Science and the non-scientist

By R. L. Michaelson

This address was delivered by the retiring President of The British Computer Society, in London on 1 October 1963.

Because each of the three distinguished past Presidents of the British Computer Society has given a Presidential Address, it might be inferred that a tradition has been established and that I have no option but to inflict another Presidential Address on our members. This would be a wrong inference because the Society is too young yet to have traditions, and because the most important characteristic of a tradition is that it can be broken. The penalty for ignoring a tradition varies; if you wear untraditional, but sensible, clothes you will be thought eccentric and envied for your comfort; if you do not give a Presidential Address when one is expected you will be thought either to be cowardly or not to have anything worth saying (this may be thought if you do give an address). It is not to avoid these judgements that I decided to honour the apparent tradition, but because I feel that by so doing I would make it more difficult for any future President to deny to the Society a discourse of wisdom.

This decision was not easily made, because I am unable to talk in any depth about important computer applications which are already relieving us of many man-hours of drudgery or which are doing the otherwise impossible, neither can I describe the hardware developments which are being worked on in the world's electronic and pneumatic laboratories and their likely influence on computers. I can do none of this because a close association with electronic computers which started in 1949 ceased to be close some five years ago, and in this field a quinquennium currently covers nearly two generations of hardware, application or programming evolution.

Attitude of people to computers

My theme is therefore much more general, but I believe of great importance; it is the attitude of people to computers and the other technical wonders which our contemporary scientists are creating.

One implication of a theme such as "People and the things scientists create" is that scientists are not people. Few people hold such an extreme view, but many non-scientists do believe that a scientist is a man or woman who lives and thinks in a vastly different way from other people. The main difference is thought to be that the scientist shuts himself in a laboratory and plays with test tubes, microscopes, atoms, electrons and other invisible, inaudible, but not necessarily odourless things, in order to make discoveries which are unlikely to be of interest even to another scientist, but certainly have no bearing on the practical life which normal people have to lead.

This picture of the scientist is utterly false for the obvious reason that the discoveries he makes and the theories he propounds are concerned with the material of which this world is made and in which we all have to live.

Let us consider briefly the contribution which scientists have made to the most fundamental of all the variables which might be used to describe or classify an individual. There is an infinity of such variables, each being used for different purposes, for example one can classify an individual according to nationality or occupation or age or intelligence or preferred washing powder. None of them is as fundamental as the simple binary classification—alive or dead; indeed nearly all other classifications have little significance unless the individual can first be classified as alive.

About 20 individuals out of 1,000 classified as alive 100 years ago would change this fundamental classification within a year. Today the mortality rate is about 10 per 1,000, a fall of 50% on the average with a much higher fall for the newly born.

Without troubling too much about mathematical accuracy or statistical technique it follows from these figures, which are only broad undefined averages, that about 50% of the people alive today would not have attained their present ages if they had been born 100 years earlier.

What could be more important to that 50%?

The reason for this vast improvement in status is progress in science; obviously medical science has been a contributor, but so have many other scientific developments such as a greater understanding of hygiene, better heating and ventilating techniques, better communications which summon help more quickly, better transport which brings help more quickly.

Science also kills; examples of its weapons are bombs, motor cars, aeroplanes and some electrical domestic appliances. There is no doubt that if an account could have been kept with a credit to science for every life prolonged and a debit for every early death, the balance would be greatly in favour of science.

Here perhaps I should say that this testimonial to science is unprejudiced and unsolicited for I am not a scientist in the generally accepted sense of the word. It has, however, been my fate to meet and to collaborate

with many scientists over the last fourteen years, and I claim to speak on this subject with experience but not necessarily with authority.

Scientific language

A large area of the picture of the scientist as an individual remote from mundane affairs is painted by himself. Unfortunately when he makes a scientific statement he does so in a language which the non-scientist cannot understand; this is unavoidable in the first statement of a new scientific truth because the essence of science is to describe with precision the behaviour of some precisely defined something under precisely defined conditions; variation, probability or doubt may be included without invalidating the precision of the statement, because the extent of the variation, probability or doubt can be specified.

Such precision is unnatural to most of us and can only be achieved by a great effort of discipline which is not made, because it is not necessary, when we use language, either written or spoken, for the everyday purposes of life. So imprecise is our language that the scientist has to invent and define new words, which mostly remain unknown or incomprehensible to the layman, and therefore continue to serve their scientific masters. A few of these words become devalued because they pass into common parlance; "electronic" and "feedback" are recent examples of devalued words; "I.Q." and "computer" would be others if they had precise scientific definitions. The language of science has become so specialized that some statements are comprehensible only to the limited number of other scientists working in the same field.

Sometimes the scientific discipline becomes so ingrained that a scientist is unable to talk in an informal manner even in a colloquial context. I remember asking one scientist at a cocktail party if his son, aged four, was showing any signs of having inherited his father's mathematical brain. The reply was that the boy already understood the fundamental concept of our contemporary decimal number system; later I learned from the boy's mother that this meant the child could count up to ten.

Relationship of the scientist to society

I would contend that a discoverer of a new scientific truth has not discharged his obligation to society if he communicates his discovery only to other scientists and ignores the great majority of people. Of course the discoverer of a complex truth which he announces with scientific precision is not usually the appropriate person to translate it into the simple language necessary to give it universal comprehension. My contention is that the discoverer has a duty to society to see that this is done.

I have now touched on a crucial topic which must be explored—the relationship of the scientist to society. I must start by trying to be as precise as a scientist would be, by defining the two words "scientist" and "society." I have already used the word "scientist," in the singular or plural, about 20 times without a definition, and I doubt whether I have confused anyone; it is, if you think about it, profoundly difficult to define "scientist." It is perhaps even more difficult to state what the non-scientist means or thinks he means or ought to mean, when he uses the word "scientist." A possible definition, which at first glance seems adequate for my present purposes but is far from flawless, is the following:

> A scientist is a person who studies phenomena and produces rules explaining their causes and effects.

The trouble with this definition is that it classifies as scientists many people who are not; for example, an astrologer is a person who studies natural phenomena and produces rules explaining their causes and effects. The definition is not improved by insisting that the rules should accurately explain the phenomena, because many scientific explanations have been wrong, tentative or incomplete but nevertheless profound, useful and completely justifying the label "scientific."

My definition also includes anyone who studies his situation when caught in a cloudburst and has enough common sense to nullify its effects by coming in out of the rain. This implies that each of us is a scientist some of the time, and that to be a scientist it is not necessary to have a scientific degree.

It is also true that no scientist behaves in a scientific manner in every situation in which he finds himself, for like everyone else he allows himself to be influenced by emotional factors. In fact I would suggest that the scientific outlook is no more than a factual as opposed to an emotional outlook. In other words the discipline of science is no more than a means of making soundly based judgements, including the judgement that there is as yet insufficient knowledge on which to make a soundly based judgement; if this is accepted, then it follows that everybody is a scientist of lesser or greater degree because everybody makes some soundly based judgements.

A more authoritative definition of Science, with a large "S," is implied in the following extract from an article entitled "Evolution becomes self-conscious" by Sir Julian Huxley in the *New Scientist* for 20 June 1963:

> During the last three centuries of man's occupancy of the Earth, the most powerful agency for providing new knowledge has been Science. I use the word spelt thus with a capital letter, in the continental sense, as including all branches of organised rational inquiry into phenomena, including the natural sciences, the social and psychological sciences, and the various humanistic sciences, such as history and philosophy, aesthetics and comparative religion—and as opposed to all speculative and a priori philosophies and untested explanatory systems.

I am still trying to explore the relationship of the scientist to society and must now define "society," which is a great deal easier than defining "scientist."

The components of society are human beings; you

may distinguish one society from another and talk of county society or even The British Computer society, with a small "s," but what you mean is a group of people. When one talks about the scientist and "society" one still means a group of people, but in this case it is a large group; indeed it is the largest imaginable group and is therefore everybody. I would therefore formally define "society" as "everybody."

I would now remind you that a short time ago I demonstrated to your satisfaction, I hope, that everyone is a scientist of lesser or greater degree. Combining this with our definition of society we reach the remarkable proposition that everybody is a scientist and society is everybody; therefore to explore the relationship of the scientist to society is to explore the relationship of everybody to everybody. The first reaction to this conclusion may be that it is nonsense reached after a time-wasting piece of verbal trickery. Naturally I would not agree, for my belief is that the verbal trickery is introduced by the people who use a phrase like "the relationship of science to society" without realizing that, because they are using abstract nouns like "science" and "society," they are segregating one group of human beings from another on the basis of purely imaginary characteristics. I will continue to use the words "scientist" and "society" but I hope they will be understood as no more than symbols denoting some or all of the people some or all of the time.

There are two important corollaries to the proposition that scientists are people whose work affects other people. The first is that a scientist has no right to ignore the potential changes which his work may cause sooner or later, for good or for ill, in the lives of other people.

The second corollary is that the non-scientist in his role as the person affected must be able to judge the potential of a new scientific discovery and ensure that it is properly used and controlled.

A somewhat abstract way of summarizing both corollaries is to say that science has ethical obligations.

There is no doubt that we are today moving towards a world in which more people are acquiring more scientific knowledge, though not necessarily in depth. Evidence of this is in the amount of space in the national press which contains scientific news; the success of periodicals explaining science to the layman; the number of science programmes on television; the shortage of science and mathematical teachers, which is a consequence of the recognition that the requirement is high; the existence of a Minister for Science. The period of history starting with the end of World War II will, I believe, come to be recognized as the period of transition from a world in which scientists and non-scientists were segregated to one in which they are integrated.

All discoveries, inventions and disciplines which have allowed the human race to live other than in caves and jungles have been man-made and in some degree scientific, and it is only continued scientific research which will lay the foundation for future practical advances in technology.

Welcome the new

I have inflicted these somewhat vague generalities on you as a preliminary to making a plea in more particular terms. This plea is basically that anything new should be welcomed, studied and substituted for the old if it would be advantageous.

There are reasons why it is natural to cold-shoulder instead of welcome the new. First is that the something new did not exist when we were children, and we allow our early built-in prejudices to dominate our thinking. Typical of this attitude is the remark—"there is no need to improve this model, it has been successful from the time the first was made by my grandfather."

A lack of enthusiasm for the new is most marked when the new is complex and has to be learned. We are mostly lazy and, anyway as adults, reluctant to make any significant mental effort to understand a new technique. If the new is a substitute for something old we tend to believe that because we have had a successful period of usage with the old we might just as well continue with it. If the new is really new and nothing like it has ever existed, then we adopt it only if it is simple and its benefits are immediately apparent, or if it is expensive and it can be used, irrespective of its merits, as a status symbol.

Another factor delaying the adoption of the new is the resistance of those aged and middle-aged experts who are unwilling or unable to make the effort to become experts in the new techniques. Such resistance is caused by a fear that the adoption of the new device, method or procedure will damage the expert's personal status or power, and not by an unemotional study of the facts. Fortunately there are usually a few old dogs, prepared to learn new tricks, who will add their experience and perhaps money to youthful enthusiasm to pioneer practical applications of new technology.

I am not trying to suggest that every new device which comes on the market or every idea or prototype for which backers are sought is necessarily a good thing just because it is new. What does seem to be true is that most of us are prejudiced in favour of the existing and find it easy to reject the new for unsound reasons. One can understand that foolish objections should be made from sheer ignorance; witness the outraged lady, who on hearing of the plans for the then new-fangled telephone, protested to the Postmaster-General that she would in no circumstances allow the virtue of her three daughters, who slept in the attic, to be threatened by the immoral conversations carried by those wires over her roof. It is more difficult to understand why otherwise intelligent people should make ludicrous predictions about the effect of new inventions. Here are two extracts, which, like the outraged lady, may be found in that most recommendable book, Heinz Gartman's *Science as History*, published by Hodder and Stoughton.

The panel of experts from the Royal Society decided that it was dangerous for trains to exceed

thirty miles an hour, because the air would enter the compartments and the passengers would be suffocated.

Even in the 1800's doctors were issuing warnings against the dangerous pleasure of telephoning. It was even "proved" statistically that the mortality of telephone subscribers was three times that of other people, since telephoning caused diseases of the brain, chest and nerves.

The impact of science on the world today is much more significant than it was thirty years ago. There are at least three reasons for this.

(*a*) Fundamental discoveries are more frequent and their applications to a marketable product is more rapid.
(*b*) The difference in the efficiency of the new and old, if the latter existed at all, is much higher.
(*c*) The high cost of modern research and development and therefore the high cost of the product, at least in its early stages.

Re-equipment

We therefore find ourselves frequently faced with the alternatives of re-equipping ourselves at a high monetary cost in order to be efficient, or of trying to survive in our now obsolescent condition. This can be a personal dilemma, such as whether to install central heating, and will be resolved entirely on the basis of available cash and the other items competing for that cash; all such domestic and personal choices, amongst which one would include the purchase of a better television set or a better car, are critical only if one allows oneself to be carried away by the advertisements and if one is unable to resist the urge to keep up with the Joneses. Although new domestic and personal hardware is generally more efficient than the old, we should assess them not only on economic grounds but on whether or not we can enjoy a happy life without them and usually we can.

On a commercial level the situation is vastly different. Here we must keep up with the Joneses of all nationalities, for if we fail then the Joneses will put us out of business. This can happen by the marketing of a new product which renders ours obsolete, for example diesel locomotives and steam locomotives; it can happen by the development of a new method of production or other cost-cutting process which significantly cheapens the product, or by the adoption of a new marketing procedure.

We have to realize that we cannot escape from our modern scientific environment, and the only rational step is to recognize it, understand it and exploit it for the general good. We must examine our traditional institutions and procedures and even our traditional attitudes, and be prepared to adapt or change them in order to control and make good use of the continuously changing technical potential.

About this we can be mildly optimistic because the pressures to adapt are irresistible, and evidence of the yielding of tradition can be seen. The attempt to find a solution to the problem of the railways is an example, and the computer-inspired modern bank statement is another. My contention is not that we will not adapt ourselves but that we will not do so as fast as we should to avoid hardship and unhappiness, and that the fundamental reason for this regrettable slowness is a reluctance to question the rules established by our ancestors for operation in an environment so different from our own.

The context in which I am speaking should make it clear that I am not pleading for universal anarchy, but I feel it necessary to add that, in spite of a belief that our ancestral industrial and commercial customs and procedures should be questioned, nothing should be abandoned merely because it is not new. Although out of context I would like to say that I firmly believe in the preservation of traditional ceremonies and rites which serve as a rededication to sound ethical principles.

The B.C.S.

Some optimism should be generated by the existence of this Society, with a big "S," which is in reality a group of people with diverse skills and interests, but each of whom is or expects to be affected by the invention of electronic computing hardware applicable to commercial, industrial and scientific tasks.

The Society does good work in its specialist field of furthering the knowledge and influence of computers, but it is also playing a small part in the much greater task of bringing together the scientist and the non-scientist. So are a large number of other societies, although few of them have so diverse a membership as The British Computer Society. Other contemporary contributions to the widening understanding of the technical possibilities are made by the computer and automation committees which have been established by professional bodies and trade associations. Indeed it may be that the ubiquity of the computer will do more than any other single factor to force more and more people to learn how to make a scientific approach to their problems.

I shall conclude this address in the near future with a quotation which will emphasize my theme of the need for the non-scientist to make an effort to understand science. Before doing this a little time must be taken in suggesting that there exists at least one attitude of some scientists which needs changing.

This is the attitude that those who are engaged in a business activity of manufacturing or buying and then selling at a profit are participating in something sordid or at least demeaning. From this concept springs the judgement that business men are mercenary and somehow not as pure as the scientist or other academic. It is not necessary, I am glad to say, to examine the relative purity and altruism of business men and scientists to suggest that no one has a right to hold this view.

The simple fact is that we are all able to follow our separate occupations only because the processes of manufacturing and selling at a profit continue. This is

obviously true of those employed by industrial enterprises and such commercial undertakings as banks and insurance companies. It is true of the professional man whose clients are able to pay him only with money derived directly or indirectly from profitable transactions, either past or present. It is also true of the scientist living in the remotest ivory tower; the connexion between the selling at a profit and his income may also be remote and indirect but nevertheless exists. He may be living from an endowment made possible by commercial activity, or he may be a member of an institution with a Government grant or an income from invested funds. The Government grant is derived from taxes, all of which can be traced ultimately to a commercial activity. In the same way income from invested funds or property can be traced to business activity.

These economics may be naïve, but I think the point is fundamental, and that unless we are prepared to reject the basic monetary system of our culture we must recognize that we all live by the consequences of the buying and selling which we transact with each other.

That I have only generalized and rambled is due mainly to a lack of competence to do anything else; it is also partly due to the inherent characteristics of my theme which is concerned with the way in which people think, especially the way in which they think about other people whom they call by incompletely defined names.

As a last generalization I make the suggestion that there is a serious fault in our system of education. This fault is not that insufficient time is given to teaching scientific subjects, which some people would contend. It is that we do not teach an understanding that all progress has been and will be based on scientific discovery. Because of this omission we mature, both scientists and non-scientists, without an appreciation of the importance of controlling and exploiting science. I make this criticism without the ability to make a constructive suggestion other than that a step in the right direction would be the teaching of the history of science and scientists, with a minimum of technical detail, expressed in simple language; this might prove to be of more value and more interesting than the history of wars and politicians.

Conclusion

Almost to conclude, and by way of a summary of what I have tried to assert should be our attitude to science, I quote from an article entitled "Using the Scientific Mind" in the *Sunday Times* of 12 May 1963, by Lord Hailsham:

> It is not enough to buy a scientific mind. You must have it yourself if you wish to use it in others. We are moving out of the pre-scientific era and no one, not a managing director, not a Cabinet Minister, not junior counsel conducting a running down case, can afford to preserve a lot of useless lumber in his mental attics.

Before I stood up here some of my best friends were non-scientists and others were scientists; to avoid losing all of them I must state categorically that I have not said all non-scientists believe all scientists are unworldly pedants, nor that all scientists believe all non-scientists are mercenary ignoramuses. This is far from the truth, but I do believe that if we and our descendants are to live in an environment which will permit a fulfilled existence, both spiritual and material, then it must become as difficult to divide people into two mutually exclusive groups labelled "scientist" and "non-scientist" as it is today to classify an individual permanently as either a motorist or a pedestrian.

Book Review

Redundancy Techniques for Computing Systems, by RICHARD H. WILCOX and WILLIAM C. MANN, 1962; 403 pages. (London: *Cleaver-Hume Press Ltd.*, 80s.)

This book is based upon the Symposium on Redundancy Techniques held in Washington in February, 1962. Like all such books, consisting of more or less direct reproductions of the papers presented at a conference, it suffers from a number of disadvantages. Some of these are: non-uniformity of style, or more seriously, of notation; duplication of material; lack of coherent plan, apart from that imposed by the organizers of the original conference; and the absence of introductory material, however brief, without which the book cannot be self-contained either as a textbook or as a work of reference.

The book contains 21 papers, abstracts of two further papers, and a bibliography. About half of the papers treat the subject from the point of view of mathematical statistics or information theory. In these the presentation varies from a fully rigorous treatment to a bald statement of a series of results. Some results are given graphically or as numerical tables, others are stated in analytic form.

The style of the papers ranges between the extremes of the formal academic and the "chatty." While some readers may find this somewhat disconcerting, it can to a certain extent offset the tedium of reading the same basic argument in several different guises. It is inevitable that a certain amount of repetition will occur in such a collection of papers. What is interesting, however, is not that different arguments often lead to similar conclusions, but that occasionally similar arguments lead to differing conclusions. It is undoubtedly tiresome for the reader to have to learn a fresh notation for each chapter of a book, particularly since some authors omit to define all their terms. It must be assumed that it was in the interests of timely production that the editors declined the task of re-writing the mathematical expositions in a uniform notation.

Turning from the manner to the matter of the book, this is undoubtedly a valuable contribution to the science of com-

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