation for faulty product and workplace designs that have injured or killed users or bystanders. Some have argued that the number of cases is distorted; that causes are too minor for such pursuit; that awards, especially punitive ones, are excessive. Though we may be aware of some cases that seem to be without much foundation, I disagree strongly that such cases are rampant.

TABLE 5

Theses from Petroski's *To Engineer Is Human*

- Human desire for innovation leads to greater likelihood of failure.
- Humans are fallible and so must be their creations.
- Falling down is part of growing up.
- Failure often teaches us more than does success.
- Each new design should be considered as a structural hypothesis.
- We must accept risk as the cost of life's pleasures—and we have no choice in that.
- Absolute certainty about fail-proof can never be achieved.
- We cannot learn enough from successes to go beyond the state of the art.
- Design engineers cannot factor the unknown human element into calculations.
- People are not expected to "push" themselves, so machines or structures should not be expected to be "pushed" or overloaded.
- Failure leads to conservatism and new successes.
- While there is no excuse for faulty design, there should be room for understanding.
- Endangering life "is bad for business."

If there is more such litigation than previously, I believe that to be a result of several factors – a heightened sense of social consciousness about personal safety, a more complex technology rapidly evolving with uneven regard for standards, a more sophisticated legal system for seeking redress, and a more informed populace that is angered by stupidity or carelessness in design or by authority not exercised with responsibility.

The resurgence of penalty litigation may well be only a reawakening of our collective social sense of justice. Several thousand years ago, the concern of the Babylonians for safety was reflected in legal prescriptions in what became known as the Code of Hummurabi. In the code are provisions for such penalties as paraphrased in Table 6. So humankind has long desired proper design and imposed rather severe penalties on those judged to be at fault in not meeting requirements.

It is not surprising, then, that the human factors specialist is increasingly involved in forensic matters. The legal profession has only relatively recently become aware of the value of expert-witness testimony by human factors practitioners. If we accept the premise, as I think we do, that there is a human involved in almost every accident, then it is clear that we have much to contribute. The matters to which we can testify rest heavily on such familiar areas of human behavior as perception, reaction during stress, influence of environmental factors, job aids, procedures, skills, anthropometrics, and all of the other topics that compose typical human factors texts.

REVERIE

I don't know completely how many parallels there were between Three Mile Island and Chernobyl (as well as with the *Challenger*), though there seem to be plenty suggested by such terms as *human error, poor workmanship, faulty design, poor decision making,* and *mismanagement*. In looking over my notes, reports, and articles regarding TMI, I was struck by the remarkable similarity of the immediate lack of accurate information surrounding the two nuclear accidents. After Chernobyl, there was a popular outcry of indignation that the Soviets withheld information for 2 or 3 days following the accident. Reading accounts of Chernobyl may make that somewhat understandable in light of TMI if one considers the remoteness of the site, lack of direct communication with the Kremlin, and the self-serving actions of plant management in providing little information to the bureaucratic authorities.

TABLE 6

Babylonian Code of Hammurabi (Paraphrased)

- Build a wall, and if it collapses, you will rebuild the wall at your own expense and materials
- Build a structure, and if it collapses, you will rebuild the structure at your own expense and materials
- Build a structure, and if it collapses and kills its owner's son or slave, your son or slave shall die
- Build a structure, and if it collapses and kills its owner, you shall die

The Presidential Commission Report on TMI also cites lack of knowledge, inaccuracy of utility representatives, discord and disagreement within the NRC, and lack of information for a similar amount of time to that in the Soviet Union – *four* days. In its preface, the Commission Report states, "During the next 4 days, the extent and gravity of the accident was unclear to the managers of the plant, to federal and state officials, and to the general public." How soon we forget our own faults when we see egg on the other fellow's face.

There really should be no satisfaction in gloating about the other party's misfortune. When TMI occurred, regional concern for nuclear safety became elevated to a national concern. Chernobyl had forced nationalistic concerns to become international ones. Indeed, we are a world community, and the responsibility for public safety, for astronaut safety, for excellence in product design, is every individual designer's or the government's.

Penalties for agency mismanagement are increasingly severe, as seen in NASA's organizational shake-up and in the management of nuclear energy in the Soviet Union; penalties for companies that produce faulty products are being exacted in the courts; and individual professionals who are party to unsafe products, procedures, inspections, and maintenance are increasingly open to judgments and loss of licenses.

As a profession assisting the design process through analysis, research, application, and evaluation, we have not only an opportunity but also an obligation to be involved early in design, to refuse to sign off on specifications that do not meet criteria, to stay entrenched in the decision-making process, to conduct research to exacting standards, to teach and inspire students not only with knowledge but also with ethical principles, and to be willing to testify with integrity in litigation where our expertise matters.

Fortunately, the Human Factors Society has many infrastructures for providing mechanisms and support to individual members in accomplishing these objectives. Our many committees and technical groups can provide a platform and resources that include, among many others, organizational design and management, environmental design, industrial ergonomics, safety, training, system development, consumer products, forensics, professional standards, education, certification, ethics, and technical standards. Each of us has an avenue in this Society to reaffirm and to recommit to these ideals.

I urge that we in the human factors profession maintain such behavior. If we do so, then we can be confident that we have rejected a resigned attitude about risk and failure and moved instead to the positive position of making humankind's dreams become realized in exciting destiny.

ACKNOWLEDGMENTS

I express sincere gratitude to O. Keith Hansen and Michael Lyon for their constructive comments during the writing of this address. My thanks are also extended to my many colleagues who have stimulated conversations about these matters.

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AUTOMATION

Thomas B. Sheridan
Massachusetts Institute for Technology

Broadly considered, automation includes all those things computers and machines can do to perform tasks for people faster, more accurately, and more efficiently (in terms of time, resources, and human labor) than if they were done directly by people.

Having started more or less in the 1940s and gotten a boost from inexpensive computers in the 60s and 70s, automation itself is now in a stage of awkward adolescence. The childhood, full of promise and user tolerance, is over. In fact there has been much disappointment, as much that was promised (e.g., versatile industrial robotics for manufacturing, artificial intelligence for medical diagnosis and language translation) has not materialized. Yet there have been and will be steady gains. Now automation in the factory, process plant, aircraft, hospital, and marketplace are common, while automation in the home and automobile is just making its entry.

Gradually it is being realized that *automation has not replaced people and never will*, and that to regard automation and human intelligence as mutually exclusive (e.g., astronauts vs. robots in space) is silly, that some *combination* of humans and automatic machines working together is better than either by itself. This usually means the human complements the machine, the human acting as supervisor. Supervision breaks down into the functions: (1) planning, (2) programming, (3) monitoring of the automation, (4) diagnosing of problems if and when they occur, (5) intervening if necessary, and (6) learning from experience. Given this functional breakdown, it is still difficult to understand the proper human role in each different context.

It is now clear that *there is no single model or supervisory control of automation*, but a whole host of applicable models which apply to the six supervisory functions listed above, and typically include all of the traditional psychological categories of attention, perception, cognitive modeling, memory, workload, communication, decision, valuation, control, and learning. Modeling the human operator's relation to automation is not unlike modeling "management" – it seems not to make sense to expect a single model at this level of system generality. Yet I do believe human factors professionals will be more and more concerned with developing and using models of the supervision components.

I would call particular attention to three human factors activities which I feel will be more and more in demand, not only with automation, but also with other aspects of technology application in relation to human users, operators, clients, patients, customers (in the home, health care, education, transportation, business and commerce, industry, government, national security). These are:

1. Inferring people's mental models. This has been much talked about, but the art is still very primitive. Some might say it really can't be done. In any case, as perceptual-motor skills become less important and cognitive activities of the supervisory functions become more important, we must find practical ways to do this.

2. Measurement of costs and benefits not only in dollars but also in terms of individual values (relative worth, utility, "satisficing"). Promising new computer-interactive techniques are becoming available to do this. In the past, human factors professionals have been handed performance criteria, or they were obvious. Now they will have to be inferred in situ. Human factors professionals will also have to consider cultural norms to a greater extent than has been the practice.

3. Monitoring what people actually do throughout their whole day (as contrasted to what they say they do, or say they like, in a confined workplace). Human factors will have to look more and more at larger slices of life, as work and living become more intermixed. This monitoring will have to be done in ways that maintain anonymity or otherwise are ethically defensible.

Human supervision of automation is planning the automatic operation, programming the computer, monitoring of the automatic operation, diagnosing problems if and when they occur – intervening if necessary – and learning from experience.

Three new activities for HF professionals are inferring people's mental models, measuring costs and benefits not only in dollars but also in terms of individual values (relative worth or utility, "satisficing", cultural norms), and monitoring what people actually do throughout their whole day (as contrasted to what they say they do, or say they like, in a confined workplace)[identical wording above—OK?].

Alienation is physical and temporal separation from a task, threatened or actual unemployment, erratic mental workload, centralization of management control and loss of worker control, desocialization, deskilling, intimidation of the computer's power, user's technological illiteracy, user mystification and misplaced trust, user sense of not being productive, diffusion and abandonment of responsibility, and user's sense of enslavement.

To have trust in the machine is to have reliability, robustness, familiarity, understandability, explication of intention, usefulness, and user dependence

Automation must be limited based on user education, user expectations, user creativity, and user responsibility.

EVERYBODY KNOWS – OR DO THEY?

Kenneth R. Laughery, Sr.
Rice University

Presidential addresses, like presidents, seem to come in a variety of sizes and shapes. As I reviewed the addresses of some of my distinguished predecessors, I noted they included presentations of research, analyses of the current state of some substantive area of work, analyses of the discipline, including our own society, and sprinklings of predictions and exhortations about the future.

As I thought about an appropriate topic or subject matter for my address, two general self-observations emerged immediately. First, I decided, or realized, that I am not good at predicting the future. My crystal ball has always been hazy, the lines in my palms seem silent, and I make my tea with tea bags not tea leaves. So, except for a few comments about opportunities for human factors specialists and ergonomists near the end of my talk, I will leave futuristic prognostications to others more talented than I. The second self-observation in considering an appropriate topic was, of course, the kinds of subjects about which I knew enough about to put together an address. This consideration immediately led to a substantial reduction in the alternatives.

So, today I am going to talk about a problem that I believe exists in our American society. It is a safety problem; that is, it concerns reasons, or causes, as to why accidents occur, property gets damaged, and people get hurt. It might be labeled the "Everybody Knows Problem." My plan is to define or describe the problem, to give you some examples of circumstances or situations in which it exists, to share some thoughts about why it exists, and then to talk about where human factors/ergonomics specialists fit with regard to addressing it, or putting it another way, what are some opportunities and/or responsibilities that it creates for people like us.

The "everybody knows" problem is essentially this: Engineers, architects, and designers of other stripes often design products and environments that have associated safety problems – hazards. The safe use of these products requires some knowledge or information on the part of users, which the users – at least some of them – may not or do not have. The design process frequently includes little or no attention to the knowledge requirements of users and/or the knowledge states of users. Worse still, where knowledge requirements are addressed, inappropriate assumptions are often made as to what people know or what they will do, and seldom is any effort made to assess whether or not such assumptions are valid.

The "everybody knows" problem is part of a general class of safety problem that has been around for a long time. Susan Hadden, in her book *Read the Label* (1986), noted that for centuries the implicit doctrine governing consumer products was caveat emptor, or "let the buyer beware."

This doctrine assumed that consumers would use their intelligence and experience to protect themselves. Certainly we have witnessed some changes in such attitudes in recent decades, and we have seen an increase in concern for consumer safety here in the United States. But the problem has not gone away; indeed, it is very much with us.

The "everybody knows" problem also has a sister (or brother) problem with which human factors and ergonomics specialists are familiar. It goes under the rubric "common sense." Most of us have probably had the experience of listening to a physical scientist, an engineer, a wife, a husband, or a friend say: "Isn't human factors just common sense?" There is an excellent treatment of this issue in Chapanis's classic book *Research Techniques in Human Engineering* (1959), where he says: "Common sense is too shifty a standard upon which to base design decisions. A science of human engineering built on common sense is like a house built on quicksand." The point is that commonsense ideas not only change, they are often wrong.

There is a parallel between the "everybody knows" problem as it relates to safety and the kinds of problems Donald Norman addressed in his excellent book, *The Psychology of Everyday Things* (1988). Norman drew on numerous examples of common things in our everyday lives that were designed in ways that did not adequately consider characteristics, limitations, and knowledge of users. A major focus of his analyses was the way in which performance and utility are affected by the mismatches between things and the people who use them.

Another related issue is that we seem to have a predisposition in our culture to believe that when an accident occurs, it is because someone screwed up, usually the person who was injured. Those who have worked in industrial safety are familiar with Heinrich's (1941) work in the 1930s proclaiming that 85% of industrial accidents are caused by human error. That work had enormous effects on thinking about industrial safety. What has struck me is how pervasive this way of thinking about accidents and injuries is. It extends to almost every kind of product or situation in our everyday lives.

I've come to the conclusion that the "everybody knows" problem represents one of the most important safety issues we face. This conclusion is based partly on the statistics: Currently about 21,600 product-related deaths and 28.5 million product-related injuries occur each year. But it is also based on discovering that the problem seems to show up in a wide variety of products.

EXAMPLES

My examples of the "everybody knows" problem represent an attempt to show some variety in the nature and extent of the problem.

BabyCushion

A product first appeared in the marketplace in the early or mid-1980s which I will refer to as a baby cushion, though different manufacturers (about 10 in all) had different names for it. These cushions tended to be soft, fluffy, about 2 feet long, 1 foot wide, and 4 or 5 inches thick. The baby was placed on the cushion on its stomach with its head to the side to sleep. The hazard here is that the baby would get its face down in the pillow and suffocate. Dozens of infant deaths over a couple of years ultimately led the Consumer Product Safety Commission to ban such products, based in part on a thorough human factors analysis by Shelly Deppa (CPSC internal memorandum, 1990).

What did users of this type of product – usually parents of infants – know and not know about this hazard? Some data collected on this issue indicated that perhaps more than half of them did not perceive suffocation to be a hazard associated with placing the baby on its stomach on the cushion. Why don't people perceive this hazard? There are some interesting dimensions to the perception and knowledge problem. Here are a few relevant observations:

- In the United States it is common practice to place a baby on its stomach to sleep.

- Crib mattresses are more solid than the cushions and do not present a suffocation hazard.

- Babies tend to cause an indentation in their pillow when they turn and wiggle their heads. Concentrations of carbon dioxide tend to build up in the indentation, causing the baby to breathe faster and harder, exacerbating the problem.

- When the infant's face presses on the pillow, soft cartilage in its nose limits airflow.

- More than a third of infants up to three months old are not mouth breathers. That is, if the nasal passage becomes blocked, they do not begin breathing through the mouth.

How many young parents in their 20s would you guess have the knowledge to understand the suffocation hazard associated with the cushion? Some data collected in the Rice University Human Factors Laboratory on this matter indicate that many do not.

Tire-Rim Size Mismatches and Explosions

In the mid-1960s manufacturers introduced a 16.5-inch tire and rim combination for light trucks. Prior to that time the common size was 16 inches, and the 16-inch size has continued to be marketed. Since the 1960s, there has been a history of accidents, often including injury or death, in which a 16-inch tire was inadvertently mounted on a 16.5-inch tire rim.

During efforts to inflate the tire after it has been placed on the wrong-sized rim, the tire will not properly seat on the rim, the beads in the tire fail, and the tire ruptures with explosive force. Perhaps a few thousand such accidents have occurred, and there is no evidence that on even one occasion the person knew he or she was dealing with a size mismatch.

An analysis of the products and some survey research on what vehicle owner and tire changer know about the problem revealed the following:

- The outer flange diameter of the 16- and 16.5-inch rims are the same. If examined from the side, the two rims look, and are, alike.

- Size markings and codes on the rims are frequently difficult to determine.

- Because of the like flange diameters, the 16-inch tire will go onto the 16.5-inch rim with the same level of ease or difficulty that it goes onto a 16-inch rim. Thus, when that part of the task is being carried out, the tire changer is receiving information that the mounting task is proceeding correctly.

- Most people who work as tire changers – and certainly most of those who may be changing their own tire – do not know about the mismatch problem and hazard.

Hair Dryers and Bathtub Electrocutions

Many people are aware that operating an electrical appliance, such as a hair dryer, around water is dangerous. But these same people may not understand that the hair dryer, when turned off but still plugged in, poses a life-threatening hazard.

Automatic Shoulder Belts in Automobiles, Lap Belt not Fastened

Research at the Highway Safety Research Center of the University of North Carolina (Reinfurt, St. Cyr, and Hunter, 1990) indicates that lap belts are fastened only 29% of the time when there are motorized, automatic shoulder belts. One finding of the study was that many drivers incorrectly perceive that they are fully protected because the shoulder portion of the restraint automatically moves into place. Like the 16-inch tire going on the 16.5-inch rime, here is an example of a characteristic or property of the product leading to a *false perception of safety*.

Over-the-Counter Medications: Side Effects and Contraindications

Some medications have side effects, such as drowsiness, that can be hazardous when performing tasks such as driving. Others may have important contraindications – that is, they should not be taken if some other condition exists. People tend to underestimate such hazards because the medications are not prescriptive.

REASONS PEOPLE DO NOT KNOW

Why don't people know about the hazards associated with common products such as those just described? Below are some possible explanations for why people do not perceive a product as hazardous and why they often do not think about hazards at the proper times.

The Hazard Is Hidden

In the law there is a concept of an open and obvious hazard. In essence, this concept refers to the notion that the design or function of a product itself communicates the hazard. A sharp knife blade that can cut, or function of a product itself, communicates the hazard. A sharp knife blade that can cut or the possibility of a fall from a high place are examples of open and obvious hazards. But a great many hazards do not fall into this category, and they can be characterized as hidden. Several of the product hazards cited earlier fit this category.

New Technology

Recent decades have witnessed the development of new technology at an ever-increasing pace. These developments show up not only in electronic products but in products influenced by advances in chemistry and biology. Pesticides, herbicides, insecticides, cleaning agents, and solvents are some examples. Many such products have ingestion, inhalation, and skin contact hazards that are not generally known or appreciated by many people.

Misleading Information

In using the term *misleading,* I am not referring to the notion that people are intentionally misled, for example, by false information on a label. Such circumstances may occur, but I have in mind a somewhat different kind of situation: something about a product that indicates it is safe when in fact it is not. Putting a 16-inch tire on a 16.5-inch rim fits in the category of misleading information for two reasons: the 16- and 16.5-inch rims look almost exactly alike, and the fact that the tire goes on the 16.5-inch rim as if it belonged there is telling the person changing the tire that everything is OK. The perception that the automatic shoulder belt in our cars means we are safe is another example.

Accidents Are Rare Events

We are frequently exposed to accident statistics, but the fact is that for most individuals, an accident accompanied buy an injury is a rare event. This point has at least two implications. First, the fact that accidents are rare provides little opportunity to learn more about their causes. Second, people are less likely to attend to or ask questions about safety issues.

Bad Mental Models

Norman (1988) addressed the problems of inappropriate mental models. If the user's model of the product of environment – what it is and how it functions – is inappropriate or wrong, hazards and risks may fail to be perceived or understood.

THE DESIGNER'S PERSPECTIVE

What about the people who design and market consumer products? Why do they not adequately address these issues of consumer hazard perception and knowledge?

The concern is certainly not new. For nearly half a century, members of the human factors discipline have been advocating, pushing, hustling, and preaching that the person component must be addressed more seriously in the design of systems involving people. We have made some significant progress along these lines, but we still have a long way to go.

History

Because people are so adaptive and because, until the past several decades, systems have been relatively simple, we got by without giving the people component the attention it deserved. So, from a historical perspective, designers have had to learn – and many still have to learn – to think this way.

Cognitive Characteristics and Limitations

I recently examined a book by Gloss and Wardle titled *Introduction to Safety Engineering* (1984). The book devoted approximately 11 pages to the topic of ergonomics; actually, these pages consisted of four brief sections on the topic scattered across chapters. Nowhere was there any mention of hazard or risk perception or knowledge – or, for that matter, anything that resembled them. This is symptomatic of a characteristic of designers – especially hardware engineers – that they do not think about such properties of people. Engineers are accustomed to thinking about sizes, shapes, and strengths of things, or how fast they move, but not about their users' cognitive properties (that is, how they perceive and what they know). Further, it seems clear that where such issues *are* addressed, there is a lack of understanding about the limits of people's perceptions and knowledge regarding safety issues associated with products. Assumptions are being made about knowledge and patterns of behavior that the literature on risk perception and accidents would indicate are not warranted. It is not a case of "everybody knows" but, rather, a case of "not everybody knows."

I am not suggesting that such people do not care about the safety of their products and the people who use them. Safety may occasionally bite the dust in the context of cost-benefit analysis, or the line on this trade-off may be drawn at a point that violates our own taste. My concern focuses on the fact that the design is not adequately considering the hazard and risk perceptions and knowledge of people.

WHAT ERGONOMISTS CAN DO

There are no easy formulas or strategies for successfully getting more human factors and ergonomics into the design process. There are at least two dimensions of the problem. First, designers must become more aware of the need to take into account human hazard and risk perceptions and knowledge when designing products. Second, we need to help provide the kind of data, information, and methodologies that will help the design process along.

In the task of increasing designer awareness, we may have some very powerful allies. The first is the government; more specifically, government regulations regarding product and environment safety. Clearly, agencies such as the Occupational Safety and Health Administration, the Food and Drug Administration, and the Consumer Product Safety Commission have brought about changes in the attention given to product and work environment safety among industries and product manufacturers. One can debate the effectiveness of these and other agencies, and one can lament – at least speaking for myself – the gutting such agencies suffered during the Reagan/Bush years, but it seems clear that they have had some "attentional impact." It also seems to me that these changes have created some opportunities for human factors people to influence the design process regarding safety.

The second ally is litigation. In the United States the litigation process is viewed with varying degrees of support, puzzlement, apprehension, and even distaste. But one conclusion about it seems valid: When it comes to attention to product and environment safety, litigation has had some effect. In the opening chapter of *Handbook of Human Factors*, Julien Christensen wrote:

> *Those who have devoted their professional careers to the human factors/ergonomics movement watch with wonder and awe as the legal profession does through the courts what they have been unable to do*. (1987, p. 6)

Granted, these effects may include a lot more jobs for lawyers in industry. But they may also be creating a climate in which people like us can make some inputs.

Certainly it is possible to make a list of actions we might take and programs we might initiate to influence product design regarding peoples' hazard perceptions and knowledge. Such actions could be educational, including greater efforts to incorporate such information into educational curricula, short courses, and seminars marketed to designers with a need to know, and publications in places where they are likely to be read by designers.

We also have a responsibility to then provide the kind of support that will enable designers to be effective in their efforts. We need to provide guidelines and answers, and generally that means research, both basic and applied. There is a growing body of basic and applied research findings on risk perception that bears on the problem, but there is more to be done. People in the human factors profession are qualified to contribute at both the basic and applied levels of research.

In addition to research, human factors and ergonomics professionals need to be more involved in field testing and marketing testing of products. Manufacturers almost never attempt to assess the target audience's knowledge regarding the use of a product; nor do they assess the effectiveness of their own communication vehicles in terms of educating the user regarding product hazards and risks.

SAFETY PHILOSOPHY

There is a standard approach to dealing with hazards, be they product or environmental hazards that can be found in many published works on safety. It says: first try to design it out. If you cannot, guard; if you cannot, warn. This "design it out/guard/warn" prioritization is most consistent with human factors and ergonomics design philosophies. It has to do with designing things in ways that forgive human limitations and human errors.

I am not suggesting that users' possession of hazard and risk knowledge – either through past experience or through communication – is always the answer. There are potential problems of attention, distraction, and task overload to challenge such solutions. In the design process we need to do our best to determine what safety knowledge requirements exist for the user and whether those requirements are met through the a priori experiences of the user or through safety communications to the user.

These are the kinds of issues that are near and dear to the hearts, guts, and minds of those in the human factors and ergonomics discipline. The growing awareness of and concern for consumer safety is, in my view, providing us both an opportunity and a responsibility. It is a chance to make significant contributions to the safety and well-being of those not always perceptive, not always knowledgeable, but always valued system components that we know as human beings.

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THE ERGONOMICS OF ECONOMICS IS THE ECONOMICS OF ERGONOMICS

H. W. Hendrick
University of Southern California

INTRODUCTION

One of the clearest ways to delineate a discipline is by its unique technology. At its recent workshop, the HFES Strategic Planning Committee noted, as have others internationally, that the technology of human factors/ergonomics is *human-system interface technology*. Thus, the discipline of human factors can be defined as the *development and application of human-system interface technology*. Human-system interface technology deals with the interfaces between humans and the other system components, including hardware, software, environments, jobs, and organizational structures and processes. Like the technology of other design-related disciplines, it includes specifications, guidelines, methods, and tools. As noted by the Strategic Planning Committee, we use our discipline's technology for improving the *quality of life*, including health, safety, comfort, usability, and productivity. As a *science* we study human capabilities, limitations, and other characteristics for the purpose of developing human-system interface technology. As a *practice*, we apply human-system interface technology to the analysis, design, evaluation, standardization, and control of systems. It is this technology that clearly defines us as a unique, stand-alone discipline; that identifies who we are, what we do, and what we offer for the betterment of society.

Although they may come from a variety of professional backgrounds, such as psychology, engineering, safety, the rehabilitation professions, or medicine, it is their professional education and training in human-system interface technology that qualifies persons as human factors/ergonomics professionals. Indeed, the discipline needs both the breadth and richness of these professional backgrounds as well as the education and training in the unique technology of human factors/ergonomics.

Human factors/ergonomics professionals have long recognized the tremendous potential of our discipline for improving the health, safety, and comfort of persons, and both human and system productivity. Indeed, through the application of our unique human-system interface technology, we have the *potential* to truly make a difference in the quality of life for virtually all persons on this globe. In fact, I know of no profession where so small a group of professionals has such a tremendous potential for truly *making a difference.*

In light of our potential, why is it, then, that more organizations, with their strong need to obtain employee commitment, reduce expenses, and increase productivity, are not banging down our doors for help, or creating human factors/ergonomics positions far beyond our capacity to fill them? Why is it that federal and state agencies are not pushing for legislation to ensure that human factors/ergonomics factors are systematically considered in the design of products for human use and work environments for employees? Why is it that both industry associations and members of Congress sometimes view us as simply adding an additional expense burden and, thus, *increasing* the costs of production, and thereby *decreasing* competitiveness? In response to these questions, from my experience, at least four contributing reasons immediately come to mind.

First, some of these individuals and organizations have been exposed to *bad ergonomics* – or what, in a recent article on this topic, Ian Chong (1996) labels as "voodoo ergonomics" – either in the form of products or work environments which are *professed* to be ergonomically designed, but are not, or in which the so-called ergonomics was done by incompetent persons. This, indeed, is a concern – particularly when persons lacking professional training pass themselves off as ergonomists or human factors professionals; or tout their services as a panacea for almost anything. It is one of the major reasons that both establishing educational standards for professional education in human factors/ergonomics *and* professional certification have become top priority issues for the International Ergonomics Association and, indeed, for many national human factors/ergonomics societies and governmental groups – such as the European Union.

Another reason, well known to us, is that "everyone is an operator" (Mallett, 1995). Everyone "operates" systems on a daily basis, such an automobile, computer, television, and telephone; and thus, it is very easy to naively assume from our operator experience that Human Factors is nothing more than "common sense". Most experienced ergonomists have their own personal list of "commonsense" engineering design decisions that have resulted in serious accidents, fatalities, or just plain poor usability. Buy me a beer and I will be glad to tell you some of my personal ergonomics "war stories." I also would refer you to Steve Casey's book, *Set Phasers on Stun*.

Third, I believe we sometimes expect organizational decision-makers to proactively support human factors/ergonomics simply because it is *the right thing to do*. Like God, mother, and apple pie, it is hard to argue against doing anything that may better the human condition, and so, that alone should be a compelling argument for actively supporting use of our discipline. In reality, managers have to be able to justify *any* investment in terms of its concrete benefits to the organization – to the organization's ability to be competitive and survive. That something "is the right thing to do" is, by itself, an excellent but decidedly *insufficient* reason for managers actually doing it.

Finally, and perhaps most importantly, as a group, we have done a poor job of documenting and advertising the cost-benefits of good ergonomics – of getting the word out that most often, *good ergonomics is good economics.* In fact, that the ergonomics of economics *is* the economics of ergonomics.

As one attempt to rectify this situation, I want to share with you a broad spectrum of ergonomics applications that my predecessor as HFES President, Tom Eggemeier, and I have collected from within the U.S. and elsewhere, where the costs and economic benefits were documented.

ERGONOMICS APPLICATIONS

Forestry Industry

My first set of examples deal with forestry. A coordinated series of joint projects were undertaken by the Forest Engineering Technology Department of the University of Stellenbosch and Ergotech – the only true ergonomics consulting firm in South Africa – to improve safety and productivity in the South African forestry industry.

Leg protectors. In one project, an anthropometric survey was conducted of the very heterogeneous workforce to provide the basic data for redesigning leg protectors for foresters. The South African forestry industry is populated with a wide variety of ethnic groups, having widely varying anthropometric measurements. The original protector, obtained from Brazil, was modified to ergonomically improve the types of fastening and anthropometric dimensions, as well as to incorporate improved materials. Included in the ergonomic design modification process was an extensive series of usability tests over a 6-month period. Then, in a well-designed field test, this ergonomically modified leg protector was introduced in a eucalyptus plantation for use by persons responsible for ax/hatchet de-branching. Among the 300 laborers, an average of ten injuries per day was occurring with an average sick leave of 5 days per injury. During the 1-year period of the test, not one single ax/hatchet leg injury occurred, resulting not only in the considerable savings in human pain and suffering, but also in a direct net cost savings to the company of $250,000. Use of the leg protectors throughout the South African hardwood forestry industry is conservatively calculated to save $4 million annually (Warkotsch, 1994).

Tractor trailer redesign. A second study involved ergonomically improving the seating and visibility of 23 tractor-trailer forwarding units of a logging company with an investment of $300 per unit. This resulted in a better operating position for loading, improved vision, and improved operator comfort. As a result, downtimes caused by accident damage to hydraulic hoses, fittings, etc. went down by $2,000 per year per unit; and daily hardwood extraction was increased by one load per day per vehicle. All told, for a total investment of $6,900, a hard cost savings of $65,000 per year was achieved – a 1 to 9.4 cost-benefit ratio (Warkotsch, 1994).

Other innovations. Other innovations by this same collaborative effort between Stellenbosch University, Ergotec, and various forestry companies have included (a) developing a unique lightweight, environmentally friendly pipe type of timber chute for more efficiently and safely transporting logs down slopes, (b) redesigning three-wheeled hydrostatic loaders to reduce both excessive whole-body vibration and noise, (c) classifying different terrain conditions – including ground slope, roughness, and other conditions – and determining the most effective tree harvesting system (method and equipment) for each, and (d) developing ergonomic checklists and work environment surveys tailored to the forest industry. All of these are expected to result in significant cost savings, as well as greater employee satisfaction and improved quality of work life (Warkotsch, 1994).

I believe this is a good example of what ergonomics potentially can contribute to *any* given industry when there is a true collaborative effort and commitment.

C-141 Transport Aircraft

Some 35 years ago, I joined the US Air Force's C-141 aircraft development system program office as the project engineer for both human factors and the alternate mission provisions. The C-141 was to be designed so that its cargo compartment, through the installation of alternate mission kits, could be reconfigured for cargo aerial delivery, carrying paratroopers and paratroop jumping, carrying passengers, or for medical evacuation. As initially configured, anything that did not absolutely have to be included in the aircraft for straight cargo carrying was placed in one of the alternate mission kits, making them heavy, complex, and requiring considerable time and effort to install. By meeting with the intended using organization, the Air Force Material Air Transport Command, and discussing their organizational design and management plan for actual utilization of the aircraft, I was able to identify numerous kit components that rarely ever would be removed from the airplane. Using these data, I worked with the Lockheed design engineers to reconfigure the kits to remove these components and, instead, install them permanently in the aircraft. As documented by the engineering change proposals, this effort greatly simplified the system and reduced actual *operational* aircraft weight and thus, related operating and maintenance costs for over 200 aircraft over the past 35 years. The changes also reduced installation time and labor, and storage requirements for the kits. In addition, it saved over $2 million in the initial cost of the aircraft fleet. I believe this is a good illustration of how macroergonomic considerations can result in highly cost-effective microergonomic design improvements to systems.

These, and numerous other cost-benefit human factors evaluations and improvements to the C-141's design, came at a total cost of less than $500,000 of professional human factors effort, and resulted in over $5 million in cost savings – better than a 1 to 10 cost-benefit ratio. I believe the aircraft's truly exceptional safety record, and related untold savings in lost aircraft avoided, can, at least in part, be attributed to having had a sound human factors engineering development effort.

MATERIALS HANDLING SYSTEMS

One group that does a somewhat better job of documenting the costs and benefits of its ergonomic interventions than many of us is the faculty of the Department of Human Work Sciences at Lulea University of Technology in Sweden. The following examples are from the Department's Division of Environment Technology's work with steel mills. The basic approach to ergonomic analysis and redesign in these projects was to involve employee representatives with the Lulea faculty. For each project, the economic "payoff" period was calculated jointly with the company's management.

Steel Pipes and Rods Handling and Stock-Keeping System

A semi-automatic materials-handling and stock-keeping system for steel pipes and rods was ergonomically redesigned. The redesign reduced the noise level in the area from 96 db to 78 db, increased production by 10%, dropped rejection from 2.5% to 1%, and paid back the redesign and development costs in approximately 18 months. After that, it was all profit.

Tube Manufacturing, Handling, and Storage System

In a tube manufacturing facility, a tube-handling and storage system had an unacceptably high noise level, high rejection rate from damage, required heavy lifting, had inefficient product organization, and had a poor safety record. Ergonomic redesign eliminated stock damage, improved stock organization, reduced lifting forces to an acceptable level, reduced the noise level by 20 db; and has, to date, resulted in zero accidents, and in a productivity increase with a payback period of only 15 months.

Forge Shop Manipulator

In a forge shop, the old manipulator was replaced with a new one, having an ergonomically designed cabin and overall better workplace design. In comparison with the old manipulator, whole-body vibration was reduced, noise was reduced by 18 db, operator sick leave dropped from 8% to 2%, productivity improved, and maintenance costs dropped by 80%.

PRODUCT DESIGN OR REDESIGN

The economic benefit of ergonomic design or redesign of a product can be assessed in several ways. For example, by its impact on (a) the value of the company's stock, (b) sales, (c) productivity, or (d) reductions in accidents. Four very different kinds of products are provided herein as illustrations of each of these beneficial economic impacts.

Replacement for Forklift Truck Lines

Alan Hedge and his colleagues at the Human Factors Laboratory at Cornell University participated with Pelican Design, a New York industrial design company, and the Raymond Corporation in the design and development of a new generation of forklift trucks to replace Raymond's two existing product lines. Human factors design principles were given prime consideration and an "inside-out" human-centered approach was taken, with the form of the truck being built around the operator's needs. The goal was to maximize operator comfort, minimize accident risks, and maximize productivity by optimizing task cycle times. At the time the development project was begun, Raymond's market share had eroded from its former position of dominance in the market of over 70% of sales to about 30%, and shrinking. Both the new narrow isle[?] and swing-reach truck lines were introduced in the U.S. in 1992, and the swing-reach in Europe in 1993. Order books at Raymond are full and once again the company is enjoying success. Raymond stock has risen from around $6 per share at the start of the project to around $21 today (Alan Hedge, personal communication).

TV and VCR Remote Controls

Thompson Consumer Electronics first developed their highly successful approach to user-centered design when they developed "System Link," an ergonomically oriented remote control that can operate various types of products made by different manufacturers. The original Thompson remote control design differed little from the competition's: A rectangular box with rows of small, identical buttons. It is the one in the middle of the picture[?]. Using their user-centered design approach, the initial design was replaced with the new ergonomic one, shown on the left in the picture, which, among other things, was easier to grasp, used color-coded, soft-touch rubber buttons in distinctive sizes and shapes, and [had] . . .the VCR and TV buttons . . . separated above and below the keypad. When introduced in 1988, this new, ergonomically designed "System Link" remote control gained the jump on the competition; and

Thompson has since sold literally millions of them. As a result of this success, user-centered ergonomic design has become a key aspect of all new Thompson development projects (March, 1994).

DSS System

A more recent highly successful example is Thompson's RCA DSS satellite digital television system. All aspects, including the on-screen display and remote control, utilized user-centered design and received extensive ergonomic attention (March, 1994). These units now are selling like "hot cakes."

CRT Display

The CRT display used by the Directory Assistants at Ameritech (a U.S. regional telephone company) were ergonomically redesigned by Scott Lively, Richard Omanson, and Arnold Lund to meet the goal of reducing average call processing time. Included in the redesign were replacement of an all uppercase display with a mixed-case display and the addition of a highlighting feature for the listing selected by the Directory Assistant. Based on extensive before and after measurements, results showed a 600ms reduction in average call operating time after introduction of the ergonomically redesigned CRT display. Although seemingly small, this reduction represents an annual savings of approximately $2.94 million across the five-state region served by Ameritech (Scott Lively and Arnold Lund, personal communication).

Training System Redesign

In a related effort, done jointly with Northwestern's Institute for Learning Sciences, the traditional lecture-and-practice training program for new Directory Assistants was replaced by an ergonomically designed computer-based training program which incorporates a simulated work environment and error feedback. As a result, operator training time has been reduced from 5 days to 1.5 days (Scott Lively, personal communication).

Center High-Mounted Automobile Rear Stop Lamp

The Center High-Mounted stop Lamp is perhaps the best known ergonomic improvement to a widely used consumer product. In the 1970s, the National Highway Traffic Safety Administration (NHTSA) sponsored two field research programs which demonstrated the potential of adding a center high-mounted stop lamp or CHML to reduce response times of following drivers and, thus, avoid accidents. In the mid 70s, this ergonomic innovation and three other configurations were installed in 2,100 Washington, D.C., area taxicabs. The CHML configuration resulted in a 50% reduction in both rear-end collisions, and collision severity. Following several additional field studies, Federal Motor Vehicle Safety Standard 108 was modified to require all new passenger cars built after 1985 to have CHMLs. Based on analyses of both actual production costs for the CHMLs and actual accident data for the 1986 and 1987 CHML-equipped cars, NHTSA calculated that, when all cars are CHML equipped (1997), 126,000 reported crashes will be avoided annually at a property damage savings of $910 million per year. Addition of the savings in medical costs would, of course, considerably increase this figure. The total cost of the entire research program was $2 million and for the regulatory program, $3 million (Transportation Research Board, National Research Council, 1989). A $5 million investment for a projected $910 million annual return: Not a bad ergonomics investment by the federal government!

PoultryDeboning Knife

A conventional type butcher's knife was being used for deboning chickens and turkeys at a poultry packaging plant. The knife did a poor job of deboning; and a high incident rate of carpal tunnel syndrome, tendinitis, and tenosynovitis, resulted in a $100,000 per annum increase in workers' compensation premiums. A new, ergonomically designed pistol-shaped knife was introduced by ergonomist Ian Chong, Principal of Ergonomics, Inc., of Seattle, Washington. Less pain and happier cutting crews were reported almost immediately. Over a 5-year period, upper extremity work-related musculoskeletal disorders were greatly reduced, line speeds increased by 2% to 6%, profits increased because of more efficient deboning, and $500,000 was saved in workers' compensation premiums (Ian Chong, personal communication). This is a good example of how a simple, inexpensive ergonomic solution sometimes can have a very high cost-benefit payoff.

WorkStation Redesign

Food service stands. Using a participatory ergonomics approach with food service personnel, my USC colleague Andy Imada, and George Stawowy, a visiting ergonomics doctoral student from the University of Aachen in Germany, redesigned two food service stands at Dodger Stadium in Los Angeles (Imada and Stawowy, 1996). The total cost was $40,000. Extensive before and after measures demonstrated a reduction in average customer transaction time of approximately 8 seconds. In terms of dollars, the increase in productivity for the two stands was approximately $1,200 per baseball game, resulting in a payback period of 33 games, or 40% of a single baseball season. Modification of these two stands was relatively costly because, as the development prototypes, they consumed considerable time and effort. Modifying the other 50 stands in Dodger Stadium can now be done at a price of $12,000 per stand, resulting in a payback period of only 20 games. Potentially, the resulting productivity increases can be used to reduce customer waiting time, thereby also increasing customer satisfaction (Andrew Imada, personal communication).

This modification effort is but one part of a macroergonomics intervention project to improve productivity. Imada anticipates that ongoing work to improve the total system process, including packaging, storage and delivery of food products and supplies, and managerial processes, eventually will result in a much greater increase in productivity.

Fine assembly workstations. Typical workstations at a major electronics assembly plant result in poor postures and resultant work-related musculoskeletal disorders. Valerie Venda of the University of Manitoba has designed a new type of fine assembly workstation which utilizes a TV camera and monitor. Not only does the TV camera provide a greatly enlarged image of the assembly work, but enables the worker to maintain a better posture and more dynamic motion. Based on extensive comparative testing of the old and new workstations, a 15% higher productivity rate is obtained with the new one. Venda reports that the average value of products assembled per worker per shift at these types of workstations varies between $15,000 and $20,000. Thus, the additional value produced by one worker per day using the new workstation will be $2,250 to $3,000 per day. Although it is too early to say precisely, Venda predicts the new workstations eventually will decrease occupational injuries for these jobs by 20% (Valerie Venda, personal communication).

REDUCING WORK-RELATED MUSCULOSKELETAL DISORDERS

Given the importance of this issue, and the rather considerable attention and debate which have resulted from the introduction of proposed workplace ergonomics regulations at both the federal and state (e.g., California) levels, and two Canadian provinces, I have included five examples of documented, highly successful ergonomic intervention programs.

AT&T Global

AT&T Global Information Solutions in San Diego employs 800 people and manufactures large mainframe computers. Following analyses of their OSHA 200[ok?] logs, the company identified three types of frequent injuries: lifting, fastening, and keyboarding. The company next conducted extensive work site analyses to identify ergonomic deficiencies. As a result, the company made extensive ergonomic workstation improvements and provided proper lifting training for all employees. In the first year following the changes, workers' compensation losses dropped more than 75%, from $400,000 to $94,000. In a second round of changes, conveyor systems were replaced with small, individual scissors-lift platforms, and heavy pneumatic drivers with lighter electric ones; this was followed by moving from an assembly line process to one where each worker builds an entire cabinet, with the ability to readily shift from standing to sitting. A further reduction in workers' compensation losses to $12,000 resulted. In terms of lost workdays due to injury, in 1990 there were 298; in both 1993 and 1994 there were none (Center for Workplace Health Information, 1995a). Alltold, these ergonomic changes have reduced workers' compensation costs at AT&T Global over the 1990–1994 period by $1.48 million. The added costs for these ergonomic improvements represent only a small fraction of these savings.

Red Wing Shoes

Beginning in 1985 with (a) the initiation of a safety awareness program which includes basic machine setup and operation, safety principles and body mechanics, CTD's, and monthly safety meetings; (b) a stretching, exercise, and conditioning program; (c) the hiring of an ergonomics advisor; and (d) specialized training on ergonomics and workstation setup for machine maintenance workers and industrial engineers, the Red Wing Shoe Company of Red Wing, Minnesota, made a commitment to reducing WMSD's via ergonomics. The company purchased adjustable ergonomic chairs for all seated operators and antifatigue mats for all standing jobs; instituted Continuous Flow Manufacturing, which included operators working in groups, cross-training, and job rotation; ergonomically redesigned selected machines and workstations for flexibility and elimination of awkward postures, and greater ease of operation; and modified production processes to reduce cumulative trauma strain. As a result of these various ergonomic interventions, workers' compensation insurance premiums dropped by 70% from 1989 to 1995, for a savings of $3.1 million. During this same period, the number of OSHA reportable lost time injury days dropped from a ratio of 75, for 100 employees working a year, to 19. The success of this program is attributed to upper management's support, employee education and training, and having everyone responsible for coordinating ergonomics. I also would note the total systems perspective of this effort (Center for Workplace Health Information, 1995b).

Ergonomics Training and Follow-Up Implementation

In 1992, Bill Brough of Washington Ergonomics conducted a 1-day seminar for cross-disciplinary teams of engineers, human resource management personnel, and safety/ergonomics committee members from seven manufacturing companies insured by Tokyo Marine and Fire Insurance Company, Ltd. The seminar taught the basic principles of ergonomics and provided the materials to implement a participatory ergonomics process. The training focused on techniques for involving the workers in evaluating present workplace conditions and making cost-effective improvements. The class materials provided the tools for establishing a baseline, setting improvement goals, and measuring results. In six of the companies, the seminar data and materials were used by the teams to implement a participatory ergonomics program with the workers; and received both funding from management and support from labor. The seventh company did *not* participate in the implementation of the training. Follow-up support was provided by a senior loss control consultant for Tokyo Marine. For the six companies that *did* participate, reported strain-type injuries dropped progressively from 131 in the 6 months prior to the training to 42 for the 6-month period ending 18 months later. The cost of these injuries for the 6 months prior was $688,344, for the 6-month period ending 18 months later, the injury costs had dropped to $72,600, for a net savings over 18 months of $1,348,748, using the 6 months prior as the baseline. Worker involvement reportedly created enthusiasm and encouraged each individual to assume responsibility for the program's success. According to Bill Brough, the reduction of injuries resulted from a commitment to continuous improvement and was obtained by many small changes, not a major singular event. For the one company that did not participate in implementing the training, the number of reported strain injuries was 12 for the 6 months prior to training, and 10, 16, and 25, respectively, for the next three 6-month periods. In short, things got worse rather than better (Bill Brough, personal communication and supporting documentation).

Coupled with both management's and labor's active support, Tokyo Marine traces these reductions in strain-type injuries for the six participating companies directly back to Bill Brough's participatory ergonomics training program and related materials. A good example of what can happen when you couple collaborative management-labor commitment with professional ergonomics.

Deere and Company

One of the best known successful industrial safety ergonomics programs is that at Deere and Company, the largest manufacturer of agricultural equipment in North America. In 1979 Deere recognized that traditional interventions like employee lift training and conservative medical management were, by themselves, insufficient to reduce injuries. So the company began to use ergonomic principles to redesign and reduce physical stresses of the job. Eventually, ergonomics coordinators were appointed in all of Deere's U.S. and Canadian factories, foundries, and distribution centers. These coordinators, chosen from the industrial engineering and safety departments, were trained in ergonomics. Today, job evaluations and analyses are done in-house by both part-time ergonomics coordinators and wage-employee ergonomics teams and committees. The company has developed its own ergonomics checklists and surveys. The program involves extensive employee participation. Since 1979, Deere has recorded an 83% reduction in incidence of back injuries, and by 1984 had reduced workers' compensation costs by 32%. According to Gary Lovestead, each year, literally hundreds to thousands of ergonomics improvements are implemented; and today, ergonomics is built into Deere's operating culture (Center for Workplace Health Information, 1995c).

Union Pacific Railroad

In the early 1980s, the Palestine Car Shop near Dallas, Texas, had the worst safety statistics of the Union Pacific Railroad's shop operations. Of particular note was the high incidence of back injuries. For example, in 1985, 9 out of 13 lost-time injuries were back injuries; and 579 lost and 194 restricted or limited workdays accumulated. Only 1,564 cars were repaired that year, and absenteeism was 4% (Association of American Railroads, 1989). The University of Michigan Center for Ergonomics computer model for back compression was modified and expanded for easy application to the railroad environment, and packaged by the Association of American Railroads. The AAR-Back Model was introduced at the Palistine Car Shop to identify job tasks that exceeded acceptable back compression values, and equipment supporting various jobs requiring lifting was redesigned. For example a coupler knuckle storage table was designed for storing the 90-lb. knuckles. Previously, they were manually piled on the ground, and then lifted from there. In addition, a commercial back injury training program, "Pro-Back," was adopted and every employee was taught how to bend and lift safely. Finally, management attitude and priorities about safety were conveyed through weekly meetings with safety captains from each work area, and quarterly "town hall" meetings with all shop employees.

From 1985 to 1988, the total incidence of injuries went from 33 to 12; back incidents from 13 to 0; lost days from 579 to 0; restricted days from 194 to 40 (all from minor, non-back injuries), and absenteeism from 4% to 1%. Number of cars repaired per year went from 1,564 in 1985 to 2,900 in 1988, an increase in dollar value of $3.96 million. Union Pacific calculates the cost-benefit ratio as approximately 1 to 10 (American Association of Railroads, 1989).

HUMAN FACTORS TEST AND EVALUATION

One of the regional U.S. telephone companies, NYNEX, developed a new workstation for its toll and assistance operators, whose job is to assist customers in completing their calls and to record the correct billing. The primary motivation behind developing the new workstation was to enable the operators to reduce their average time per customer by providing a more efficient workstation design. The current workstation had been in use for several years and employed a 300-baud, character-oriented display and a keyboard on which functionally related keys were color coded and spatially grouped. This functional grouping often separated common sequences of keys by a large distance on the keyboard. In contrast, the *proposed* workstation was ergonomically designed with sequential as well as functional considerations; it incorporated a graphic, high-resolution 1200-baud display, used icons and, in general, is a good example of a graphical user interface whose designers paid careful attention to human-computer interaction issues.

Under the name *Project Ernestine,* Wayne Gray and Michael Atwood of the NINE Science and Technology Center, and Bonnie John of Carnegie Mellon University (1993) designed and conducted a comparative field test, replacing 12 of the current workstations with 12 of the proposed ones. In addition they conducted a goals, operators, methods and selection rules (GOMS) analysis (Card, Moran, & Newell, 1980) in which both observation-based and specification-based GOMS models of the two workstations were developed and used.

Contrary to expectations, the field test demonstrated that average operator time was 4% *slower* with the proposed workstation than with the currently used one. Further, the GOMS analyses accurately predicted this outcome, thus demonstrating the validity of the GOMS models for efficiently and economically evaluating telephone operator workstations. Had this test and evaluation *not* been conducted, and the proposed, presumably more efficient, workstation been adopted for all 100 operators, the performance decrement cost per year would have been $2.4 million. A good example of the value of doing careful human factors test and evaluation before you buy (Gray et al., 1993).

MACROERGONOMICS

Petroleum Distribution Company

Several years ago, Andy Imada of the University of Southern California began a macroergonomic analysis and intervention program to improve safety and health in a company that manufactures and distributes petroleum products. The key components of this intervention included an organizational assessment that generated a strategic plan for improving safety, equipment changes to improve working conditions and enhance safety, and three macroergonomic classes of action items. These items included improving employee involvement, communication, and integrating safety into the broader organizational culture. The program utilized a participatory ergonomics approach involving all levels of the division's management and supervision, terminal and filling station personnel, and the truck drivers. Over the course of several years, many aspects of the system's organizational design and management structure and processes were examined from a macroergonomics perspective and, in some cases, modified. Employee-initiated ergonomic modifications were made to some of the equipment, new employee-designed safety training methods and structures were implemented, and employees were given a greater role in selecting new tools and equipment related to their jobs.

Two years after initial installation of the program, industrial injuries had been reduced by 54%, motor vehicle accidents by 51%, off-the-job injuries by 84%, and lost workdays by 94%. By 4 years later, further reductions occurred for all but off-the-job injuries, which climbed back 15% (Nagamachi & Imada, 1992). The company's area manager of operations reports that he continues to save one-half of 1% of the annual petroleum delivery costs every year as a direct result of the macroergonomics intervention program. This amounts to a net savings of approximately $60,000 per year for the past 3 years, or $180,000, and is expected to continue (Andrew Imada, personal communication). Imada reports that perhaps the greatest reason for these *sustained* improvements has been the successful installation of safety as part of the organization's culture. From my firsthand observation of this organization over the past several years, I would have to agree.

Implementing TQM at L. L. Bean

Rooney, Morency, and Herrick (1993) have reported on the use of macroergonomics as an approach and methodology for introducing total quality management (TQM) at the L. L. Bean Corporation, known internationally for the high quality of their clothing products. Using methods similar to those described above for Imada's intervention, but with TQM as the primary objective, over a 70% reduction in lost time accidents and injuries was achieved within a 2-year period in both the production and distribution divisions of the company. Other benefits, such as greater employee satisfaction and improvements in additional quality measures, also were achieved. Given the present emphasis in many organizations on implementing ISO 9000, these results take on an even greater significance.

CONCLUSION

The above are but a sample of the variety of ergonomic interventions which we, as a profession, are capable of doing to not only improve the human condition, but the bottom line as well. From my 35 years of observation and experience, only rarely are truly good ergonomic interventions *not* beneficial in terms of the criteria that are used by managers in evaluating the allocation of their resources.

As many of the above ergonomic interventions also illustrate, ergonomics offers a wonderful common ground for labor and management collaboration; for invariably, both can benefit – managers, in terms of reduced costs and improved productivity; employees, in terms of improved safety, health, comfort, usability of tools and equipment, including software; and improved quality of work life. Of course, both groups benefit from the increased competitiveness and related increased likelihood of long-term organizational survival that ultimately is afforded.

Clearly, to enable our profession to approach its tremendous potential for humankind, we, the professional human factors/ergonomics community, *must* better *document* the costs and benefits of our efforts, and proactively *share* these data with our colleagues, business decision makers and government policy makers. It is an integral part of *managing* our profession. Thus, it *is* up to *us* to document and spread the word that *good ergonomics IS good economics*.

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HUMAN FACTORS AND THE OLDER ADULT: PROFESSIONAL DIVERSITY BRINGS SUCCESS

Arthur D. Fisk
Georgia Institute of Technology

As is well known, the number of older adults within developed countries is increasing faster than their younger counterparts. Such a change in demographics brings with it unique challenges and opportunities for both the public and private sectors. Human factors and ergonomics has played, and can continue to play, a major role in meeting these challenges and capitalizing on the opportunities. At the very least, economic factors should increase the need for human factors and ergonomic input oriented toward older adults for the design of work, home, and leisure environments. Thus, the topical focus of this paper is becoming a central concern of many professions. With this increased concern comes the crucial need for increased communication among the contributing professions and increased leadership from the human factors and ergonomics professional community.

It is clear that the life expectancy of the population in America and in other countries is, collectively, increasing (Rowe and Kahn, 1998). Rowe and Kahn highlighted the dramatic nature of the increase in life expectancy when they pointed out that of *all* humans who have ever lived to be 65 years or older, half of them are currently alive. Our populations in the world are growing older. Such good news brings with it certain challenges. These challenges are the result of shifts in demands for goods and services.

A DAY IN THE LIFE OF MY MOTHER

If such demographic change points to shifts in demands for goods and services, what might those be? To better understand the range of systems encountered by older adults; let's examine a day in the life of an individual approaching the fastest growing age group. Let's consider my mother. Fortunately, for her and for her family, she is in rather good health, both physically and mentally.

Mom's day begins early, about 6 a.m., and she must take a correct dosage of several medications. After taking her medication she begins her daily routine. In the bathroom she is careful not to slip and fall as she enters the shower. She wonders about those new products that not only clean but also add a non-slip surface to the tub. As she is getting dressed and putting on her stockings she feels lucky that she can easily bend down. She thinks about one of her friends who can't bend down to put on her own stockings; rather than worry about it, her friend uses a cane to pull up the stockings. "An older person's life is never dull, we're always solving problems that seem routine to a younger person," thinks Mom.

After getting dressed she fixes her breakfast using the stove and microwave with all of those knobs and dials. Because her memory is not as good as it use to be, she checks her daily reminder list to help plan her day. Mom does volunteer work as a county zoning board member and as a hospice volunteer. So, she makes a few calls to some businesses and works her way through all of those phone menus. With each call she tries to remember what the options are and whether or not an option matches what she wants to do. Even though she has a push-button telephone, sometimes she's just glad when the mechanical voice says, "If you have a rotary phone please hold" – finally she can talk to a real person.

She remembers that some of the retirees from where she last worked are having trouble getting medical things worked out between insurance and Medicare. Fortunately she knows all of the ropes, and the forms are not hard for her to fill out. Because she does this so much, she knows many of the administrative personnel at the doctors' offices and the hospitals so she is able to get things worked out for the retirees.

Mom is not doing badly financially but she does not have enough money to afford the minimum balances to talk to a real teller at her bank. So, she does the best she can with the on-line banking software and shifts some money from savings to checking. The bank tells her how easy it is to use an ATM but she wonders why they do not provide training on those darn things so that she does not have to use the software.

Grocery shopping is on her task list for the day. The drive in town has many intersections and stop signs. Her car is relatively new so she is extra careful and slow so that she does not hit anything. A few people are upset because she takes her time at the intersections but she thinks it is better that they are upset about her being slow than with her hitting them. On her way to the grocery store she gets on the new four-lane road. This is a new route for her so she needs to follow all of the signs, not get lost, and prepare for the unexpected.

At the grocery store Mom thinks how nice it would be not to have to push such a heavy cart around. At the store she compares prices, nutrition value of the foods, and reads the labels for some over-the-counter medicine to make sure that it does not interact with her prescription medicine. From the store Mom goes on to visit one of her hospice patients, calling on her cell phone to tell the family she is on her way. Mom is a retired nurse, but at the house she finds an array of new medical devices. If used correctly these devices will ease the patient's suffering. If not used correctly . . . well, she is glad she got the proper instruction at the last hospice training meeting but wonders how folks with less medical background than her can get these things to work.

She leaves and takes her groceries home. She has built a makeshift carrier for her groceries, how else would she get them in the house. When younger she cut her own firewood but as she loses her strength even simple lifting is not so simple anymore.

She needs to prepare a report for the zoning board meeting this evening so she turns on her computer and thinks about how easy it was before Windows 95 made her learn all of those new commands. She accesses her word processor and prepares and prints her report. More telephone calls and she is off to the zoning board meeting for a series of appeals on local ordinances. After the zoning meeting she goes home and enters her notes into the computer and adjusts her daily planner for tomorrow. Thinking of the full day she has planned for tomorrow, Mom sets her home security monitoring system and goes to bed.

SUCCESS STORIES

With this background of a real day in the life of a real person, I would like to further explore why our work as human factors practitioners and scientists is crucial for improving the lives of older adults. What follows is a discussion of a few success stories, work in progress, and future needs. Although many more examples are available, the following examples should be sufficient to point to why human factors and ergonomics, because of its unique technology and its inherent diversity, is the field to help solve age-related issues of safety, mobility, and well-being. Indeed, the examples point to why the field of human factors and ergonomics should be the general contractor in the progress.

Just as a forest is rather boring if composed of only one single type of vegetation, so too would human factors be stagnant if only one type of professional effort were its makeup. Indeed, Human Factors is a forest of much varietal differentiation. Let us look at some of the variety adding to success in the area of human factors and the older adult.

A driving force in our design efforts should be to enhance the daily lives of older individuals. Indeed, a primary goal of many older individuals is to maintain an independent lifestyle. What are the types of frustrations and difficulties active older individuals encounter in their efforts to remain fully functional in a changing environment? How do we discover this information? The field of human factors and ergonomics is quite versed and well prepared to address these two questions. One of our cornerstone tools is task analysis. With slight adaptation, we can understand aspects of functional limitations, why these limitations exist, and ways to address the limitations.

Consider a study conducted in Georgia to assess such issues (Rogers, Meyer, Walker, and Fisk, 1998). Constraints on daily living were assessed in focus-group interviews of healthy, active adults aged 65 to 88. Individual comments about specific problems were coded along the dimensions of (a) locus of the problem – motor, visual, auditory, cognitive, and so on; (b) the activity involved – for example, transportation, leisure, housekeeping; (c) whether the problem was due to task difficulty or the perception of risk; and (d) response to the limitations – persistence, cessation, compensation, or self-improvement. The data provided information about the types of difficulties encountered in everyday activities as well as the ways in which individuals responded to such difficulties.

Each comment was also coded in terms of whether it was remediable via training, design changes, or some combination of the two. More than half of the problems reported had the potential to be improved by human factors intervention. Think of it: over half of the problems reported by this sample of quite diverse older people – diverse in terms of culture, economic, life history, and so on – could be potentially overcome by what our field does in the normal course of our professional daily activities. Moreover, almost all of the cognitive challenges were amenable to human factors intervention. This, indeed, is quite exciting for us as a profession and for the enhanced quality of normal daily living of older adults.

Training alone seemed a reasonable approach for skills not involving complex devices. Redesign alone was best for primarily motor or sensory difficulties. Combined redesign and training seemed most appropriate for learning more complex devices such as computers. Although these devices could certainly be designed to be simpler, the tasks of using them are probably complex enough to warrant training even with improved designs. Many of the participants were reluctant to even try such devices without some initial training. But, importantly, many of these older adults expressed a desire to learn to use computers, fax machines, and many other technologies.

Transportation was a very limiting factor of activities of daily living, particularly for non-drivers. This is particularly notable given that the participants had access to Atlanta's public transportation system. While there were some issues with crime and inadequate bus schedules, participants were mainly hindered by bus steps and station escalators, and by not knowing how to find their way around – these are all problems we as a profession can address.

The data were striking in the variety of new technologies that participants reported encountering. Some technologies they had little choice about using, such as phone menus or new gas pumps. However, some participants had voluntarily learned to use new devices, and most were eager to learn. It was not only that they could not insulate themselves from changing technology – most did not wish to do so. However, because of inadequate design and lack of accessible training, many had not been able to use a host of new technologies.

SAFETY AND MOBILITY OF OLDER ADULTS

The safety and mobility of older drivers have probably received the most attention in human factors. Why is this the case? As pointed out by Barr and Eberhard (1991), a moment's reflection reveals that safety *and* mobility are twin goals but these goals are not always perfectly compatible. Most older drivers do not wish to stop driving, nor do they wish to have their driving curtailed. Most do not need to stop driving. Yet motor vehicle crash rates do begin to increase after age 60, implying that human factors countermeasures are necessary to maintain safe driving in this population.

Much work has been done in this area including work on visual attention, cognitive factors, diseases of the eye, environmental design, and driving. For example, Staplin's work has demonstrated that highway environments need not be taken as a given but instead can be modified through human factors efforts to suit diverse populations of drivers using the highway (e.g., Staplin and Fisk, 1991).

Ball and Owsley (1991) have modeled visual and cognitive correlates of accident frequency. Their work has demonstrated that a crucial single predictor of accident frequency is the concept of useful field of view. Useful field of view has been defined as the visual field area over which information can be acquired during a brief glance. Ball and Owsley have demonstrated that aging can bring with it a dramatic restriction in the useful field of view such that, conceptually speaking, the driver may be looking out of a peephole. This would be important on its own. Yet, Ball and her colleagues (Ball et al., 1988) have developed training programs showing that much of this loss can be reversed. They have reported improvements in useful field of view up to 133% and these improvements are maintained over a 6-month period without additional training. This is quite a success story. There are numerous other success stories as far as improving both safety and mobility of older drivers archived in papers in our journal *Human Factors*.

The concept of automated banking is deceptively simple: You walk up to the machine, enter your card, input your personal identification number, and then do your banking. However, as many of us know, things can (and do) go wrong. Automatic teller machines (ATMs) were designed to increase the flexibility of banking for customers, and to save banks money. When you open an account you get all you need, except instruction on how to use the system. More often than not, bankers assume that the ATM is intuitive to use and that you can learn how to use the ATM on your own. An informal survey of banks in two large metropolitan areas revealed that only 15% provided even a brief pamphlet describing the functions of the ATM. Officials at the remaining banks reported that they did not provide any materials for using ATMs. Those 85% expressed the feeling that such systems were trivially easy to use, so intuitive that training was not necessary. Research suggests that this is not the case, especially for older adults (see Rogers, Fisk, Mead, Walker, and Cabrera, 1996; Rogers and Fisk, 1997).

A survey of over 1,500 adults in Memphis and Atlanta showed that adults aged 18 to 34 use ATMs far more than those 65 and older — 86% versus 33%. Most instructive, nonusers aged 61 to 81 years old gave several reasons for avoiding ATMs including not feeling safe using them, not needing them, and not knowing how to use them. Yet, safety and need were not the most compelling reason for nonuse. Indeed, 21% said they would use ATMs if they were easy to use and someone showed them how to use them. Design and training, or lack thereof, were the bottlenecks to effective use or even use at all. The studies with older adults who had never used ATMs showed they made correct transactions only 20% of the time; as startling, using an ATM with no guided training, but given what you would get from the best of the banks, resulted in no improvement across practice – practice that was the equivalent of using the ATM daily for a month. Other work demonstrated that embedded, action-guided training greatly improved older adults' performance (to about 80% correct), greatly improved their ability to transfer to new systems and new transactions, and greatly improved their retention of the material so that performance was maintained at least over 30 days with no practice (Mead and Fisk, in press).

This type of research has also aided the development of principles for system design. Such system improvements benefit all users, not just older adults. These guidelines involve changing system design to embed training so that lack of knowledge about how to use an ATM can be overcome. Another important design consideration includes dealing with the breadth versus depth issue of menu design such that the problem of getting lost in the system is attenuated. Interestingly enough, being able to effectively correct errors on-line needed to be implemented within the ATM design philosophy. Environmental design issues can be important to adequately deal with the fear of lack of security. And of course, correcting the poor visual displays is a straightforward human factors contribution.

MOVEMENT CONTROL AND USING A COMPUTER MOUSE

There is large body of literature that shows that as people age, their movement control performance gets worse. Generally, older adults take longer than younger adults to make similar movements. Walker, Philbin, and Fisk (1997) found that older adults also have more difficulty in using a mouse to position a cursor on a computer. Given the prevalence of point-and-click–based interfaces, this age-related difference in performance can be a major impediment to computer usage by older adults.

Why are older adults slower and more error prone when it comes to movement control, especially computer mouse control? Walker's basic laboratory research established the source of the age-related performance decline as a combination of (1) poorer perceptual feedback, (2) increased "noise" in the motor pathway, and (3) strategy differences in approaching the task. This information is important but what does one do from a design perspective?

Given this difference in performance discovered in the lab, a straightforward approach to making the interface easier to use was to implement software changes in the gain and acceleration profiles that translate mouse movement into cursor movement. All current computer systems have software that allows a user to adjust the gain ratio to customize cursor-positioning performance. Walker's research showed which gain functions could compensate for poorer movement control of older adults, a cost-effective way to partially compensate for age-related differences in movement control in this domain.

What about redesign? Further research has also evaluated effective interface design solutions for movement control facilitation (Worden, Walker, Bharat, and Hudson, 1997). In those studies the data nicely show that with proper interface design, in this case area cursor with sticky icons with adaptive gain control, older adults' performance can be improved by at least 40%, without training. An important by-product of attending to age-related issues is that an interface was designed that also improved young adults performance by about 20%.

HEALTH CARE AND REHABILITATION

There are numerous opportunities for human factors input to improve the quality and safety of daily living of older adults. Space does not permit me to do much more than mention one more important area. Consider health care and rehabilitation. The important issues surrounding human factors, aging, and health care or rehabilitation recently received excellent coverage in a report by Gardner-Bonneau and Gosbee (1997). They point to the fact that this important area has received little attention until recently from the human factors community. However, there are numerous opportunities for substantive contributions from the broad field of human factors and ergonomics. Work is needed in both basic research and applications.

Consider remote video medicine. Telemedicine provides much promise in the health care of older adults. Interactive videoconferencing as well as video e-mail offer opportunities to provide much needed health care to individuals in remote areas while potentially reducing cost, transportation problems, and so on. The concept is simple. The health care provider is in one location, the patient is in another location, and they are linked via the technology. Although telemedicine can be successful, numerous human factors issues remain. Video-mediated communication issues must be investigated as they most surely compound age-related face-to-face communication issues. Decision making capability from both diagnostician and the patient must be addressed. All of the classic design-related problems of interface, navigation, cognitive, perceptual, and motor control issues must be addressed. Indeed, this one area cries out for vigorous human factors input.

The need for more human factors input into medical device design is quite apparent. Consider the relatively simple home-based glucose monitoring systems. On the surface these systems are simple, you prick your finger, you drop blood on a test strip, and you measure. But, these systems introduce classic problems that human factors specialists are well situated to address and solve. The problems include motor control: you load the lance and prick your finger and get the blood onto the test strip. This sounds simple but try to do it while your hand shakes or with severe arthritis. There are classic perceptual issues relating to display design and reading test strips, and there are cognitive issues associated with calibration, instruction following, and so on. Although progress has been made, much more needs to be accomplished in this important area.

WHAT DO WE DO NEXT?

Our profession certainly has some successes; but, we also have much more to do. What should be our next steps? Certainly we need to continue to do what we are good at doing. We need to continue to work as a diverse team with overarchingly similar end goals. Czaja (1997) has nicely summed up some further specific steps for our continued success. These include (a) the fact that research is required to gather information concerning the needs of older adults and the types of problems encountered when interacting with products, devices, and so on; (b) data are required on specific aspects or demands of tasks that are problematic for older adults; (c) research must be conducted and translated such that specifics concerning capabilities and limitations of older adults can be specified in terms of implications for system design parameters; (d) a principled approach to technology evaluation, from the perspective of the older adult is required; and (e) specification of design of training programs is required to ensure that older adults can acquire the requisite skills to use systems.

SUMMING UP – WHAT IS THE MESSAGE?

What is a message that I hope you take from this paper? I hope that you see how, as a profession with much diversity, we are poised to add value to the lives of older adults. Indeed, it is this diversity that will bring much success. I have tried to show that we know much about aging that is being usefully applied, but there are still gaps in our basic, fundamental knowledge. With research efforts conducted in the context of design (see Fisk and Kirlik, 1996), success on the research side is quite within our grasp.

The history of human factors demonstrates that its unique technology can be used to solve complex, challenging problems. Our profession has worked to ensure the safety, the productivity, and the well-being of individuals working and living in rather complex environments. We can most certainly help solve the challenges facing older adults in daily living. Yet, much must be done in the design of tasks, devices, systems, and environments to better accommodate the aging user.

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THE HUMAN FACTORS-ERGONOMICS PARADE: A TALE OF TWO MODELS

William C. Howell
Arizona State University

If you attended the last two presidential addresses, you'll recall some pretty heavy use of the parade metaphor. Dave Woods deplored the fact that we HF/E professionals are always cleaning up after it; then Peter Hancock boosted our collective self-esteem by explaining that indeed it's our parade and our rightful place is at the front. I like this metaphor, so I'm making it a three-peat. But my main purpose in bringing it back is to ponder with you a question that's been nagging me for at least a quarter century and I don't think either Dave or Peter addressed—a question that I believe has profound implications for our future: *What, exactly, is this parade all about?*

I'm going to argue that the reason we find ourselves in the poop-scooping detail so often is that in our preoccupation with getting ahead, we've never really resolved the question of what we want this thing we call HF/E to be. As a result, we've been operating implicitly under two incompatible models, and drifting steadily toward the one that I feel holds the least promise. I'll spend the rest of my time today contrasting these models and exploring their respective implications. But first, we need to revisit the problem that kicked off all this parade talk in the first place.

It's pretty much summed up in Rodney Dangerfield's line: "We get no respect." Human considerations are underrepresented in design, our field is underutilized, and we're underappreciated as a science and a profession –by the public, by policy makers, by designers, and by the disciplines we're related to. Why is this? Again, we have a standard list of reasons:

- HF/E is small in numbers and relatively young as a field,
- our public image isn't the best (e.g., packaged common sense; a pseudoscience),
- we're functioning in a culture that's preoccupied with nailing the culprit when things go wrong rather than analyzing the total system,
- decision-makers in industry and government don't appreciate Hal Hendricks' dictum that "good ergonomics is good economics,"
- there are too many scruffy riders on the HF/E gravy train who didn't buy a ticket and give the legitimate passengers a bad name,
- we don't invest enough in self-promotion,
- we don't make our knowledge convenient for designers to use.

Clearly these are all legitimate complaints that merit our attention. But they aren't the *causes* of our influence problem; they're really just *symptoms*—consequences of the unresolved conflict between fundamentally different models of our field. Treating these symptoms will not cure what ails us. Returning to the parade metaphor, it's hard to drum up popular support for a parade if you can't agree on what, exactly, it's promoting, where it's going, or who gets to march in it. And it's even harder if you make the wrong decisions.

Let me put it another way. I think we all share this vision of an ergonomically correct world in which everything's designed from the user's perspective. But we have very different ideas on how to get there, and these differences stem from alternative – and largely incompatible – conceptions of our field. One views HF/E as an emergent discipline through which we influence design directly; the other, as a general philosophy that we promote through as many disciplines as possible. I'll refer to these respectively as the *unique discipline* and the *shared philosophy* models. I maintain that we've avoided confronting this issue overtly because we know it would stir up a lot of internal dissension and, whichever side won, a lot of valuable members would leave in a huff. Instead, we've contented ourselves with treating symptoms and drifting toward the unique discipline model.

In the interest of full disclosure, I need to make of couple of admissions right up front. First, I'm strongly partial toward the shared philosophy model – and against the unique discipline model – although I realize that I represent a dwindling minority in this regard. Second, to make my point, I'm exaggerating the differences. Obviously, gaining acceptance as an independent discipline doesn't totally *preclude* cultivating a place within related disciplines. Practically speaking, however, I believe focusing on the one works against the other as I'll explain in a moment.

The essence of both models is the belief that human characteristics should be taken seriously in system affairs – something that isn't likely to happen by itself. The default condition is systems that bite – and as we all know, there's no shortage of those. Let's call this core belief the *HF/E philosophy*. Where the two models start to diverge is over the best strategy for getting the rest of the world to buy into this philosophy.

The unique discipline model suggests that we do it by establishing HF/E as the one official headquarters for this philosophy. We proclaim ourselves the one-stop shop for valid knowledge and expertise on human-oriented design, and get other disciplines –along with educators, corporate decision makers, politicians, the media, the courts, and the public – to recognize it. Once they've accepted our discipline's legitimacy, it's just a matter of selling them on the practical merits of what we're peddling (e.g., the "good economics" pitch). But unless we first make it as a unique discipline, this argument goes, HF/E will be doomed forever to an existence on the fringes of respectability. We'll remain a bunch of outcasts manning pooper-scoopers and competing with charlatans for the occasional crumb that designers and decision makers toss our way. Our world vision becomes a pipe dream.

By contrast, the shared philosophy model focuses on selling the HF/E philosophy through disciplines that are already well recognized – or coming to be – and the more the better. Think of it in theological terms. Instead of spreading the gospel by founding a new denomination, you do it Billy Graham style, welcoming any and all comers to your revival meeting – hoping for a lot of conversions. In our case, this means drawing people of all disciplinary faiths into our big tent. The more the merrier and the more of the HF/E gospel they take away with them, the better. But we don't insist that they abandon their faith in favor of ours, or earn a certificate in order to qualify as disciples. Mostly we just want them to understand and value our core philosophy, and to recognize that it's shared by many disciplines, all of which contribute importantly to user-oriented design. We'd like them to appreciate their limitations (as we should ours).

With this basic distinction in mind, let's dig a bit deeper into the implications of the respective models. The unique discipline view is necessarily about boundaries and turf: defining it, controlling it, defending it, and promoting it. To make it as a discipline, you have to have several things. First, you need a *content domain* that's distinguishable from others, that's widely accepted by those who identify with it, and that's recognized by the outside world. Second, you need a *critical mass* of people who are well versed in that content and identify with it. And finally, you have to have *institutional control mechanisms* like accreditation of training programs and credentialing of practitioners to reinforce the boundaries and ensure the legitimacy of those who represent it – especially those who market their services. You also want the folks who generate new knowledge to do so under your banner instead of some already recognized one. You can't afford to let incompetents give your discipline a bad name, nor can you hope to impress anyone if you have to rely on other disciplines for most of your substantive content.

Now, let's contrast these implications with what follows from the shared philosophy view. Since you don't lay exclusive claim to any turf, you don't need control mechanisms to protect it from infidels, or to vouch for its citizens. Rather, the idea is to make disciplinary boundaries as permeable as possible – to encourage human-oriented concepts, theories, and methods (along with those who develop and apply them) to move uninhibited throughout the territory. The goal is to get all kinds of people to grasp the power of this philosophy, to appreciate the wealth of scientific knowledge it has generated under a host of disciplinary flags, and to commit to advancing the cause – through science, practice, or merely public support. The assumption is that the synergy resulting from diverse disciplines converging on a shared philosophy enriches them all.

Let me make this implication a bit more concrete by focusing on our existing institutions – our professional organizations, scientific publications, professional conferences, and the like. They're important for promoting the HF/E philosophy under both models, but they do it in different ways. Under the shared philosophy view, they serve mainly to educate and lead rather than define and control. Their orientation is outward rather than inward; their perspective, inclusive rather than exclusive. In this model, an institution like HFES serves as the *big tent* under which folks from many disciplines can gather and share their respective knowledge. In the other model, it functions more like an *exclusive club*, reserved for those who've survived the screening process, taken the oath, and learned the secret handshake.

Now, as I said at the outset, we've never made a conscious choice between these two models, although we're clearly drifting toward the exclusive club concept. Lest you doubt it, let me quote from the current HFES Strategic Plan. Our first official objective is to "Articulate the definition and boundaries of the discipline of HF/E and its unique technology," and the first action item under that goal is to "deliver the message about the boundaries/definitions of the discipline to other organizations." In other words, stake out turf and put others on notice. I don't think that's quite what our founders had in mind, and I don't think it's the result of thoughtful consideration of where this path leads. Rather, it's the result of knee-jerk acceptance of the unique discipline argument. I'm going to suggest that we've become so fixated on the professional identity route that we've all but lost sight of our original destination: that ergonomically correct world. The means has become the end. And we've all but stopped considering the alternative route.

So at the risk of getting bombarded with ripe fruit, I'm going to explain why I think we're traveling the wrong path. In particular, I want to point out the practical problems that stand in the way of our really making it as a discipline, and by extension, that limit our ultimate impact. Let's review what it takes to be a viable discipline and see how we stack up. You'll recall the core requirements include a *unique content domain*, a *critical mass* of like-minded folks who identify with it, and *effective institutions* to control its boundaries.

What about *content*? Ours is large and diverse, and getting more so all the time. Some consider this our greatest strength. The problem is, our diversity and growth come not from within, but mostly by annexing new territory – pieces of well-established disciplines that we've recently discovered (like *Organization Theory* and *Psychometrics* and *Gerontology*), or newly emerging specialties that we want to co-opt (like *Cognitive Engineering* and *Computer Supported Cooperative Work*). Consider the topics in the 1997 Handbook: they run the gamut from architecture to toxicology, from eyeball anatomy to transportation systems. And if you compare this one to the 1987 edition, you'll find that their number is expanding rapidly, and virtually all of them – especially the newer ones – draw heavily on other disciplines.

Now, desirable as diversity may be in theory, simply accumulating pieces of other disciplines doesn't add up to a unique content. Raising our flag over a piece of *Organization Theory* and calling it *Macroergonomics*, for instance, doesn't make it exclusively ours. Nor does grabbing a hunk of *cognitive science* or *biomechanics* or *social psychology*. And the more we lay claim to, the more problems we encounter. As the former Soviet Union discovered in the geopolitical domain, it's not easy to mold a lot of diverse pieces together into a coherent whole.

I'm told that after the Society crafted its Strategic Plan, the HFES Executive Council struggled mightily to identify our unique content. They found it a daunting task, but ultimately settled on "interface technology." While this label certainly covers a lot of what we do, I know plenty our folks who don't consider themselves in the interface business, and a lot of outsiders who do – and who wouldn't take kindly to the idea that they're treading on foreign soil. So much for our *unique content*.

What about our *critical mass*? Do we have – or are we likely to attract – a substantial body of like-minded individuals who are well versed in our unique content and crave to be identified as HF/E professionals? Let's look at the Society's recent history. We have only about 4,700 members (including students and affiliates), and we've been pretty much stuck on that number for 15 years despite heroic recruitment efforts. In fact, the trend over the last few years has been slightly downward. Now, this tells me two things. First, we may be claiming a lot of new territory, but we aren't converting many of the natives. Second, we don't seem to be faring much better in growing our own – I've seen little evidence that the number of newly minted professionals from accredited HF/E programs is increasing substantially.

I hasten to add, however, that the demand for folks who do what we consider HF/E work *is* growing by leaps and bounds – and that demand is being satisfied largely by folks trained in the disciplines we've been trying to annex. Many of these people and the programs that train them just aren't keen on adopting our name or joining our club – and their employers could care less so long as they can do the job. Let me relate a personal episode that brought this reality home to me.

A while back the late Earl Alluisi and I worked on a survey of experimental psychology graduates who'd wound up in nonacademic jobs – we interviewed them, their employers, and their graduate program mentors. What we found was that most were doing what you'd consider HF/E work under all sorts of job titles, their employers were extremely happy with them, but very few wanted to be identified with human factors or ergonomics. Or, for that matter, with psychology. To them, human factors signified old-fashioned "knobs and dials"; ergonomics, "time and motion studies"; psychology, the shrinking of heads. They much preferred specialized labels like *HCI professional* or *usability analyst* or even *cognitive scientist*. Admittedly this was a biased sample from another decade, but my recent experience editing your journal and chairing the NRC Committee on Human Factors tells much the same story. Folks who are attracted to what we consider HF/E work – be it research or application – aren't exactly beating a path to our disciplinary door.

Or to the HFES. But while the Society may not be getting bigger, its membership – like its content – is certainly getting more diverse. And not just in areas of expertise but in positions on fundamental policy issues like whether we ought to sanction selected credentialing bodies, endorse government ergonomic regulations, or limit HF/E applications to things that are solidly grounded in science. Such differences of opinion may be stimulating, but they certainly don't do much for the *critical mass* requirement. A small cadre of diverse specialists who disagree on fundamental professional and scientific issues is hardly the formula for successful discipline building.

And that brings us to our third requirement – defensible, meaningful, *consensus-based control mechanisms.* Since this gets us into the business of credentialing, which I want to explore in depth momentarily, I'll simply point out that a large, diverse content domain shared with many other disciplines and populated by folks who don't all see eye to eye isn't real conducive to the creation of defensible control mechanisms.

So where does this put our chances of making it as a unique discipline? I don't know what the Las Vegas oddsmakers would say, but I sure wouldn't lay my money on it. We seem to be lacking in all three core requirements, and the trends are not encouraging.

Much of the huge, diverse content domain that we now include within our self-defined boundaries really belongs to other disciplines that don't seem inclined to cede it to us. It's they who are doing the cutting edge research in their specialties, and very often it's their students who wind up in the design roles we feel should be reserved for our kind. We complain, sometimes with good reason, that they aren't prepared – either by training or disposition – to do HF/E right. And what's worse, some of them don't even realize it. *But the question is, will tightening control over our small flock of sheep and distinguishing it from their vast herd of assorted goats improve the situation?* I doubt it, and I'll be very specific as to why. Let's return to the unfinished discussion of boundaries and quality control.

The standard means of exercising control over an applied discipline is *credentialing* – accrediting training programs and certifying individuals. Of course, we're already doing both to some extent, and a lot of you want to see more of it. Problem is, our growing diversity and lack of a unique content make it very difficult to define and enforce meaningful credentialing standards. If we expect programs and individuals to cover the waterfront, their knowledge will be a mile wide and a foot deep – offering little improvement over the ill-prepared outsiders we so roundly criticize. If, on the other hand, we sacrifice breadth for depth and tolerate wide variation in specialty profiles, how can we distinguish our sheep from their goats? Can we really say that a well-trained cognitive psychologist or computer scientist who doesn't know squat about ¾ of the topics in our Handbook, but recognizes that human considerations are important, is less qualified to design interface software than somebody who's got some HF/E credential for roughly the same content? I don't think so.

In my view, what credentialing generally does – unless it's very specific and rigorous and demonstrably valid – is encourage mediocrity at the expense of excellence. This is particularly true in cases like ours where the content domain is large and diverse. All you can do is set minimal, flexible standards that result in wide variation in the quality of those holding the credential. Programs with few other virtues will make sure they clear the accreditation bar; marginal individuals will do likewise with certification. In both cases, it's their only route to respectability, and it puts them on a par – officially – with the best in the field. If you want to see how this works, you need look no further than that paragon of institutionalized mediocrity, the *public education* profession. Will it spare society from *real* incompetents? Maybe a few, but at considerable cost. And the evidence of overall benefit is shaky. Personally, I've seen just as much dubious work – research, applications, and court testimony – from certified members of this profession as I have from the unwashed. And I've seen some damn competent work in all three areas from outsiders. I understand the concern about clueless computer scientists and physical therapists calling themselves *HF/E experts*. I just don't think credentialing will fix it.

Looking at it from another angle, I'm not sure expanding certification and accreditation would have much practical effect even if it actually did elevate quality. Why? Because you still have to convince the rest of society, and when you're small and new and competing against firmly entrenched disciplines that claim large hunks of the same turf, that's not easy to do. Especially when you don't even register on the public radar scope, and what you're pushing is basically a generalist product in a specialized world. What HF/E credentialing really does, in my opinion, is give club members a leg up on the competition in a few settings – like the justice system – where any official-looking credential is presumed to mean something. Usually by people like judges or managers who are clueless as to its significance.

Summing up the case against the unique discipline model, I don't think we have a well-defined domain that we can call our own, or much hope of creating one. We're small in numbers and holding – neither defectors from other disciplines nor bright-eyed students are beating a path to our disciplinary door. And that catchy name we've saddled ourselves with doesn't help much either. On the other hand, the HF/E philosophy is alive and well and beginning to take hold. If we weren't so hung up on the discipline thing, we could be giving it a real boost in the right direction. And one more thing, the further we move toward establishing our independence, the more distance we put between ourselves and the disciplines from which we draw the most vital new information. I've seen it happening already in material submitted to the journal, and it's not a pretty sight.

Okay, so I'm big on the shared philosophy model, but I haven't said anything about what, exactly, we'd do differently if we were to move in that direction. Now I will, starting with education and training. Would we scrap the excellent programs that now train folks in HF/E? Of course not. But we wouldn't waste our energy and theirs on some futile accreditation effort. We'd let the educators decide how to train them, and the market decide which programs produced the most useful talent. Instead of *dictating*, we'd *facilitate* – helping educators and students track the market and vice versa, and promoting information exchange among our many disciplinary constituencies. We'd continue to do surveys. And we'd publish educational *guidelines* (not *requirements*) – not just for HF/E programs, but for courses at all levels in all sorts of programs, from kindergarten to the doctorate to adult education. *If anything, we'd devote more attention to getting the HF/E philosophy into "foreign" fields than to protecting the purity of our own*. We'd put more emphasis on short courses, workshops, continuing education programs. Conversely, we might encourage our own HF/E programs to rely more heavily on other disciplines for content such as organizational behavior or psychometrics or cognitive psychology instead of [them] trying to do it all themselves.

Would we give up our HF/E publications and conferences? No way! These are, after all, the very institutions through which we can best promote and illustrate the HF/E philosophy and connect the diverse disciplines that contribute to it. We'd want to attract leaders in related fields to submit manuscripts to our journals and become avid readers. We'd want them well represented at our Annual Meeting. The wider the audience, the greater our influence. We might even want our Annual Meeting to feature more cross-discipline programming instead of just competing sessions that appeal only to specialists.

Would we continue to lead the effort to develop evidence-based HF/E standards or "best practices" documents? Why not? Who's better positioned than we are to convene the necessary experts to do this job right? But instead of searching primarily within our own boundaries, we'd start with the disciplines where the best information on the relevant human characteristics is found – be it biomechanics, sociology, medical ethics, cognitive engineering, or gerontology. This is a role, I believe, for which we are preeminently qualified.

And finally, what about the HFES? Would it wither and die if it abandoned its primary objective of defining and defending boundaries? Would it suffer irreparable damage if it quit trying so hard to get recognized as an exclusive club and focused instead on drawing the unwashed into our tent and enlightening them? I don't think so. To the contrary, I believe we might over time experience growth beyond our wildest dreams – and not just in numbers, but influence. Heretical as it sounds, I'd *relax* membership requirements and category distinctions rather than tighten them, making it available to almost anyone who could demonstrate a sincere interest in human-oriented design. If Society membership wasn't viewed as an implicit disciplinary credential, we wouldn't have to worry so much about who we let in. And if we didn't pretend to represent a unified disciplinary perspective, we'd have far fewer internal problems. Let me dwell on this point for a moment.

As President, I've spent much more time and effort this past year wrestling with issues caused by our disciplinary compulsion and related politics than on anything else. Members want the Society to speak loudly and with one voice on matters of great significance, like the OSHA ergonomics standards, the IOM medical accidents report, and the Florida voting debacle. The problem is, each of our constituencies wants us to say something different, and gets very upset if we don't. Issues like HFES's role in accreditation and certification, what we publish in our journals, our Fellowship status requirements, and even what we call ourselves are equally contentious – for exactly the same reason. *Most of these problems would vanish if we didn't try to cobble ourselves together into something we aren't.*

I've often wondered how we got ourselves so committed to this unique discipline model in view of what seem to me its obvious limitations. I don't have the answer, although I have strong suspicions. I think some of our folks truly believe it's the only way we can have a real impact on design. I respect their conviction but question their logic. Others are somewhat less altruistic: they realize that claiming and holding turf can give our folks a competitive advantage, and that's at least partially what's driving them. It's purely a guild thing. I respect their logic but question their motives. But I think the biggest reason of all is simply inertia. After all, we've got a name (of sorts), a clubhouse, some journals, an annual meeting, and a gaggle of folks with at least something in common – why *not* call ourselves a discipline? Most of us have just sort of assumed it's the thing to do without seriously questioning it or thinking through the implications.

To me, the bottom-line question for the field and the Society to ponder is one and the same: *Do we want to remain a relatively ineffectual mutual admiration society or make a difference?* If our parade is really about making the world a better ergonomic place, the unique discipline model won't get it: we're too small, too diverse, and too obscure. The only way we can reach that goal is by leading a movement within *a lot* of established and emerging disciplines – adopting some version of a shared philosophy model. This doesn't mean stepping aside or compromising values; just changing strategies. We can and should be the driving force within the HF/E movement, the main spreaders of the gospel. Integrating, facilitating, convening, and, as Dave and Peter so graphically put it, *leading* rather than cleaning up after what in fact *is* our parade.

If, instead, our parade is mostly about gaining for the chosen few a dubious edge on the competition, the unique discipline model may well succeed – but only at the expense of the loftier objective. Just let's not delude ourselves into believing it's a viable means to that noble end rather than the end itself. That's what's known in my discipline as *rationalization*.

So, that concludes my substantive remarks. I imagine many of you will remain unconvinced, and some may even be angered by my audacity in straying so far from orthodox thinking and spoiling the party. One would expect a Presidential address at a Society's annual celebration to be a rallying cry – a stirring pep talk that sends everyone away feeling good, fired up, and ready to do or die for the home team.

Let me assure you that my intent was not to offend or deflate. Quite the contrary, it was merely to stimulate serious thought at a most propitious time. As you may or may not know, our Strategic Plan is currently undergoing an intensive review – and I hope you'll pay close attention, letting your representatives know how you feel. If you're happy with the current emphasis on defining and defending boundaries, fine; after all, it's *your* parade. I just wanted you at least to consider another option – the one that once attracted enthusiastic marchers still has a lot going for it but has succumbed, I believe, to more parochial interests. If you all do that, and do it seriously, there'll be no lingering doubt over what this parade is really all about once the review is completed – whatever path it takes.