One

IDENTIFYING THE PROBLEM

Architect or Bee? was not really written as a book. It is more a mosaic of sketches and views, experience and analysis, worked out in practice and brought together on a rather unusual journey through sections of the engineering industry, trade unions, academic circles and political activities. Obviously, a closely argued conference paper with appropriate references is a very different matter from sections of a speech made from a plinth in Trafalgar Square, yet both are important aspects of the formation of the ideas in this book, and so both are contained here. Inevitably this means that the book is somewhat uneven, but it is based on actual experience – and there is nothing more uneven than the real world!

In spite of this unevenness there are, I believe, consistent threads running through the whole book. Firstly, an assertion that we must always put people before machines, however complex or elegant the machines might be, and, secondly, a sense of marvel and delight at the ability and ingenuity of human beings. I also hope that it will offer some insight into the way we work, and through our work the way we relate to each other and to nature.

It is not enough to identify problems clearly, sharply and sometimes polemically. We also have a profound responsibility to try to do something about them. I seek to be constructive.

Architect or Bee? starts with a critique of the technologies emerging out of the 1960s, and goes on to illustrate the way these concerns found expression in the Lucas Workers' Plan of 1976. This in turn laid the basis for further developments, including technology work at the Greater London Enterprise Board, popular planning in the GLC from 1983 to 1986, and human-centred technologies such as the EEC ESPRIT project, which started in May 1986. I would also like to think that in describing these projects the book highlights some of the problems associated with

They are led to believe that there is something great and profound going on out there, and it is their own fault that they don't understand it. If only they had a PhD in computer science or theoretical physics they would be able to grapple with the new theological niceties. The scientific language, the symbols, the mathematics and the apparent rationality bludgeon ordinary people's common sense. A concern that things simply are not right and could and should be otherwise is flattened into abject silence.

However, those who do have the appropriate 'qualifications' are also increasingly uncertain, confused and disoriented. The discussions among physicists about the limits of their existing 'objective' techniques and the concern among computer scientists about the implications of artificial intelligence all indicate that the fortress of science and technology in its present form is beginning to show gaping cracks.

Above all this, there is a seething unhappiness among both manual and intellectual workers because the resultant systems tend to absorb the knowledge from them, deny them the right to use their skill and judgement, and render them abject appendages to the machines and systems being developed. Those who are not directly involved in using the equipment are merely confused bystanders. I find a deep concern that individuals feel frustrated because their common sense and knowledge, and their practical experience, whether as a skilled worker, a designer, a mother, a father, a teacher or a nurse, are less and less relevant and are almost an impediment to 'progress'.[2]

Hopefully, we can examine the nature of this 'progress' and seek to identify alternatives which would constitute real progress and involve masses of ordinary people in the definition and construction of that progress.

COMMON SENSE AND TACIT KNOWLEDGE

I will refer frequently throughout the book to 'common sense'. In some respects this is a serious misnomer. Indeed, it may be held to be particularly uncommon. What I mean is a sense of what is to be done and how it is to be done, held in common by those who will

have had some form of apprenticeship and practical experience in the area.

This craftsman's common sense is a vital form of knowledge which is acquired in that complex 'learning by doing' situation which we normally think of as an apprenticeship in the case of manual workers, or perhaps practice in law or medicine.

I shall also refer frequently to tacit knowledge. This knowledge is likewise acquired through doing, or 'attending to things'.

These considerations are of great importance when we consider which forms of computerised systems we should regard as acceptable.

It is said that we are now approaching, or are actually in, an information society. This is held to be so because we are said to have around us 'information systems'. Most of such systems I encounter could be better described as data systems. It is true that data suitably organised and acted upon may become information. Information absorbed, understood and applied by people may become knowledge. Knowledge frequently applied in a domain may become wisdom, and wisdom the basis for positive action.

All this may be conceptualised as at Figure 1 in the form of a noise-to-signal ratio. There is much noise in society, but the signal is frequently dimmed.

Another way of viewing it would be the objective as compared with the subjective.

At the data end, we may be said to have calculation; at the wisdom end, we may be said to have judgement. Throughout, I shall be questioning the desirability of basing our design philosophy on the data/information part rather than on the knowledge/wisdom part. It is at the knowledge/wisdom part of the cybernetic loop that we encounter this tacit knowledge to which I will frequently refer.

The interaction between the subjective and the objective, as indicated in Figure 2, is of particular importance when we consider the design of expert systems. In this context, I hold a skilled craftsworker to be an expert just as much as I hold a medical practitioner or a lawyer to be an expert in those areas.

If we regard the total area of knowledge required to be an expert

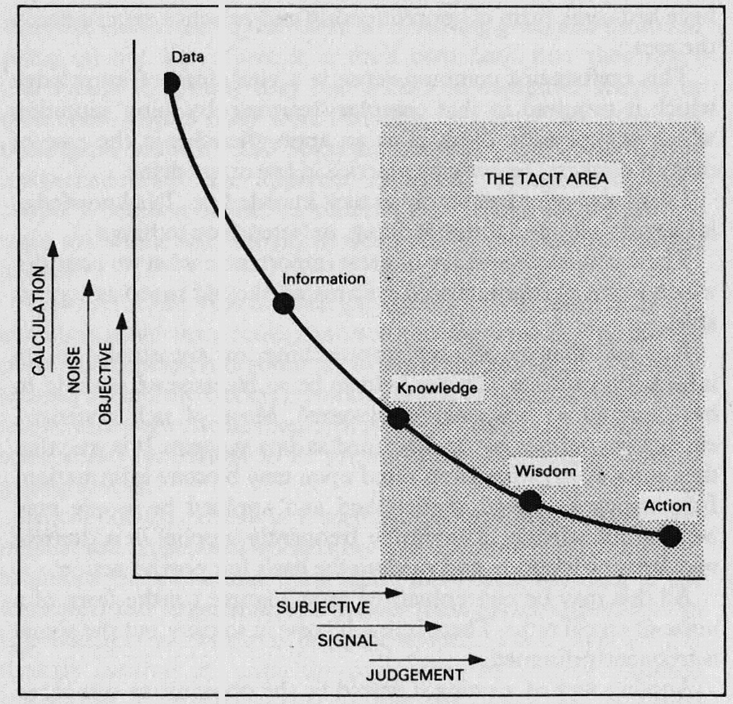

Fig. 1. The tacit area.

as that represented by A, we will find that within it there is a core of knowledge (B) which we may refer to as the facts of the domain, the form of detailed information to be found in a text book.

The area covered by B can readily be reduced to a rule-based system. The annulus AB may be said to represent heuristics, fuzzy reasoning, tacit knowledge and imagination. I hold that well-designed systems admit to the significance of that tacit knowledge and facilitate and enhance it. I reject the notion that the ultimate objective of an expert system should be so to expand B that it totally subsumes A. It is precisely that interaction between the objective and the subjective that is so important, and it is the concentration upon the so-called objective at the expense of the subjective that is

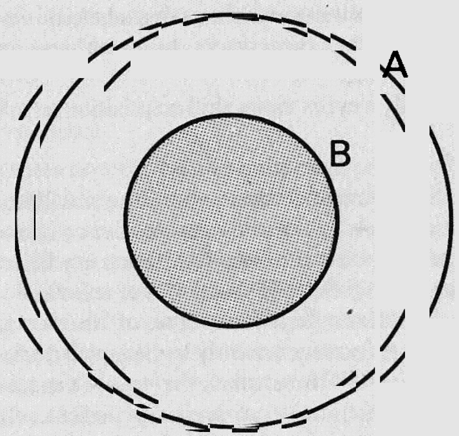

Fig. 2. The limits of rule-based systems.

the basis of the concern expressed in respect of existing systems design.

THE ACQUISITION OF SKILL

In the processes and systems described below, my concern is not merely about production but also about the reproduction of knowledge. I frequently refer to learning by doing, for as a result of this, human beings acquire 'intuition' and 'know-how' in the sense in which Dreyfus uses these. This is not in contradiction with Polanyi's concept of tacit knowledge; it is rather a description of a dynamic situation in which through skill acquisition people are capable of integrating analysis and intuition. Dreyfus and Dreyfus[3] distinguished five stages of skill acquisition: 1) novice; 2) advanced beginner; 3) competent; 4) proficient; and 5) expert.

I think learning-development situations are absolutely vital, and when someone has reached the knowledge/wisdom end of the cybernetic transformation (see Figure 1) and has become an 'expert' in the Dreyfus sense, they are able to recognise whole scenes without decomposing them into their narrow features. Thus I do not counterpose tacit knowledge, intuition or know-how against analytical thinking, but rather believe that a holistic work situation is one which provides the correct balance between analytical thinking and intuition.

Broadly stated, Dreyfus views skill acquisition as follows:

Stage 1 *Novice*

At this stage, the relevant components of the situation are defined for the novice in such a way as to enable him or her to recognise them without reference to the overall situation in which they occur. That is, the novice is following 'context-free rules'.

The novice lacks any coherent sense of the overall task and judges his or her performance mainly by how well the learned rules are followed. Following these rules, the novice's manner of problem solving is purely analytical and any understanding of the activities and the outcome in relation to the overall task is detached.

Stage 2 *Advanced Beginner*

Through practical experience in concrete situations the individual gradually learns to recognise 'situational' elements, that is, elements which cannot be defined in terms of objectively recognisable context-free features. The advanced beginner does it by perceiving a similarity to prior examples. The growing ability to incorporate situational components distinguishes the advanced beginner from the novice.

Stage 3 *Competence*

Through more experience the advanced beginner may reach the competent level. To perform at the competent level requires choosing an organisational plan or perspective. The method of understanding and decision-making is still analytical and detached, though in a more complex manner than that of the novice and the advanced beginner.

The competent performer chooses a plan which affects behaviour much more than the advanced beginner's recognition of particular situational elements, and is more likely to feel responsible for, and be involved in, the possible outcome. The novice and the advanced beginner may consider an unfortunate outcome to be a result of inadequately specified rules or elements, while the competent performer may see it as a result of a wrong choice of perspectives.

Stage 4 *Proficiency*

Through more experience, the competent performer may reach the stage of proficiency. At this stage the performer has acquired an intuitive ability to use patterns without decomposing them into component features. Dreyfus calls it 'holistic similarity recognition', 'intuition' or 'know-how'. He uses them synonymously and defines them as 'the understanding that effortlessly occurs upon seeing similarities with previous experiences . . . intuition is the product of deep situational involvement and recognition of similarity'.

Though intuitively organising and understanding a task, the proficient performer is still thinking analytically about how to perform it. The difference between the competent and the proficient performer is that the proficient performer has developed an intuitive way of understanding based on more experience while the competent performer is still forced to rely on the detached and analytical way of understanding the problem.

Stage 5 *Expertise*

With enough experience, the proficient performer may reach the expert level. At this level, not only situations but also associated decisions are intuitively understood. Using still more intuitive skills, the expert may also cope with uncertainties and unforeseen or critical situations.

Dreyfus and Dreyfus's essential point is to assert that analytical thinking and intuition are not two mutually conflicting ways of understanding or of making judgements. Rather they are seen to be complementary factors which work together but with growing importance centred on intuition when the skilled performer becomes more experienced. Highly experienced people seem to be able to recognise whole scenarios without decomposing them into elements or separate features.

My criticism of the prevailing systems-design methodology and philosophy and my rather scathing remarks about 'training' in Chapter 4 stem from the fact that in both cases they deny us that 'deep situational involvement'. Our development tends to be constrained within the novice end of the skill-acquisition spectrum.

I describe later those experiences, systems and machines which could reverse this approach and provide instead developmental situations to facilitate the acquisition of those attributes to be found at the expert end of the skill spectrum.

Many designers fear to discuss these concerns because they may be accused of being 'unscientific'. There is no suggestion in this line of argument that one should abandon the 'scientific method'; rather we should understand that this method is merely complementary to experience and should not override it, and that experience includes 'experience of self as a specifically and differentially existing part of the universe of reality'.[4] Such a view would help us to escape from the dangers of scientism which, as was once suggested, may be nothing more than a Euro-American disease.[5]

FRAGMENTATION

I take the Hegelian view that truth lies in the totality, and therefore, after considering some of the equipment currently in use, I will relate its effects to the labour process and try to give an overall view of what is happening. The equipment and processes described are not necessarily the most advanced or the latest in their field. They are chosen because they are typical of the kind of changes that are taking place in design.[6] The problems I describe within the design activity can be regarded as universal problems and also apply to computers in insurance, banks, newsprint industry or any other field.

The Equipment

The first system considered is an early forerunner of that which culminated in the mid 1980s in advanced CAD (computer-aided design) and complete CIM (computer-integrated manufacturing) systems. It conveniently serves to demonstrate the tendency to fragment, and ultimately replace, the functions of the draughtsman with computer-based equipment. In Britain and much of Europe up to the 1940s the draughtsman was the centre of the design activity. He could design a component, draw it, stress it out, specify the material for it and the lubrication required. Nowadays, each of these is fragmented down to isolated functions. The designer designs, the draughtsman draws, the metallurgist specifies the material, the stress analyst analyses the structure and the tribologist specifies the lubrication. Each of these fragmented parts can be taken over by equipment such as this automatic draughting equipment. (See Figure 3.)

With this equipment, the draughtsman no longer needs to produce a drawing and so the subtle interplay of interpretation and modification as the commodity was being designed and related to the skilled manual workers on the shop floor is being ruptured. What the draughtsman now does is work on the digitiser and input the material through a graticule or teletype. An exact reading is set of the length of each line, the tolerance and other details.

The design emerges as a set of 'instructions' which are expanded in the computer and then used to control a machine tool such as a jig borer, lathe or continuous path milling machine. The same 'instructions' may also be used to control a device which undertakes the inspection function. If perchance you want a drawing in order to show the customer exactly what they are purchasing – and that's the only reason you would bother to do it – then you can produce one on a master plotter very accurately. You can get a less accurate one on the microplotter, which also produces an aperture card.

What is important in all this is not only that the fragmented functions of the designer have been built into the computer, but that the highly skilled and satisfying work on the shop floor has been destroyed. It is no longer a question of supply and demand, of a slump or a boom; these jobs have been technologically eliminated.

The second system considered is a design system called manned computer graphics. In the past, skilled workers have had a tacit understanding of mathematics through their ability to analyse the size and shape of components by working on them.[7] More and

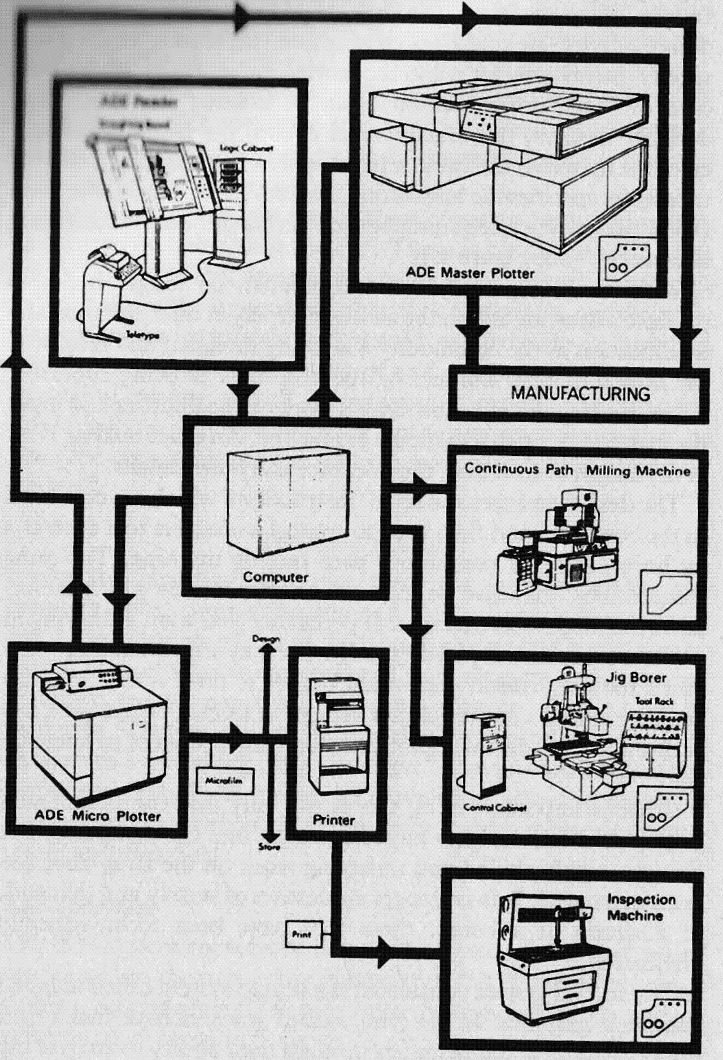

Fig. 3. ADE system for engineering data processing.

more, that knowledge has been abstracted away from the labour process and rarefied into mathematical functions. In diagrammatical form the function might, for example, be of the kind shown in Figure 4. This is a sinusoidal function and might represent the way a shaft is vibrating.

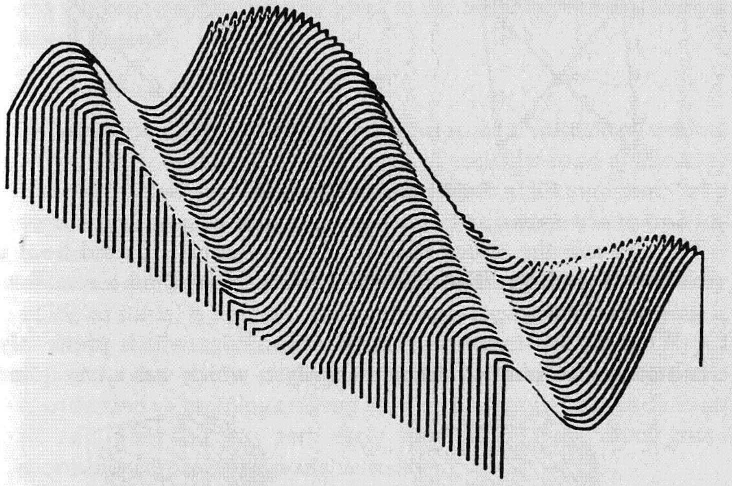

Fig. 4. Computer-produced solution space surface for $\mathrm{SIN}\,(8*(X-1)/X_L+1/4\,(Y-1)+1.0$.

A major application of manned computer graphics is in the field of structural analysis. Equations required for the analysis of the structure are automatically set up and are solved automatically upon request of the analytical output. Displacement, loads, shear and moments are computed and conveniently displayed for perusal. Changes of input conditions are easily facilitated and the corresponding output is displayed upon request. Constraining forces may be placed by using a light pen. Figure 5 shows the exaggerated displacement under load.

This equipment represents a deskilling process because it becomes possible to use designers and stress analysts with much less ability and experience than was previously required.

The windloading on a tower is a quite complex analysis problem.

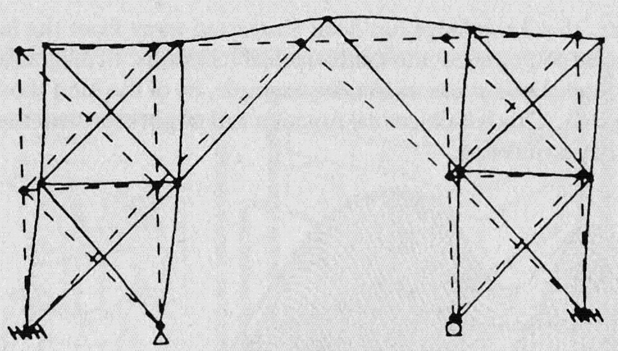

Fig. 5. Exaggerated displacement under load.

The stress in the structure as it distorts can be obtained from a computer package. The distortion is represented on a screen as shown in Figure 6.

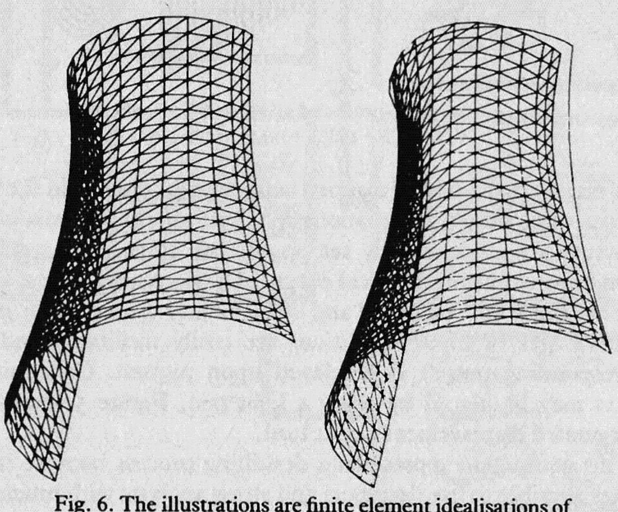

Fig. 6. The illustrations are finite element idealisations of a sectioned cooling tower. The right-hand picture shows the exaggerated distortion under wind loading.

What all this means is that the knowledge which previously existed in the mind of the stress analyst, which was taken home every night and was part of that person's bargaining power, has now been extracted from them. It has been absorbed and objectivised into the machine through the intervention of the computer and is now the property of the employer, so the employer now appropriates a part of the worker and not just the surplus value of the product. Thus we can say that the worker has conferred 'life' on the machine and the more he gives to the machine, the less there is left of himself.

Further Examples

Another possibility for the computer, as some architectural readers will know, is to analyse a whole range of variables in an application and plot the solution. This has been used by a planning agency who required a layout of villas on an island. The layout was to be such that each villa had the same amount of sunlight, garden space, view of the sea and many other variables. The computer handled this by doing an initial layout and gradually rearranging and modifying it to fit in with the terrain until it ended up with a final layout superimposed on the map of the island. It created a very dense distribution of buildings (in my view a grotesque thing to do to an island). This too was very early work. There are much more sophisticated packages available today.

In the medical field there are several uses of computer-aided design which in my view are positive although they bring with them a whole range of problems which I shall describe later.

One example is the use of a visual display unit in the design of equipment for ear protection. The VDU will display the form of soundwaves in the inner ear so your protective equipment can be modified until certain sounds are shown to have been eliminated. Theoretically, you could design ear-protection equipment that would allow human speech through and eliminate other forms of noise. You could in fact choose what you want to hear.

A second example is the use of a VDU in the design of artificial limbs. A graphic system will work out the area of the kneecap joint required for the particular individual for whom it is being designed. The whole structure can be animated on the screen. The person who was to use the limb could be involved in discussing its design before it was actually made. The limb could therefore be designed specifically for the patient unlike those ill-fitting objects which compel the patient to hobble along, often at an angle of ten degrees to the vertical, and still have a stench of Victorian charity about them!

A third example is the use of computers in the design of heart valves. Techniques originally developed to display characteristics in hydraulic circuits in aircraft are used to display the venturi and other characteristics and the blood flowing through the heart valve. Working interactively, it is possible to modify the valve-orifice diameters and other critical physical dimensions and display on the screen the resultant flow characteristics. It is thus possible to optimise the heart-valve design to meet the special requirements of the individual patient.

When one considers all these uses for the computerised equipment, one gets the immediate impression that it must automatically improve the whole creativity of the designer using it. However, there are enormous problems involved which require discussion. The complex communications that go on between human beings during problem-solving activities are being distanced by the computer and by the systems interfacing the people with the computer, and the consequences are very serious and far-reaching. Look at the job of a building designer, for example. In the past, when designing a building, he would go out to the site to see how the structure was progressing. He would discuss it with the site engineer and maybe modify the design. Now it is possible to have a VDU on the site so that visits are unnecessary because the designer and engineer can have a conversation via the equipment. The designer's drawings will be transmitted through British Telecom lines and displayed on the screen. The physical contact between the designer and the site is cut out. Apart from the design implications, the system will tie people down to the machine more and more and the break of getting away from the drawing office and on to the site, which was always one of the perks of the job, will no longer be necessary.

MODELS OF REALITY

Part of the skill of a draughtsman or a designer was the ability to look at a drawing and conceptualise what the product would look like in practice. That conceptualisation process is now also being eliminated by computers. There are systems capable of tracing round the profile of a conventional drawing which includes plan and elevation views, and producing an accurate three-dimensional representation of the object on the screen. The computer will rotate it through any angle for you when given instructions. This can be extended further in the field of architecture, for example. A visual display like the one described could be made of any proposed municipal building, and local people could look at it and see whether they approved of its design and its location. Normally, a plan of a proposed municipal building is available for inspection in the town hall, but to most people this means very little. It is intelligible only to an elite group.

By sensitive use of the computer in this way we could involve the community in deciding the kind of buildings it wanted.[8]

Theoretically, then, there is the potential for democratising the decision-making process. I will argue elsewhere, however, that the computer is in fact used to reinforce the power of minorities over majorities. There is a real danger in that the whole design process could be extremely manipulative. If you have a perspective view of a building on a visual display unit and you take the point of convergence far away, you can make the building look slim and attractive, disappearing into the horizon. On the other hand, if you take it close up you can make the building look like a high-rise block. Thus it is very easy to manipulate public opinion and I think that some architects are not beyond that sort of thing.

At an even higher level you can get what appears to be all the power of retrospective logic. Anyone who has worked as a designer will know that you get your best ideas afterwards, when you can see the mistakes you have made while designing. There are systems now used in the field of architecture which aim to provide the designer with some kind of retrospective logic. They were adapted from visual simulation techniques used to train astronauts in docking manoeuvres. The underlying principle is that images are presented thirty times per second on a colour visual display unit. Standard cues of depth are given as overlapping surfaces and the apparent size of the object is given as inversely proportional to the distance from the observer. This of course is the typical Western cultural way of presenting visual data of this kind.

In computer-aided architectural design, each building and object is defined in its own three-dimensional coordinate system. These are then presented as a hierarchical structure of coordinate data. This means that all the existing buildings can be input as data structure and the new building to be designed is shown within the context of the existing architectural arrangements. The VDU can give the user the illusion of walking towards a building that does not yet exist. One can experience the sensation of going inside the proposed building and looking out at the existing buildings. One can take windows out, move them about, enlarge the entire building and take it right outside the proposed site. The aim is to assess the total effect of the new building on the whole environment before constructing it. There are already grounds for believing, however, that images of reality as presented in that form are still very different from the actuality. When the building is erected you can get a sort of ghettolike prison atmosphere which is not apparent on the screen.

Quite apart from the destruction of the creativity the worker used in doing the job, what must be of concern to all of us is where the next generation of skills is coming from, skills which will need to be embodied in further levels of machines. The feel for the physical world about us is being lost due to the intervention of computerised equipment and work is becoming an abstraction from the real world. In my view, profound problems face us in the coming years due to this process.[5] If human beings increasingly work with models of reality rather than with reality itself, and are thereby denied the precious learning process which flows from it and the accumulation of tacit knowledge, the problems are likely to be significant and have been discussed by writers of widely varying 'political stances'.

Two

THE CHANGING NATURE OF WORK

RATE OF CHANGE

In spite of the power of computer equipment to do some really good work, it brings in its wake all the problems which high-capital equipment brought to manual work at an earlier historical stage. Firstly, it shares with all other equipment historically an ever increasing rate of obsolescence. Wheeled transport existed in its primitive form for thousands of years; Watt's steam engine was working for over 100 years after it was built. High-capital equipment in the 1930s was written off after twenty-five years and equipment of the latest kind will be obsolete in three or four years' time. Economists would say that this shows the increasingly short life of fixed capital.

Further, when viewed historically, it will be seen that the total cost of the means of production is ever increasing. This is in spite of the reduction in the cost of hardware. While these costs are reduced dramatically as computerised systems are miniaturised, the total cost of the system, including the plant and the processes which the hardware is used to control, is increasing. The most complicated lathe one could get 100 years ago would have cost the equivalent of ten workers' wages per annum. Today, a lathe of comparable complexity, with its computer control and the total environment necessary for the preparation of the software and the operation of the machine, will cost something in the order of 50 workers' wages per annum. This is frequently forgotten when people talk about microprocessors, and you are almost given the impression that you could fly the Atlantic on a chip, that you could excavate the foundations of buildings or process chemicals (even food) with microprocessors in isolation.

A discernible feature of modern equipment of any kind is the rate of change that is now driving us along at an incredible tempo.

Over the last century alone, the speed of communication has increased by 10^7, of travel by 10^2, of data handling by 10^6. Over the same period, energy resources have increased by 10^3 and weapon power by 10^6. We are being drawn into a tremendous technological inferno, and it means that the knowledge we have and the basis upon which we judge the world about us are becoming obsolete at an ever increasing rate, just like the equipment. It is now the case in many fields of endeavour that simply to stand still, you have to spend 15 per cent of your time updating your knowledge. The problems for older workers are enormous.

There is a mathematical model justifying this.

Suppose S represents the total stock of useful theoretical knowledge possessed by an engineer.
F the fraction of this knowledge which becomes obsolete each year.
R the fraction of his working time devoted to acquiring fresh theoretical knowledge.
L his learning rate.
Then $LR = FS$.

Assuming S is constant and equal to the stock of knowledge with which the engineer left university and that his average rate of learning remains the same as it was during his three-year university course, and assuming also that 5 per cent of his knowledge becomes obsolete each year, the equation becomes:

$$R\frac{S}{3} = 0.05\,S \quad \text{whence } R = 0.15 \text{ or } 15\% \text{ of working time.}$$

As might well be expected, the number of journals to be studied is also increasing. This was shown by Hilary and Steven Rose in 'Science & Society' (Figure 7).

In some fields, the rate of obsolescence is much greater than that indicated above, particularly in certain areas of computer application. As far back as 1972, Norman Macrae, deputy editor of the *Economist*, stated,[1] 'The speed of technological advance has been so tremendous during the past decade that the useful life of the knowledge of many of those trained to use computers has been

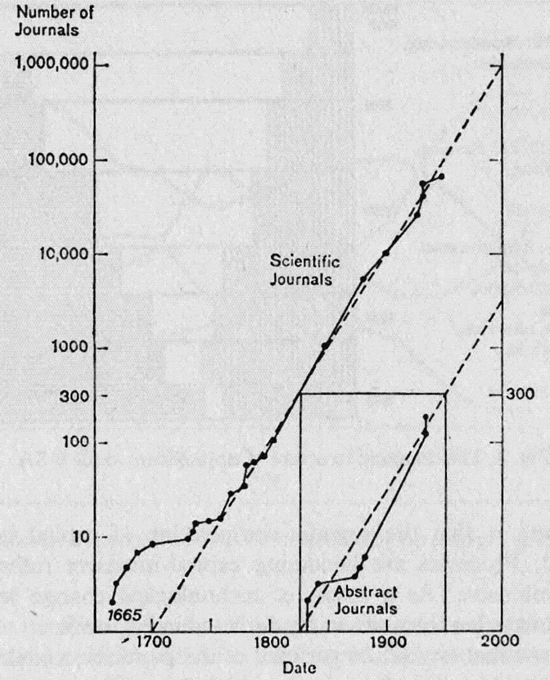

Fig. 7. Total number of scientific journals and abstract journals founded, as a function of date.

about three years.' He further estimated that 'a man who is successful enough to reach a fairly busy job at the age of thirty, so busy that he cannot take sabbatical periods for study, is likely by the age of sixty to have only about one eighth of the scientific (including business scientific) knowledge that he ought to have for proper functioning in his job'.

It has been said that if you could divide knowledge into quartiles of outdatedness, all those over the age of forty would be in the same quartile as Pythagoras and Archimedes. This alone shows the amazing rate of change, and the stress it places on design staff, particularly the older ones, should not be underestimated. What is

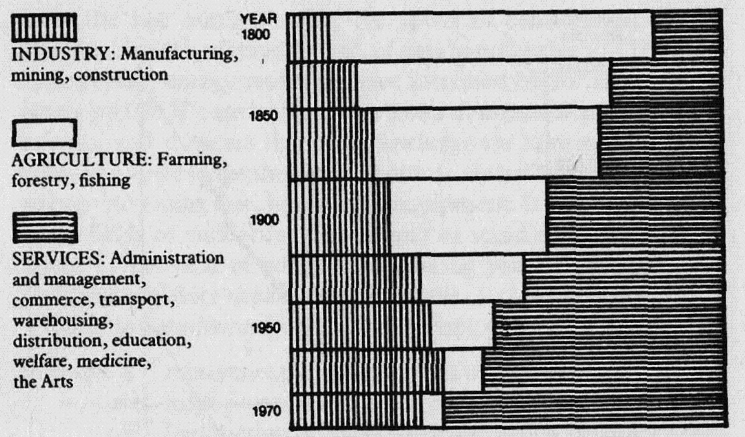

Fig. 8. The changing structure of employment in the USA.

happening is that the organic composition of capital is being changed. Processes are becoming capital-intensive rather than labour-intensive. As a result of technological change we have moved towards a form of society depicted in Figure 8.

It shows that around 86 per cent of the population of the USA was involved in agriculture in the early 1800s. This was subjected to mechanisation, the use of chemicals and then automation, so that now only 6 per cent of the population produces a far greater agricultural output than in 1800. There are automatic tractors that can feel their way round a field so that no human being is required. (It should be pointed out that the calorific value of the food so produced is actually less than the equivalent energy input if one takes into account the tractors, harvesters and chemicals. This is a problem society may have to address in the long term.)

During the same period, manufacturing industry was growing. Up to the 1950s and certainly the early 1960s it was subjected increasingly to mechanisation and automation. The proportion employed in manufacturing is now reduced to about 30 per cent and declining rapidly, while at the same time, the administrative, information and scientific area has been growing. (Figure 9.)

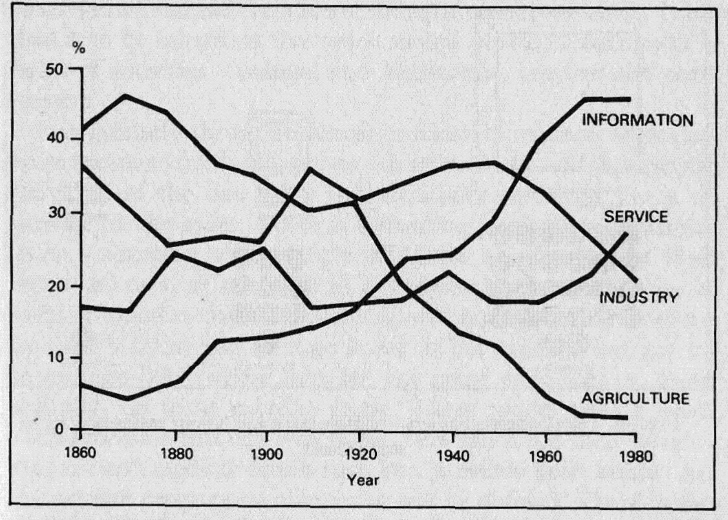

Fig. 9. Change in composition of US work force by percentage, 1860–1980.

That in turn is now being subjected to massive computerisation and automation which will do to this area what has been done to the others. We are confronted therefore with high and growing structural unemployment. More and more we are moving into a position where large numbers of people are being denied the right to work at all.

If we look at given sectors of industries, for example the manufacture of telecommunication exchanges, we will see that whereas it required twenty-six workers to produce one unit of switching power in the electro-mechanical field, with a first-generation electronic system it is ten, and with fully electronic systems in the year 1990 it will require only one worker. (Figure 10.)

Such productivity increases of 26 to 1 cannot be met by increases in production. Our inability to do so results from the constraints of energy and materials.

The fact that there is no work for large numbers of people may

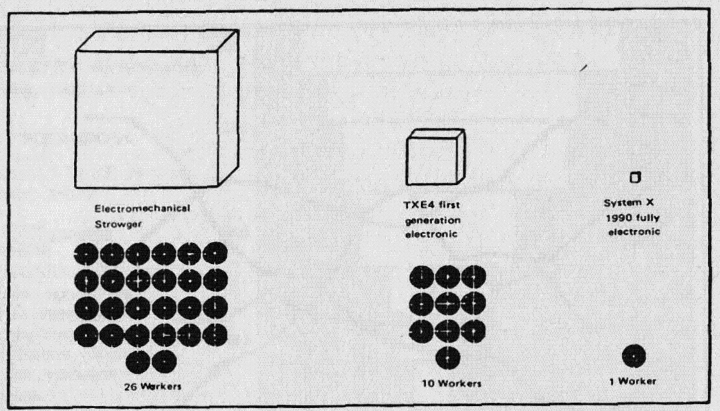

Fig. 10. Telephone exchanges – relative sizes and labour ratios needed to make them.

not seem too great a tragedy to some. Indeed, it has been said that if work were such a good and fulfilling activity, the ruling class would have monopolised it themselves. There is also the view that if people lose their jobs in traditional industries, it will simply liberate them to engage in more creative activities. During one of the closures in the steel industry, a middle-class member of one of the audiences I addressed asserted this so strongly that he must have believed it possible for a redundant steelworker to get a block of wood, carve a Stradivarius, find three of his mates who had done something similar and together play the late string quartets of Beethoven! What we witness is not freedom to enjoy leisure, but rather enforced idleness. The educational, cultural and other facilities simply do not exist in Britain to allow people to enjoy leisure fully, nor are the economic resources available, and leisure can often be a comparatively expensive activity. Furthermore, the cultural background gives no basis for this.

However, over and above this, I do hold that work is vitally important for human beings. I do not mean here grotesque alienated work like that on a production line at Ford's – the type of work developed for the last fifty years – but work in its historical sense

which links hand and brain in a meaningful, creative process. I also hold it to be important that work should provide a balance of a range of activities – manual and intellectual, creative and non-creative.

It is precisely these imbalances in forms of modern work that cause people to frantically pursue leisure activities and therapeutic activities on the one hand and artificially contrived forms of exercise on the other. There is something particularly ludicrous about a situation where people will drive into London in their individual cars, sit at a desk all day (denied even the exercise of walking round to collect documents, which they may now call up on their VDUs) and then go home in the evening and got on an exercise bike (where they are not going anyplace) or, more absurdly, on to an exercise spade. These spades have a small microprocessor through which the users can input their weight, age, sex and medical details such as a previous heart attack. An appropriate programme of exercise will be defined. There in the comfort of their own front room they can pretend they are digging. In those circumstances it is leisure and fun. If they were required to do a little digging in the course of their work during the day they would be downright insulted by having to do manual work.

Work also provides a learning, developing situation, and one through which we begin to identify ourselves. If, for example, you ask somebody what they are, they never say, 'I'm a Beethoven lover', 'a James Joyce reader' or even 'a keen footballer'. They will say, 'I'm a fitter', 'a nurse', 'a teacher' and so on.

What is being suggested here is that we need to develop new or holistic forms of work which link the human being as producer and consumer, and which provide a balanced range of intellectual and manual activities, given that these will vary considerably from individual to individual. Furthermore, the hours of work will have to become much more flexible and will also need to be linked with a shorter working week, longer holidays and more leisure time. These, it seems to me, are prerequisites for dealing with the growing structural unemployment which is now beginning to be evident in most of the technologically advanced nations.

It used to be suggested that, as jobs were lost in the manufacturing industries as a result of technological change, new jobs would become available in the white-collar and service sectors, but computerisation is taking its toll there as well. A recent report in France (the NORA report) suggested that modern computing technology in banks over the next ten years will reduce the staff in that area by 30 per cent. Similar figures apply to the insurance industry. A survey in West Germany suggests that by 1990, 40 per cent of the present office work will be carried out by computerised systems. The West German unions have translated this into figures and calculated that it would mean a staggering loss of 2 million out of West Germany's 5 million clerical and office jobs. Thus, not only will there be labour displacement in the manufacturing industries, but those displaced and their children will be in competition with growing numbers of other white-collar workers who have themselves been displaced by these systems.

It is being suggested that even if the EEC countries could maintain their present growth rates there would still be 20 million people out of work by 1988. Two issues arise here. First, we are underestimating how important meaningful work is to human beings.

Secondly, we should recognise that these jobs are not ours to give away. We are the guardians of those jobs for future generations, and in guarding them we can also ensure that there are jobs which are more fulfilling and creative than the ones we have now got. Once society begins to accept that the unemployment problems it is facing are structural rather than cyclical, there should then be the basis for mobilising public opinion, political and other movements to begin to redress the situation.

There is more to it than that, however, for those who are displaced by technological change are not the only ones seriously affected. What is happening to those remaining in work is really worth analysing.

THE PRESSURE IS ON!

It is widely recognised on the shop floor that technological change has resulted in a frantic work tempo for those who remain. Even at the Triumph plant in Coventry in the mid '70s, it was reckoned

that a worker was 'burned up' in ten years when working on the main track. The engineering union to which I belonged at the time was asked to agree that nobody would be recruited over the age of thirty, so that the last ten years would be from thirty to forty. The same kind of thing is happening in parts of the steel industry. The workers there have become party to an agreement which includes a medical check.

Now, in a civilised society, a medical check would be an excellent thing. If something were the matter with you it would be discovered, put right, and you would continue working. *This* medical check is a sort of industrial MOT test. Your response rate is worked out (like a diode) to see whether or not you are fast enough at interfacing with the equipment. If you fail, you are put on to second- or third-rate work. There is an established list of wages for those who have been so replaced because their reaction time was not fast enough.

For those who do not work in the automotive industry, it is difficult to appreciate how bad the situation has become and to what extent workers are even being paced by these computerised high-technology systems. In the section where they press out the car bodies in one car company, workers in 1973 were subject to an agreement on the make-up of their rest allowance. The elements are as follows:

Trips to the lavatory	1.62 minutes. It is computer precise; not 1.6 or 1.7 but 1.62!
For fatigue	1.3 minutes
Sitting down after standing too long	65 seconds
For monotony	32 seconds

And so the grotesque litany goes on.[2] The methods engineers located the toilets strategically close to the production line so that operators could literally flash in and flash out. What arrogance some technologist had, to be able to do that to another human being! If we have strikes in the automotive industry we must not be surprised. In my view they are right to strike against conditions of this kind, yet this is the kind of philosophy behind the design of much of the equipment produced for industry today.

TASK-ORIENTED TIME

Compare this itemised industrial agreement with the playwright J. M. Synge's account of the Aran islands, which provides us with a vivid example of differing notions of time and its relation to natural rhythms of work. In such natural rhythms fishing boats are launched to attend the tides, crops must be sown in spring and harvested in autumn, cows have to be milked when their udders are full and sheep guarded during lambing time. 'Few people, however, are sufficiently used to modern time to understand in more than a vague way the convention of the hours. And when I tell them what o'clock it is by my watch, they are not satisfied, and ask how long is left them before the twilight.'

Time viewed in this way is task-oriented, more understandable, acceptable and natural than timed labour. The worker deals with tasks which are comprehensible and universally agreed necessities. In activities organised in this manner, there appears to be less demarcation between work and life, between the human being as producer and as consumer. Social activities like harvest festivals are integral to the process. Social interaction and labour are intermingled during the working day, which extends or contracts according to the season and the work. Time lost because of bad weather on one day will mean labouring until dusk on another. Time is used according to the task in hand and the changing circumstances in which the task will be performed. It is not predetermined synthetically.

Such notions of time apply primarily in rural societies but are relevant also to craftspeople, writers, artists and those not totally subordinated to the industrial machine, where, in some cases, as in the example given above, the tasks of the worker are timed with a ruthless precision and are the source of continual industrial unrest. The counterproductive nature of treating human beings in this way still comes as a surprise to some outside observers. A report from Rome in early 1985 indicated that in a major car-manufacturing company with over 180,000 employees, 147,000 of whom were factory workers, 21,000 were missing on a Monday and there was a daily absentee rate averaging 14,000. Throughout the whole of the Italian economy, an average of 800,000 workers per day are absent out of a total of 20 million, according to a management association report. This was attributed to 'the increasing disgust of younger workers with the assembly-line discipline and the recent influx of untrained [sic] southern Italians into northern factories'.

EMPLOYERS CONSIDER ALTERNATIVES

Less spectacular, but even more significant as indicators, are the rising rate of production defects and errors, the widespread increase in accidents, absenteeism and turnover, and the very real difficulty, in spite of the bait of a financial anaesthetic, of finding adequate numbers of workers to submit to the degradation of the modern factory. New forms of work organisation in Sweden and Japan are indications that employers feel compelled to explore alternatives which provide some dignity and autonomy, however small, for the workers involved.

Even when the employer does succeed in finding sufficient 'human appendages', his problems are by no means at an end. The industrial worker, despite a class-ridden educational system which systematically seeks to reduce his or her expectations to an absolute minimum, and despite the continual bludgeoning by the mass media, still retains a degree of dignity and ingenuity which employers find alarming. Indeed, it is one of the greatest tributes to human dignity that the industrial worker obstinately refuses to meet the specification given by Frederick W. Taylor, 'that he should be so stupid and so phlegmatic that he more nearly resembles in his mental make-up the ox, than any other type'. (Taylor, the originator of 'scientific management', first announced his theories to American engineers in 1895. His system analyses and subdivides work into its smallest mechanical components and work activities and rearranges these elements into the most effective combination. Each component operation is timed by a stopwatch and a standard time is specified for each task. Taylor extended the division of labour into a division of time itself. The stopwatch had been used before Taylor, but only for entire jobs. He used it for each minute activity of the worker in isolation. In Taylorism, the stopwatch and its modern computer-based successors are the Bible.)

It is not surprising that human beings, when viewed in this way and when required to work within a productive process which treats them as oxen, should take what steps they can, however defensive, to assert their humanity. These attempts are not unrelated to the failure rate in parts of industry. It had reached such proportions by 1980 that something like half the equipment lay idle at General Motors' most modern factory where, as predicted by Gorz, the French political theorist, in 1976, 'the intensity and monotony of work surpasses anything previously imposed on assembly-line workers'.

So disgraceful was this waste of human and material resources that employers have felt compelled to accept improved health and safety standards and provide a less alienating environment. However, accidents and illnesses of a physical nature are replaced by psychological and stress factors to such a degree that employers seek aid from industrial psychologists, group technologists and job-enrichment specialists. These advisers in no way change the basic power relationships which give rise to the problems in the first place. It is, as a Lucas shop steward put it, 'like keeping people in a cage and debating with them the colour of the bars'.

A more acceptable solution from the employer's viewpoint, particularly in the case of errors and underutilisation of plant in the automotive industry, is to dramatically reduce the number of people required by replacing them with robots as we move towards the workerless factory. Robotic equipment is becoming cheaper and cheaper each year in comparison to the annual income of a worker employed in the same area. (See Figure 11.)

We may summarise by saying that human beings do need work, even if we redefine and restructure it significantly. Work provides people with an opportunity to express themselves at a number of different levels – to handle uncertainty, to cope with real-world situations, to demonstrate their skill and give expression to their creativity. Capital-intensive forms of production (labour-saving) are displacing human beings and rendering them more passive and

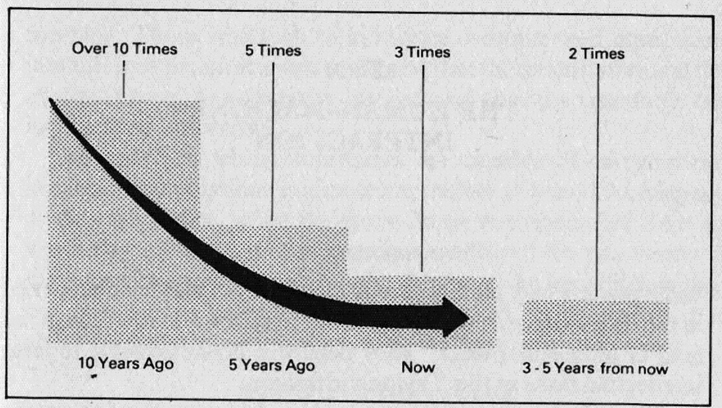

Fig. 11. The price of robots compared with the average worker's annual wage.

the systems more active. They pose serious problems for the reproduction of knowledge and the wider development of society. An attempt is made later to explore why this should be happening, and to look creatively at the alternatives which are still open to us.

Three

THE HUMAN–MACHINE INTERACTION

NONMANUAL WORK

Some readers may readily accept that this can, and has, happened in the field of manual work, but could not, or will not, occur in the field of intellectual work. They believe it is not possible to treat intellectual tasks in this Tayloristic fashion.

When a human being uses a machine, the interaction is between two dialectical opposites. The human is slow, inconsistent, unreliable but highly creative, whereas the machine is fast, reliable but totally noncreative.[1]

Originally it was held that these opposite characteristics – the creative and the noncreative – were complementary and would provide for a perfect symbiosis between human and machine, for example, in the field of computer-aided design. However, design methodology is not such that it can be separated into two disconnected elements which can then be combined at some particular point like a chemical compound. The process by which these two dialectical opposites are united by the designer to produce a new whole is a complex and as yet ill-defined and little-researched area. The sequential basis on which the elements interact is of extreme importance.

The nature of that sequential interaction, and indeed the ratio of the quantitative to the qualitative, depends on the commodity under design consideration. Even where an attempt is made to define the proportion of the work that is creative and the proportion that is noncreative, what cannot readily be stated is the point at which the creative element has to be introduced when a certain stage of the noncreative work has been completed. The process by which the designer reviews the quantitative information assembled and then makes the qualitative judgement is extremely subtle and

complex. Those who seek to introduce computerised equipment into this interaction attempt to suggest that the quantitative and the qualitative can be arbitrarily divided and that the computer can handle the quantitative.

The speed at which computers are capable of carrying out immense computations is almost impossible to grasp. As long ago as the early 1960s, when the space-frame centrepiece of Expo 67 was being designed, a computer was employed for two hours. A mathematical graduate could have performed the same calculations but would have taken about 30,000 years. This is equivalent to about 1000 mathematicians working for their entire lifetimes.

THE FASTER THE BETTER

Where computer-aided design systems are installed, the operators may be subjected to work which is alienating, fragmented and of an ever increasing tempo. As the human being tries to keep pace with the rate at which the computer can handle the quantitative data in order to be able to make the qualitative value judgements, the resulting stress is enormous. Some systems we have looked at increase the decision-making rate by 1800 or 1900 per cent, and work done by Bernholz, a CAD specialist and design methodologist working in Canada, has shown that getting a designer to interact in this way will mean that the designer's creativity, or ability to deal with new problems, is reduced by 30 per cent in the first hour, by 80 per cent in the second hour, and thereafter the designer is shattered. The crude introduction of computers into the design activity, in keeping with the Western ethic 'the faster the better', may well result in the quality of design plummeting. Clearly, human beings cannot stand this pace of interaction for long.

There are arrangements in some systems where there is a set length of time for handling the data (17 seconds is an example). If you do not comply with this you are downgraded to 'head-scratching status', as the systems designers call it. The anxiety of those involved can be measured, for they display all the signs of stress such as perspiration, higher pulse rate and increased heartbeat. Suppose the image is about to disappear from the screen and you haven't finished with it. You can hold or recall it, but everyone in the office knows when you have become a head-scratcher. You are being paced by the machine, and the pace at which you work is becoming more and more visible. There comes a time when your efficiency as an operating unit is inadequate.

HUMAN 'MATERIAL'

Since employers, particularly in non academic environments, will expect the computer equipment to be used continuously, the work can be extremely stressful. In 1975, the International Labour Office recommended safeguards against the nervous fatigue of white-collar workers, and an International Federation of Information Processing working party has suggested that mental hazards 'caused by inhumanely designed computer systems should be considered a punishable offence just as endangering the bodily safety'.[2] Thus, what may be a delightfully stimulating plaything for the systems designer may be the basis for a dehumanised work environment for the user.[3]

You may think that this is an exaggeration, so let us look at what some of the leading systems designers have had to say on the subject. I quote from the American academic Robert Boguslaw and I have checked this quotation because I could not believe it could be serious when I first came across it. I was assured, however, that this statement was made after a series of discussions with some systems engineers at a major US company.

> Our immediate concern, let us remember, is the exploitation of the operating unit approach to systems design no matter what materials are used. We must take care to prevent this discussion from degenerating into the single-sided analysis of the complex characteristics of one type of systems material, namely human beings. What we need is an inventory of the manner in which human behaviour can be controlled, and a description of some of the instruments which will help us achieve that control. If this provides us with sufficient handles on human materials so that we can think of them as metal parts, electrical power or chemical reactions, then we have succeeded in placing human material on the same footing as any other material and can begin to proceed with our problems of systems design. There are however, many disadvantages in the use of these human operating units. They are somewhat fragile, they are subject to fatigue, obsolescence, disease and even death. They are frequently stupid, unreliable and limited in memory capacity. But beyond all this, they sometimes seek to design their own circuitry. This in a material is unforgivable, and any system utilising them must devise appropriate safeguards.[4]

So according to Boguslaw, that which is most precious in human beings, the ability to design their own circuitry, or to think for themselves, is now an attribute which will quite deliberately be suppressed. The reason for all this is that the whole introduction of these systems is being based on the notion of Taylorism.

Frederick Winslow Taylor once said, 'In my system the workman is told precisely what he is to do and how he is to do it, and any improvement he makes upon the instructions given to him is fatal to success.'[5]

Taylor's philosophy is being introduced into the field of intellectual work and in order to condition us to this subordinate role to the machine and to the control of human beings through the technology, the idea is fed out in a whole series of very interesting and subtle statements. Take this one from the *Journal of Accountancy* in the United States. It talks about the idiosyncrasies of accountants and how you must control them when you introduce the computer. 'If you have got disgruntled employees, you should not allow them to start in case they might abuse the computer.' Now, I would be concerned if the computer abused the employees, but the whole philosophy is that it is the machine that matters and it is the human being who has to be modified or selected for suitability.

WHY DIMINISH THE HUMAN INTELLECT?

Professor Heath, a new-technology specialist of Heriot-Watt University, has taunted us about computers reaching an IQ of 120 'within the next two decades'. This was before 1980. He went on to say that we will then have reached the point where we shall have to decide whether they are people or not. I don't know what he thinks of people with an IQ of less than 120, but is this theological debate supposed to be a serious one? Professor Heath says, 'If they are people, the secular consequences are obvious. They must have the vote; switching them off would be classed as an assault and the erasure of memory as murder.'[6] Gradually we are being conditioned to think that this is a valid area of discussion.

Indeed, in Japan, over 50 per cent of industrial workers now fear the consequences of the introduction of robots for this very reason – not because they may lose their jobs but because the robots will be regarded as 'human beings' in the industrial-relations sense. In one company, the union has agreed that the robots may become union members and the company pays the subscriptions for those robot members.[7]

WHY SUPPRESS THE INTELLECT?

The more I look at human beings, the more impressed I become with the vast bands of intelligence they can use. We often say of a job, 'It's as easy as crossing a road,' yet as a technologist I am ever impressed with people's ability to do just that. They go to the edge of the pavement and work out the velocity of the cars coming in both directions by calling up a massive memory bank which will establish whether it's a mini or a bus because the size is significant. They then work out the rate of change of the image and from this assess the velocity. They do this for vehicles in both directions in order to assess the closing velocity between them. At the same time they are working out the width of the road and their own acceleration and peak velocity. When they decide they can go, they will just fit in between the vehicles.

The above computation is one of the simpler ones we do, but you should watch a skilled worker going through the diagnostic procedures of finding out what has gone wrong with an aircraft generator. There you see real intelligence at work. A human being using total information-processing capability can bring to bear synaptic connections of 10^{14}, but the most complicated robotic device with pattern-recognition capability has only about 10^3 intelligence units.

Why do we deliberately design equipment to enhance the 10^3 machine intelligence and diminish the 10^{14} intellect? Human intelligence brings with it culture, political consciousness, ideology and other aspirations. In our society these are regarded as somewhat subversive – a very good reason, then, to try and suppress them or eliminate them altogether. This is the ideological assumption present all the time. (See Figure 12.)

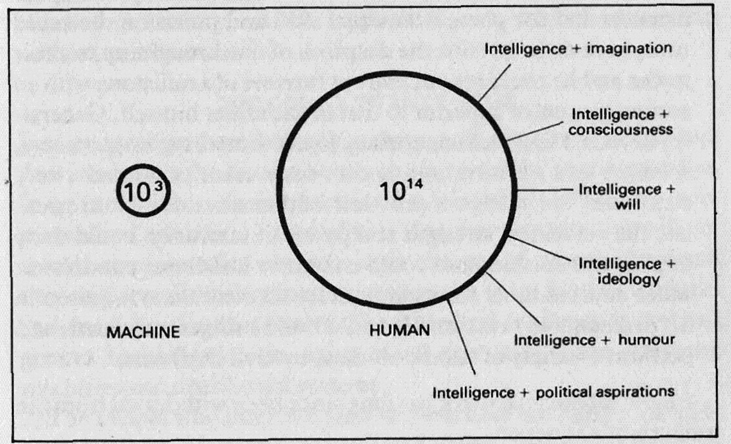

Fig. 12. Comparison of units of intelligence available for total information processing.

As designers we don't even realise we are suppressing intellects, we are so preconditioned to doing it. That is why there is a boom in certain fields of artificial intelligence. Fred Margulies, chairman of the Social Effects Committee of the International Federation of Automatic Control (IFAC), commenting recently on this waste of human brainpower, said:

> The waste is a twofold one, because we not only make no use of the resources available, we also let them perish and dwindle. Medicine has been aware of the phenomenon of atrophy for a long time. It denotes the shrinking of organs not in use, such as muscles in plaster. More recent research of social scientists

supports the hypothesis that atrophy will also apply to mental functions and abilities.

To illustrate the capabilities of human brainpower, I quote Sir William Fairbairn's definition of a millwright of 1861:

> The millwright of former days was to a great extent the sole representative of mechanical art. He was an itinerant engineer and mechanic of high reputation. He could handle the axe, the hammer and the plane with equal skill and precision; he could turn, bore or forge with the despatch of one brought up to these trades and he could set out and cut furrows of a millstone with an accuracy equal or superior to that of the miller himself. Generally, he was a fair mathematician, knew something of geometry, levelling and mensuration, and in some cases possessed a very competent knowledge of practical mathematics. He could calculate the velocities, strength and power of machines, could draw in plan and section, and could construct buildings, conduits or water courses in all forms and under all conditions required in his professional practice. He could build bridges, cut canals and perform a variety of tasks now done by civil engineers.[8]

All the intellectual work has long since been withdrawn from the millwright's function.

SQUEEZING THE MOST OUT

A decade ago, our then progressive Department of Industry produced a document that was called 'Man/Machine Systems Designing'. The different characteristics of the human being and the machine are related in this report and the different attributes listed. Under SPEED it says 'the machine is much superior' and of the human it says '1-second time lag'. Under CONSISTENCY it says of the machine 'ideal for precision' and of the human 'not reliable, should be monitored by the machine'. When it comes to OVERLOAD RELIABILITY it says of the machine 'sudden breakdown' and of the human being 'graceful degradation'.

One does not need to be a sociological Einstein to work out what is going on. The people who sell this kind of equipment make it

clear enough themselves. In the *Engineer*, which I believe most engineers read, there was an advertisement for a computer-aided design package which said, 'If you've got a guy who can produce drawings non stop all day, never gets tired or ill, never strikes, is happy on half pay with a photographic memory, you don't need . . .!'[9] Now we know why that package is marketed. It states it clearly in the advert. The *Economist* likewise spells it out clearly enough. It points out 'Robots don't strike' and it advises managements to introduce robotic equipment as a way of controlling militant work forces.[10]

TOO OLD AT TWENTY-FOUR

Just as machines are becoming more and more specialised and dedicated, so is the human being, the 'appendage' to the machine. In spite of all the talk in educational circles about wider and more generalised education, the reality is that many companies will not recruit an electronics engineer over the age of twenty-three and they will specify with minute precision the exact kind of engineer and specialisation they want. The historical tendency is towards greater specialisation in spite of all the talk about universal machines and distributed systems.

The people who interface with the machine are also required to be specialised. However, as indicated above, this is accompanied by a growing rate of knowledge obsolescence. It was recently pointed out by Eugene Wigner, the internationally acclaimed physicist, when talking about the way our education system is going to meet this problem of specialisation, that it is taking longer and longer to train a physicist. 'It is taking so long to train him to deal with these problems that he is already too old to solve them.' This is at twenty-three or twenty-four years of age.

The 'peak performance age' for people of particular specialisations is being worked out by a whole range of researchers. People of different age groups sit in front of a visual display unit solving problems of growing complexity. The 'response time' is plotted against the complexity of the task as shown in the graph (Figure 13). It can be seen that as the tasks become more complex, the response time of the older people shows a much more marked

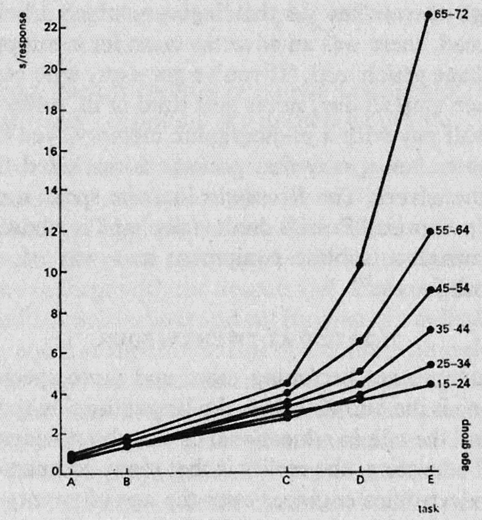

Fig. 13. Change of response time with age.

increase. So as a result of extensive scientific research, they have established that as people get older, so they get slower. Something I knew as a child of five when I looked at my grandparents!

It could be said, of course, that the older worker has a greater range of experience and knowledge and can therefore see more problems. But even if this were not the case, have we reached such a depraved stage that the natural biological process of growing old is now to be economically penalised? We design equipment to suit only the peak performance age. How many people over forty do you see in a high-pressure computerised environment, interfacing with the equipment? Yet there is nothing more natural and inevitable than growing old. 'We are all born of the gravedigger's forceps,' as Samuel Beckett once said.

The following graph (Figure 14) represents the results of experiments carried out in the USA. A group of workers (here they are scientific workers) of various ages are given some simple but

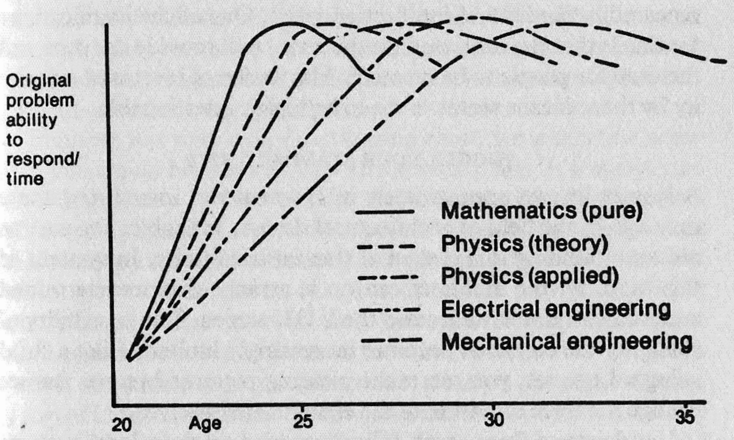

Fig. 14. Peak performance ages for various intellectual workers to achieve optimum systems interfaces.

original problems to solve. The rate at which they are solved is plotted against their age and a performance curve results.

It is found that a pure mathematician reaches his or her peak performance age at about twenty-four or twenty-five, a theoretical physicist at about twenty-six or twenty-seven and a mechanical engineer at about thirty-four. This last is the most durable profession. It happens to be my own and I am well beyond that age.

It is suggested that workers in these professions should be brought through a career pattern where they have their highest level of salary and status for a few years around their peak performance age. After that they should experience a 'career de-escalation'. This is no Orwellian projection of some grim future. It is with us here and now. Hitachi, whose chairman in Japan is seventy-three, wishes to get rid of those over thirty-five at its south Wales plant because 'older' workers are more prone to sickness, are slower, have poorer eyesight and are resistant to change.

If you have ever looked at a profile of a manual worker's pay related to physical prowess or work tempo, you will recognise that it is exactly the same kind of curve. In other words, it is now being repeated in the field of intellectual work. One of the justifications for this is that the increased productivity will provide the data and the time for people to be creative. The notion of increased creativity by these means seems to me to be highly questionable.

JUGGLE YOUR STANDARD BITS

A system known appropriately as Harness was introduced some time ago in the field of architectural design. It enables the user to reduce a building to a system of standardised units. In systems of this kind, all the architect can do is arrange the predetermined architectural elements around the VDU screen. The possibility of changing the elements becomes increasingly limited. Like a child using a Lego set, you can make pleasing patterns but you cannot change the form or nature of the elements themselves.

I understand from some colleagues who work in local government that if you use a system like Harness for about two years, you are then regarded by the architectural community as being deskilled, and have great difficulty in getting jobs. This puts the architect in a similar position to the manual worker who uses a specialised lathe and cannot then get a job doing universal and more skilled work.

Likewise, the print industry is now being transformed by the use of computers. Those in the industry are being assured that it will increase their creativity as well. Apart from the jobs permanently eliminated by these new technologies, and the conflict which arises (as at *The Times*), I would argue that much of the creative work within the print industry and the newspaper industry as a whole is being diminished. The new role of the journalists will be to work through a visual display unit where they prepare not merely the text but, through the computer, the typeface as well. It is suggested that since they can move sections of text around and modify sentences and paragraphs at great speed, their creativity will be increased. However, experience of these new technologies in the United States has already begun to show that it is resulting not in flexibility but in rigidity. This is because standard statements can be stored in the computer and called up when required to compose a story. This is done, initially, by counting, through the computer, the rate at which certain phrases or sentences occur. The most frequent ones are stored and treated as optimum sentences or 'preferred subroutines' which the journalist is then required to use. (We are obsessed with optimisation.)

Suppose you were a reporter writing about some political activity. You would have to lead in with a sentence like 'It was reported in Washington . . .' You couldn't say, for example, 'Those idiots got it wrong again' or some other unusual remark, because it would not be an available subroutine. The individual style of a journalist which gives journalism its colour and interest is gradually being diminished. There have already been complaints about some newspapers produced like this in the United States.

It is sometimes suggested that this is merely a transitional stage, a sort of industrial purgatory through which we must go on the way to a promised occupational land in which sophisticated systems and masses of data will present us with such a massive range of permutations and combinations that we can hardly fail to be highly creative. Such a view is like that of the professor with his 'contrivance' on the island of Laputa in *Gulliver's Travels*: 'Everybody knew how laborious the usual method is of attaining to arts and sciences, whereas by his contrivance, the most ignorant person, at a reasonable charge and with little bodily labour, may write books in philosophy, poetry, politics, law, mathematics and theology without the least assistance from genius or study.'

The 'contrivance' was a sort of idiot frame containing all the letters of the alphabet many times over. The pupils were trained to spin the frame continually and write down the words appearing. The logic was that if you did it often enough you could not fail to come up with something worth while – just the sort of argument used in respect of computers.

A further assumption is that 'logical' information-retrieval systems, from which we can call up dedicated packages of knowledge, will enhance our decision-making capabilities. However, as Professor Shakel of Loughborough University has pointed out, 'often human logic is not logical'.[11] Although he was talking about voice-input systems, the same may be argued for information-retrieval systems. If an intelligent human being goes to a library to look up reference material, he or she will invariably be diverted off into a series of avenues which, in terms of the dedicated knowledge required, might be regarded as redundant. Yet the richness of human behaviour and human intelligence comes about as a result of these wide bands of knowledge and experience. This apparently redundant information may subsequently be vitally important on entirely different projects and in apparently unrelated fields. We have reached a serious, if perhaps predictable, situation when *The Times* can announce in a headline, with apparent approval, 'The library where nobody browses and where automation is the chief assistant.'[12]

It is suggested that in these highly automated libraries, offices and work situations, human beings will actually enjoy conversing with machines more than with people. I have even heard it said that patients would rather converse with computers than with their doctors. This probably says more about the deplorable state of medicine in a technologically advanced society than it does for the elegance of our computer systems design. The rich interaction which comes from people discussing work problems with each other, and the open-ended intellectual cross-fertilisation which flows from that may well be lost, and human beings could become industrial Robinson Crusoes in an island of machines. This lack of human discourse and social contact, together with its effect on the functioning of the brain, has been discussed in a much wider context by the neurobiologist Steven Rose.[13]

It is typical of the narrow, fragmented and shortsighted view that our society takes of all productive processes that these important philosophical considerations are usually ignored.

LACK OF FORESIGHT

Some design methodologists have raised these questions[14] but the lack of any serious debate within the design community is itself indicative of the seriousness of the situation. One of the founders of modern cybernetics, Norbert Wiener, once cautioned, 'Although machines are theoretically subject to human criticism, such criticism may be ineffective until long after it is relevant.' It is surprising that the design community, which likes to pride itself on

its ability to anticipate problems and to plan ahead, shows little sign of analysing the problems of computerisation 'until long after it is relevant'. Indeed, in this respect, the design community is displaying in its own field the same lack of social awareness which it displays when implementing technology in society at large.

Undoubtedly, most of these problems arise from the economic and social assumptions that are made when equipment of this kind is introduced. Another significant problem is the assumption that so-called scientific methods will result inevitably in better design, when in fact there are grounds for questioning whether the design process lends itself to these would-be scientific methods.[15]

Related to this is one of the unwritten assumptions of our scientific methodology – namely, that if you cannot quantify something you pretend it doesn't actually exist. The number of complex situations which lend themselves to mathematical modelling is very small indeed. We have not yet found, nor are we likely to find, a means of mathematically modelling the human mind's imagination. Perhaps one of the positive side effects of computer-aided design is that it will require us to think more fundamentally about these profound problems and to regard design as a holistic process. As Professor Lobell, the American design methodologist, has put it:

> It is true that the conscious mind cannot juggle the numbers of variables necessary for a complex design problem, but this does not mean that systematic methods are the only alternative. Design is a holistic process. It is the process of putting together complex variables whose connection is not apparent by any describable system of logic. It is precisely for that reason that the most powerful logics of the deep structures of the mind, which operate free of the limitations of space, time and causality, have traditionally been responsible for the most creative work in all of the sciences and arts. Today it has gone out of fashion to believe that these powers are in the mind.[16]

CREATIVE MINDS

It is a fact that the highly constrained and organised intellectual environment of a computerised office is remarkably at variance with the circumstances and attributes which appear to have contributed to creativity in the arts and sciences.[17] I have heard it said that if only Beethoven had had a computer available to him for generating musical combinations, the Ninth Symphony would have been even more beautiful. But creativity is a much more subtle process. If you look historically at creative people, they have always had an open-ended, childlike curiosity. They have been highly motivated and had a sense of excitement in the work they were doing. Above all, they have possessed the ability to bring an original approach to problems. They have had, in other words, very fertile imaginations. It is our ability to use our imagination that distinguishes us from animals. As Karl Marx wrote:

> A bee puts to shame many an architect in the construction of its cells; but what distinguishes the worst of architects from the best of bees is namely this. The architect will construct in his imagination that which he will ultimately erect in reality. At the end of every labour process, we get that which existed in the consciousness of the labourer at its commencement.[18]

If we continue to design systems in the manner described earlier, we will be reducing ourselves to beelike behaviour.

It may be regarded as romantic or succumbing to mysticism to emphasise the importance of imagination and of working in a non linear way. It is usually accepted that this type of creative approach is required in music, literature and art. It is less well recognised that this is equally important in the field of science, even in the so-called harder sciences like mathematics and physics. Those who were creative recognised this themselves. Isaac Newton said, 'I seem to have been only like a boy playing on the sea shore and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me.'

Einstein said, 'Imagination is far more important than knowledge.' He went on to say, 'The mere formulation of a problem is far more important than its solution which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities and to regard old problems from a new angle requires creative imagination and marks real advances in science.'

On one occasion, when being pressed to say how he had arrived at the idea of relativity, he is supposed to have said, 'When I was a child of fourteen I asked myself what the world would look like if I rode on a beam of light.' A beautiful conceptual basis for all his subsequent mathematical work.

Central to the Western scientific methodology is the notion of predictability, repeatability and quantifiability. If something is unquantifiable we have to rarefy it away from reality, which leads to a dangerous level of abstraction, rather like a microscopic Heisenberg principle. Such techniques may be acceptable in narrow mathematical problems, but where much more complex considerations are involved, as in the field of design, they may give rise to questionable results.

> The risk that such results may occur is inherent in the scientific method which must abstract common features away from concrete reality in order to achieve clarity and systematisation of thought. However, within the domain of science itself, no adverse results arise because the concepts, ideas and principles are all interrelated in a carefully structured matrix of mutually supporting definitions and interpretations of experimental observation. The trouble starts when the same method is applied to situations where the number and complexity of factors is so great that you cannot abstract without doing some damage, and without getting an erroneous result.[19]

More recently, these questions have given rise to a serious political debate on the question of the neutrality of science and technology[20] and there is likely to be growing concern over the ideological assumptions built into our scientific methodologies.[21]

Four

COMPETENCE, SKILL AND 'TRAINING'

THE ORIGINS OF DESIGN

Around the sixteenth century, there appeared in most European languages the term 'design' or its equivalent. The emergence of the word coincided with the need to describe the occupational activity of designing. That is not to suggest that designing was a new activity. Rather, it was separated out from a wider productive activity and recognised as an activity in its own right. This can be said to constitute a separation of hand and brain, of manual and intellectual work and of the conceptual part of work from the labour process. Above all, it indicated that designing was to be separated from doing.

It is clearly difficult to locate a precise historical turning point at which this occurred; rather we will view it as a historical tendency.

Up to the stage in question, a great structure such as a church would be 'built' by a master builder. We may generalise and say that the conceptual part of work would be integral to that labour process. Thereafter, however, came the concept of 'designing the church', an activity undertaken by architects, and the 'building of the church', an activity undertaken by builders. In no way did this represent a sudden historical discontinuity, but it was rather the beginning of a discernible historical tendency which has still not worked its way through many of the craft skills, so that as recently as the last century, Fairbairn was able to give his comprehensive description of the skills of a millwright quoted in Chapter 3. To this day, there are many jobs in which the conceptual part of work is still integrated with the craft basis. The significant feature of the stage in question is, however, that separating manual and intellectual work provided the basis for further subdivisions in the field of intellectual work itself – or, as Braverman put it, 'Mental labour is first separated from the manual labour

and then itself is subdivided rigorously according to the same rules'.[1]

Dreyfus locates the root of the problem in the Greek use of logic and geometry, and the notion that all reasoning can be reduced to some kind of calculation. He suggests that the start of artificial intelligence probably began around the year 450 BC with Socrates and his concern to establish a moral standard. He asserts that Plato generalised this demand into an epistemological demand where one might hold that all knowledge could be stated in explicit definitions which anybody could apply. If one could not state one's know-how in such explicit instructions, then that know-how was not knowledge at all but mere belief. He suggests a Platonic tradition in which, for example, cooks, who proceed by taste and intuition, and people who work from inspiration, like poets, have no knowledge. What they do does not involve understanding and cannot be understood. More generally, what cannot be stated explicitly in precise instructions – that is, all areas of human thought which require skill, intuition or a sense of tradition – is relegated to some kind of arbitrary fumbling.[2]

Gradually, a view evolved which put the objective above the subjective, and the quantitative above the qualitative. That the two should and can interact was not accepted, in spite of a systematic effort and intellectual struggle to assert it. One important example of the attempt to do so was the work of Albrecht Dürer (1471–1528). Dürer was not only a 'Master of the Arts' but a brilliant mathematician as well, who reached the highest academic levels in Nuremberg. Dürer sought to use his abilities to develop mathematical forms which would succeed in preserving the unity of hand and brain. Kantor[3] points out the significance of Dürer's ability to put complex mathematical techniques to practical uses, while Olschki[4] compares his mathematical achievements with those of the leading mathematicians in Italy and elsewhere at that time. Indeed, some ninety years after Dürer's death Kepler was still discussing his geometric construction techniques. Alfred Sohn Rethel points out, in speaking of Dürer, 'Instead of, however, using this knowledge in a scholarly form, he endeavoured to put it to the advantage of the craftsman. His work was dedicated "to the young workers and all those with no one to instruct them truthfully”. What is novel in his method is that he seeks to combine the workman’s practice with Euclidian Geometry’. And further:

> What Dürer had in mind is plain to see. The builders, metalworkers, etc., should on the one hand be enabled to master the tasks of military and civil technology and of architecture which far exceeded their traditional training. On the other hand the required mathematics should serve them as a means, so to speak, of preserving the unity of head and hand. They should benefit from the indispensable advantages of mathematics without becoming mathematic or brainworkers themselves. They should practise socialised thinking yet remain individual producers, and so he offered them an artisan schooling in draughtsmanship permeated through and through with mathematics – not to be confused in any way with applied mathematics.[5]

It was said that on one occasion Dürer proclaimed it would be possible to develop forms of mathematics that would be as amenable to the human spirit as natural language. Thereby one could integrate into the use of the instruments of labour the conceptual parts of work, thus building on the tradition in which the profiles of complex shapes were defined and constructed with such devices as sine bars.

HOLISTIC DESIGN

Thus theory, itself a generalisation of practice, could have been reintegrated into practice to extend the richness of that practice and application while retaining the integration of hand and brain.

The richness of that practical tradition may be found in the sketchbook of Villard de Honnecourt, in which he introduced himself thus:

> Villard de Honnecourt greets you and begs all who will use the devices found in this book, to pray for his soul and remember him. For in this book will be found sound advice on the virtues of masonry and the uses of carpentry. You will also find strong help in drawing figures according to the lessons taught by the art of geometry.[6]

This extraordinary document by a true thirteenth-century cathedral builder contains subjects which might be categorised as follows:

1. Mechanics
2. Practical Geometry and Trigonometry
3. Carpentry
4. Architectural Design
5. Ornamental Design
6. Figure Design
7. Furniture Design
8. ‘Subjects foreign to the special knowledge of Architects and Designers’

The astonishing breadth and holistic nature of the skills and knowledge are in the manuscripts for all to see.

There are those who, while admitting to the extraordinary range of capabilities of craftspeople of this time, hold that it was a ‘static’ form of knowledge which tended to be handed unaltered from master to apprentice. In reality, there was in these crafts and in their transmission embodied dynamic processes for extending their base and adding new knowledge all the time. Some of the German manuscripts describe *die Wanderjahre* – a form of sabbatical in which craftspeople travel from city to city to acquire new knowledge. Villard de Honnecourt travelled extensively, and thanks to his sketchbook we can trace his travels through France, Switzerland, Germany and Hungary.

He was also passionately interested in mechanical devices, and one system he designed was subsequently adapted to keep mariners’ compasses horizontal and barometers vertical. He devised a variety of clock mechanisms, from which we learn ‘how to make the Angel keep pointing his finger towards the sun’, and he displayed extraordinary engineering skills in a range of lifting and other mechanisms to provide significant mechanical advantage. For example, he invented a screw combined with a lever with appropriate instructions – ‘How to make the most powerful engine for lifting weights.’

In all this, we see brilliantly portrayed the integration of design with doing – a tradition which was still discernible when Fairbairn described his millwright.

Villard was also concerned with 'automation', but in a form which freed the human being from backbreaking physical effort but retained the skilled base of work. In woodworking, he thought of a system of replacing the strenuous sawing activity – 'How to make a saw operate itself.'

He was profoundly interested in geometry as applied to drawings: 'Here begins the method of drawing as taught by the art of geometry but to understand them one must be careful to learn the particular use of each. All these devices are extracted from geometry.' He proceeds to describe 'How to measure height of a tower', 'How to measure the width of a water course without crossing it', 'How to make two vessels so that one holds twice as much as the other'.

Many modern researchers have testified to Villard's significant grasp of geometry. Side by side with this we find his practical advice to stonecutters on the building elements dimensions: 'How to cut an oblique voussoir', 'How to cut the springing stone of an arch', 'How to make regular pendants'. All of this latter, drawn from his own practical experience and skill, is a vivid portrayal of the integration of hand and brain.

Another thirteenth-century manuscript, written in the same dialect as Villard's, is still preserved and can be consulted in the Bibliothèque St Geneviève in Paris. Its author likewise concerned himself with mathematical problems: 'If you want to find the area of an equilateral triangle', 'If you want to know the area of an octagon', 'If you want to find the number of houses in a circular city'.

Throughout this period, the intellectual and the manual, the theory and the practice were integral to the craft or profession. Indeed, so naturally did the two coexist that we find practical builders (architects) with the university title like *Doctor Lathomorum*.

The epitaph of Pierre de Montreuil, the architect who reconstructed the nave and transepts of Saint Denis, runs, 'Here lies Pierre de Montreuil, a perfect flower of good manners, in this life a Doctor of Stones.'

I have cited these sketchbooks and quoted from these manuscripts in order to demonstrate that the craft at that time embodied

powerful elements of theory, scientific method and the conceptual or design base of the activity. In doing so, I am myself guilty of a serious error. I accept that a matter can only be scientific or theoretical when it is written down. I did not provide an illustration of a great church or complex structure and state that the building of such a structure must itself embody a sound theoretical basis, otherwise the structure could not have been built in the first instance.

We can also detect in the written form the basic elements of Western scientific methodology: predictability, repeatability and mathematical quantifiability. These, by definition, tend to preclude intuition, subjective judgement and tacit knowledge.

Furthermore, we begin to regard design as something that reduces or eliminates uncertainty, and since human judgement, as distinct from calculation, is itself held to constitute an uncertainty, it follows some kind of Jesuitical logic that good design is about eliminating human judgement and intuition. Furthermore, by rendering explicit the 'secrets' of craft, we prepare the basis for a rule-based system.

'RULES' FOR DESIGN

In the two successive centuries there followed systematic attempts to describe and thereby render visible the rules underlying various craft skills. This applied right across the spectrum of skills of people who were artists, architects and engineers, in the Giotto tradition, from the theory of building construction through to painting and drawing. Giotto's method was not precisely optical. The receding beams of the ceiling converge to a reasonably convincing focus, but it is only approximate and does not coincide with the horizontal line as it should, according to the rules of linear perspective. 'This method is, however, systematic and rational, factors which no doubt provided a powerful stimulus for the more fully scientific rule seekers of the subsequent centuries. Priority amongst those who preceded Leonardo in searching for precise optical laws in picture making must go to the great architect and erstwhile sculptor Filippo Brunelleschi.'[7]

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According to Manetti, at some time before 1413 Brunelleschi constructed two drawings which showed how buildings could be represented 'in what painters today call perspective, for it is part of that science which in effect sets down well and with reason the diminutions and enlargements which appear to the eyes of man from things far away and close at hand'. One of the paintings showed the octagonal baptistry (S. Giovanni) as seen from the door of the cathedral in Florence. The optical 'truth' was verified by drilling a small hole in the baptistry panel, so that the spectator could pick up the panel and press an eye to the hole on the unpainted side and, with the other hand, hold a mirror in such a way that the painted surface was visible in reflection through the hole. By these means, Brunelleschi established precisely the perpendicular axis along which his representation should be viewed.

By the use of a mirror, there was a precise matching of the visual experience and the painted representation, and this was to become Leonardo's theory of art and indeed his whole theory of knowledge.[8] He applied the same scientific methods to his architectural and other designs. One interpretation of these events is that they represented a significant turning point in the history of design and design methodology. Thereafter, there is a growing separation of theory and practice, a growing emphasis on the written 'theoretical forms of knowledge' and, in my view, a growing confusion in Western society between linguistic ability and intelligence (in which the former is taken to represent the latter). Furthermore, this is accompanied by a growing denigration of tacit knowledge in which there are 'things we know but cannot tell'.[9] We may cite that most illustrious embodiment of theory and practice – Leonardo da Vinci: 'They will say that not having learning, I will not properly speak of that which I wish to elucidate. But do they not know that my subjects are to be better illustrated from experience than by yet more words? Experience, which has been the mistress of all those who wrote well and thus, as mistress, I will cite her in all cases.'[10]

In spite of such assertions, the tendency to produce generalised, written-down, scientific or rule-based design systems continued to build on earlier work. In 1486, the German architect Mathias Roriczer published in Regensburg his deceptively named 'On the Ordination of Pinnacles'. In this, he set out the method of designing pinnacles from plan drawings, and in fact produced a generalised method of design for pinnacles and other parts of a cathedral. These tendencies had already elicited bitter resistance from the craftsmen-cum-designers whose work was thereby being deskilled.

THE MASTER MASONS

In 1459, master masons from cities like Strasburg, Vienna and Salzburg met at Regensburg in order to codify their lodge statutes. Among the various decisions, they decided that nothing was to be revealed of the art of making an elevation from a plan drawing to those who were not in the guild. 'Therefore, no worker, no master, no wage earner or no journeyman will divulge to anyone who is not of our Guild and who has never worked as a mason, how to make the elevation from the plan.' Of particular note is the exclusion of those who had never *worked* as a mason.

There is, as our German colleagues would put it, a *Doppelnatur* to this craft reaction. On the one hand there is the negative elitist attempt to retain privileges of the profession rather as the medical profession seeks to do to this day. On the other, there is a highly positive aspect, that of attempting to retain the qualitative and the quantitative elements of work, the subjective and the objective, the creative and the noncreative, the manual and the intellectual, and the work of hand and brain, embodied in the one craft.

The pressures on the master masons were twofold. Not only was the conceptual part of the work to be taken away from them, but those workers who still embodied the intellectual and design skills were being rejected by those who sought to show that theory was above, and separate from, practice. The growing academic elite resented the fact that carpenters and builders were known as masters, for example, *Magister Cementarius* or *Magister Lathomorum*. The academics attempted to ensure that '*Magister*' would be reserved for those who had completed the study of the liberal arts. Indeed, as early as the thirteenth century, doctors of law were moved to protest formally at these academic titles for practical people.

It would be both fascinating and illuminating to trace these tendencies through the five intervening centuries which take us up to the information society of computer-aided design and expert systems, but space does not permit it in this book. Suffice it to say that a number of researchers, drawing on historical perspective and viewing the implications of these information-based systems, conclude that we may now be at another historical turning point where we are about to repeat, in the field of design and other forms of intellectual work, many of the mistakes made in the field of craftsmanship in the past.[11, 12]

SEPARATION OF THEORY FROM PRACTICE

It is significant that J. Weizenbaum, a professor of computer science at the Massachusetts Institute of Technology, uses the subtitle 'from judgement to calculation' in his seminal work *Computer Power and Human Reason*[13] and highlights the dangers which will surround an uncritical acceptance of computerised techniques.

The spectrum of problems associated with them is already becoming manifest. They include such spectacular separation of theory and practice as to result in some of those who have been weaned on computer-aided design being unable to recognise the object that they have 'designed'. Epitomising this was the designer of an afterburner igniter who calculated the dimensions on the CAD screen and then set them out with the decimal point one place to the right (which, in an abstraction, is very much like one place to the left). He then generated the numerical control tapes with which deskilled workers on the shop floor produced an igniter ten times larger than it should have been.[14] Perhaps the most alarming aspect of this extraordinary state of affairs was that when confronted with the monstrosity, the designer saw nothing wrong with it.

Less spectacular, but in the long term of growing significance, is the design rigidity which menu-driven systems tend to produce. Harness, described in Chapter 3, is an example.

Given the scale and nature of these problems and the exponential rate of technological change within which they are located, it behoves all of us to seek to demonstrate, as Dürer did, that alternatives exist which reject neither human judgement, tacit knowledge, intuition and imagination nor the scientific or rule-based method. We should rather unite them in a symbiotic totality.

Unfortunately, there are few examples of such 'symbiotic' systems, that is, systems where the pattern-recognition abilities of the human mind, its assessment of complicated situations and intuitive leaps to new solutions are combined with the numerical computation power of the computer. They do exist in narrow specific areas, as Professor Howard Rosenbrock of the Control Systems Group at UMIST has demonstrated with the computer-aided design of complex control systems where the performance is displayed as an inverse Nyquist array on the screen.[15] I have myself described the potential for human-centred systems both in skilled manual work and in design.[16] Furthermore, in the technology division of the Greater London Enterprise Board, we have been working on the development of expert medical systems through our technology networks. (See Chapter 8.) These provide an interaction between the 'facts of the domain' and the fuzzy reasoning, tacit knowledge, imagination and heuristics of the expert, and no attempt is made to reduce all these aspects to a rule-based system – the system is seen as something that aids rather than replaces the expert.

An important breakthrough for these human-centred systems has been the recent decision by the EEC's ESPRIT programme to fund jointly a project to build the world's first human-centred computer-integrated manufacturing system.[17] Details of this are given in Chapter 8. Professor Rauner, Professor Wittowsky and their colleagues at the University of Bremen are developing an educational program which will go with the system since we are concerned not merely with production but with the reproduction of knowledge. Those working on the educational package are practical engineers themselves.

CONSUMER INCOMPETENCE

Efforts to deskill the producers can only become operational if they are accompanied by the deskilling of the consumers. The deskilling of bakers, for example, can come about only if that awful cotton-wool stodge in plastic packets is regarded as bread by millions of consumers. Highly automated and factory farming techniques are only possible if the public believes that there are only two kinds of potato, 'new' and 'old', that cookers and eaters are the only forms of apple, and if it cannot distinguish the taste of free-range poultry and eggs from those produced under battery-farm conditions.

The elimination of high-level skills in carpentry and cabinet-making is possible because large sections of the public do not appreciate the difference between a tacky chipboard product and one handmade with real wood and fitted joints, or between a plastic container and (say) an inlaid needlebox.

The concern for quality should not be misunderstood as an elitist tendency. Quite ordinary working-class and rural families used to pass pieces of furniture from one generation to another which, although simple, embodied fine craftsmanship and materials. A skilled joiner recently told me with great feeling how monstrous he found it that beautiful pieces of wood which could have been hand-turned and carved were being burned on a demolition site by 'builders' who couldn't distinguish between one piece of wood and another.

Given time, more and more sections of the community will lose the capacity to appreciate craftsmanship and goods of quality. As you 'break the refractory hand of labour', you must also break the refractory will of the consumer. To do so it is of course necessary to have ranges of accomplices. These are in advertising, marketing and, more generally, of the *Waste Makers* type. These accomplices are in relation to production and consumption, and there are also partners in crime in the areas of the reproduction of knowledge. The duality of the master and apprentice, teacher and student, has now been replaced by the trainer and the trainee. In large occupational areas, we no longer have education, we have 'training'.

APPRENTICESHIPS AND 'TRAINING'

An apprenticeship in the classical sense was not merely a process for the acquisition of technical skills. It was far more significantly the transmission of a culture, a way of understanding and respecting quality and acquiring a love of good materials. Even to this day, this cultural outlook is alive and well among craftspeople.

Ken Hunt is a master engraver whose work is sought worldwide. He served his apprenticeship with Purdeys, the London Sporting

Gunmakers, who arranged for him to work with Henry Kell, one of the specialist firms engraving the gun actions. This is how Ken Hunt described his work in 1987:

> I think engraving creates an intensely personal relationship between the work and the craftsman. It's the most lovely feeling when everything is going right; the cutting tool is working well, the steel doesn't fight you.
>
> To me, the beauty of a cut on steel with a graver is similar to the mark made by a quill pen on paper. It flows and tapers and is far removed from the straight line drawn by a ball point. I get so involved sometimes that I lose all track of time, and I get lost in all sorts of ideas, almost fantasies, I suppose. I find myself thinking of craftsmen centuries ago who worked metal in exactly the same way as I do now. Nothing has changed, neither the medium nor the tools.
>
> It may sound strange, but occasionally I get pieces back that I might have worked on in the sixties or even earlier, and I only have to touch them to recall exactly what I was doing and thinking when I was working on them all those years ago. Perhaps it's because each job represents and absorbs a large part of your life – maybe even your soul, who knows? Michaelangelo used to claim that all he did when confronted with a block of stone was to chip away and release the sculpture which was inside it, and I feel that too.

Ken does not use preliminary drawings of his intended work. Nor does he have tracing on the metal which will then be simply followed by the engraving tool. 'No, I go straight in and just do it. I've got an idea in my head as to how the finished work will look, but I don't believe in drawing it out carefully first.'

There is a tendency to regard such craft skills as being static and devoid of development. But the environment created by an apprenticeship encourages experimentation and innovation within a given tradition. Ken Hunt recalls that in his early days he would visit museums to admire and wonder at masterpieces from the past.

> I would stand and stare at a certain piece for ages wondering how it was done. Sometimes, I would even stay so long that the

wardens would begin to eye me with suspicion! I was intrigued with everything to do with metal work, though especially gold inlaying. I eventually worked out my own way of keying gold to steel using a series of undercut crisscross lines which have a dovetail effect.[18]

It would be unthinkable that craftspeople like Ken Hunt would waste materials or mishandle or damage tools and equipment. *All* of this was integral to the totality which was embodied in a traditional apprenticeship. It was also a process by which one learned, in a very practical way, the logistics of procuring such materials, treating them and forming them in a creative process which linked hand, eye and brain in a meaningful productive process. It embodied 'design by doing' – methods of work in which the conceptual aspects of work were integrated within the overall labour process.

Apprenticeships served to develop significant skills in the field of planning and coordination, and produced quite astonishing levels of ability in the handling of materials. I marvel at St Paul's Cathedral, for even given our modern means of project management and complex techniques for handling material, we may question whether anyone would be capable of constructing it today. Even if we could, what an infinitely greater task it was in the seventeenth century, given the limited equipment for lifting and placing the building elements into their locations.

The kind of apprenticeships those builders had gave them a deep sense of total machines as operating systems, epitomised by the vast knowledge of the great millwrights (see Chapter 3). It is true that with the introduction of Taylorism,[19] apprenticeships did embody almost anecdotal aspects, where considerable time was spent in making tea for others or in irrelevant activities, but that is not what we are addressing here; it is rather the great apprenticeships which produced those of the calibre described earlier in the chapter.

Against this richness and competence can be counterposed 'training'. The word is very apt in the modern context. My own hierarchy of verbs in terms of competence transmission would be

the following: you program a robot, you train a dog (or possibly a soldier), but for human beings you provide educational environments. Training produces narrow, overdedicated capabilities which are generally machine, system or program-specific. With the ever increasing rate of technological change, the 'knowledge' required to cope with a particular machine or system may be obsolete in a couple of years' time. The trainee is then lost, and requires further 'training'. Much of what now passes for 'training' is nothing more than a form of social therapy. Instead of putting people on Valium you put them on a training course. It is questionable whether you produce anything more than a slightly better-quality dole queue.

'Training' often hides a cruel deception. In some of the inner-city areas single-parent women on training courses are led to believe that if they can fiddle around with a BBC micro, they are then information technologists, and the multinationals will be beating the way to their door to offer them work. This complete misunderstanding of the levels of skill required for given activities in the real world, and the manner in which those skills are acquired – particularly diagnostic skills – is outside the range of this new moribund layer of 'trainers'.

Some companies have very competent training officers who themselves have actual knowledge of the processes involved. What I am referring to here is that new band of 'training advisers', 'training coordinators', 'training outreach workers' and 'training planners' who seem to believe that there is some separate activity called 'training' which transcends all other forms of professional knowledge. Some of the ones I have encountered seem to believe that if you've trained a Labrador to retrieve you can also train a nuclear physicist, and if you've trained somebody to make doughnuts in the catering industry, you can also train them to design a Rolls-Royce aero engine; it is, after all, just training! Because these people have no knowledge of the skills involved, they behave in a high-handed and arrogant fashion. Furthermore, because they are in a position to allocate funds, they are often able to impose their nonsense on people who could have provided a rich developmental environment.

The disadvantage of using this type of 'trainer' is twofold. They don't know what they are doing and are overpaid for doing it, and, more significantly, they prevent people who do have the skills and knowledge from enjoying the experience and gaining the dignity of transmitting it to a future generation. Some of the 'quality training schemes' set up by the progressive local governments are particularly hideous in this regard.

'TRAINING' AND DESTRUCTION OF SKILL

I have seen so-called training advisers and coordinators who wouldn't know one end of a building from another, travelling out in chauffeur-driven cars to building sites to decide whether they would let skilled building workers have trainees with them, and questioning them on whether they had been on this little course or that little course organised by 'trainers' like themselves. The fact that these workers had been passing their skills on to apprentices for years and that these apprentices had developed into people who produced real structures rather than long, boring, irrelevant reports was something they did not consider important. They even insisted on having, for a pathetic little 'taster' course in workshop practice, a massive report prepared which included many pages listing the tools the trainee would learn to handle. There were pages which stated 'The trainee shall be acquainted with the use of a flat file, a square file, a round file, a half round file, a triangular file . . .' and this continued until all the conceivable file forms one might encounter were listed. Every tool set likewise had to be listed. All of this was to prepare more reports, so that Filofax socialists, now calling themselves trainers, could satisfy themselves, by the sheer bulk of the report, that they had created a 'quality scheme'. All this was necessary because they hadn't the slightest idea what was going on. It really was a scorching example of 'Never mind the quality, feel the width'. A skilled person would simply have stated that the young person was capable of 'handling the tools of the trade'.

One 'training adviser' actually assured me that she had 'designed a building course' to produce a builder in one year. This was all the more extraordinary since she had never been near the building industry, had no idea of its skills, requirements or practices. It transpired that she was not talking about a builder at all, but rather somebody who could do a bit of bricklaying. The idea that a builder could construct a complete house, as skilled builders have done in the past – or can still do in many rural areas – was totally outside this person's range of experience or expectation. It is precisely because of these systems-trained so-called builders that we in Britain have had many of the failures in building construction which have resulted in miserable living conditions, accidents and, more recently, decisions to demolish and start again. New courses like this constitute a destruction of craft skills.

There is too the notion that such courses should be 'scientific'. These so-called scientific methods are held to be infinitely more important than the process of learning by doing or by working with and gaining knowledge from people who know what they are doing. In one case a group of skilled workers had to undergo a course on 'project management'. This had to do with the description of the project, the planning of the project environment, the preparation of the site, the procurement of the materials, the special tools required, the sequential steps to be taken and the assessment of the project outcome. The actual project or 'case study' which was subjected to this level of abstraction was 'repairing a tap' (changing a washer in one).

The lecture went on for nearly two hours of waffle. One of the course members, a ships engineer who had repaired high- and low-pressure, hydraulically and pneumatically operated valves, said he was so confused by all this 'theory' that he began to doubt whether in fact he would be capable of repairing a tap at all. He would, he said, have great difficulty in writing the long and boring account of how it was done. The fact that he could change a washer in a few seconds was regarded as quite irrelevant in becoming a qualified trainer by the lecturer, whose own background was in catering.

The whole attitude behind this form of training also shows that even 'progressive' local governments do put administrators and bureaucrats into positions of power and authority over those who can actually do things. When they talk about discrimination and equal opportunities, they certainly do very little to provide equal opportunities for manual workers and those whose knowledge of the world is experiential and real. I know of cases where after an interview for a job as a trainer a skilled craftsperson who had come from precisely the craft and industry involved and had answered every question absolutely correctly, if very briefly, was judged by the panel as having 'little to say'. When subsequently they interviewed a sociologist who hadn't the slightest idea of the skills involved, having never been near the industry, but could waffle on about theories of knowledge acquisition, the panel were most impressed. The sociologist got the job, and made a complete mess of it. This once again underlines the deep confusion between linguistic ability and competence.

Five

THE POTENTIAL AND THE REALITY

THE POTENTIAL

Those who initiate scientific and technological advances are frequently moved by the loftiest motives and display a genuine desire to improve the quality of life of those affected by their innovations. Who would doubt the motives of Pascal who, when he had designed and built the first true mechanical calculating machine in 1642, declared, 'I submit to the public a small machine of my own invention, by means of which you alone may, without any effort, perform all the operations of arithmetic, and may be relieved of the work which has so often fatigued your spirit when you worked with the counters and with the pen.'

The motives of those innovating in the field of computer-aided design are likely to be equally laudable. Professor Tom Mayer and his colleagues at Strathclyde would like to see computers used to democratise the decision-making process in architectural design. Arthur Llewelyn, a leading CAD specialist in the UK, has repeatedly asserted that computers should not be used as a means of eliminating designers and draughtsmen, but rather as tools to improve their responsibility and ability to carry out creative tasks.

Regrettably, the history of scientific and technological innovation is strewn with dramatic examples which contrast the dedicated and socially desirable objectives of the academic or researcher with the cynical exploitation of their ingenuity at the level of application by the owners of the means of production. Hence we find, in many fields of endeavour, a significant gap between what technology could provide (its potential) and what it does provide (its reality).

There is a tendency, therefore, to make value judgements about given technologies based on what they might achieve rather than what they have already achieved and are likely to continue to achieve within the given economic, political and social framework.

Thus, those who have no experience of CAD (or are still at the gee-whiz stage) tend to display a more positive attitude to CAD than those who have had to live with it for some time. Similarly, the genuine enthusiasm of a CAD specialist on a research project in the relative monastic quiet of a university is unlikely to be shared by the designer faced with the harsh reality of its consequences in some high-pressure multinational corporation.

In academic circles, concern has recently been expressed that if we do not properly understand this historical conjunction, we may well pursue a technological course which will permanently close off options for more humane and satisfying organisational forms in the field of intellectual work, in much the same way as we have already done in the field of craftsmanship. Failure to recognise that these options are still open to us in CAD, and that we still have the time and indeed the responsibility to question the linear drive forward of this technology, may well mean that we shall see growing alienation and loss of job satisfaction in engineering design. This is likely to be accompanied by the subordination of the operator (designer) to the machine (computer), with the narrow specialisation of Taylorism leading to the fragmentation of design skills and a loss of the panoramic view of the design activity itself. In consequence, standard routines and optimisation techniques may seriously limit the creativity of the designer, because the subjective value judgements would be dominated by the 'objective' decision of the system. To put it another way, the quantitative elements of the design activity will be regarded as more important than the qualitative ones. There is already evidence to show that CAD, when introduced on the basis of so-called efficiency, gives rise to a deskilling of the design function and a loss of job security – particularly for older men giving way to structural unemployment.

To analyse why these contradictions should arise, it seems necessary to view the computer as part of a technological continuum, and its consequences as those that arrive when high-capital equipment is introduced into any work environment, whether it be manual or intellectual. It must also be analysed within the economic, social and political context of the society which has given rise to the technology itself.

INDICATORS

If a comparison between design (intellectual work) and skilled craftsmanship (manual work) is really tenable, we will increasingly find strong indicators of the following:

a. The subordination of the operator (designer) to the requirements of the machine (computer) with shift work or systematic overtime to counter the increasing rate of obsolescence of the machine.
b. Emphasis on machine-centred systems rather than human-centred ones.
c. Limitation of the creativity of the designer by standard routines and optimisation.
d. Domination of the subjective value judgements of the designer by the 'objective' decisions of the system. That is, the quantitative elements of design will be treated as more important than the qualitative ones.
e. Alienation of the designer from his or her work.
f. Abstraction of the design activity from the real world.
g. A fragmentation of design skills (overspecialisation) with a loss of panoramic view, together with the introduction of Taylorism and other forms of 'scientific management', even to the extent of measuring the rate of performing intellectual work.
h. Deskilling the design function.
i. Increased work tempo as the designer is paced by the computer.
j. Increased stress, both physical and mental.
k. Loss of control over one's work environment.
l. Growing job insecurity, particularly for older men.
m. Knowledge obsolescence.
n. The gradual proletarianisation of the design community as a result of the tendencies indicated above, and, in consequence of this, the considerable increase in trade-union membership and industrial militancy.

THE REALITY

CAD equipment shares with all high-capital equipment in a profit-oriented society the contradiction of an increasing obsolescence rate (the increasingly short life of fixed capital). Sophisticated CAD equipment is now obsolete in about three years. In addition, the investment cost of the means of production (as distinct from the price of individual commodities) is ever increasing. As owners of equipment which is becoming obsolete literally by the minute, and which has required enormous capital investment, employers will seek to exploit it twenty-four hours a day. This trend has long been evident on the shop floor and the effects of shift working are already well documented. The same problems are beginning to be quite evident in the field of white-collar work.[1]

As far back as the early 1970s the AUEW-TASS (Amalgamated Union of Engineering Workers, Technical, Administrative and Supervisory Section) was in a major dispute with Rolls-Royce which cost the union £250,000. The company sought, among other things, to impose on the design staff at its Bristol plant the following conditions:

1. The acceptance of shift work in order to exploit high-capital equipment.
2. The acceptance of work-measurement techniques.
3. The division of work into basic elements and the setting of times for these elements, such times to be compared with actual performance.

In this particular case, industrial action prevented the company from imposing these conditions. They are, however, the sort of conditions that employers will increasingly seek to impose on their white-collar workers.

When staff workers, whether they be technical, administrative or clerical, work in a highly synchronised computerised environment, the employer will try to ensure that each element of their work is ready to feed into the process at the precise time at which it is required. A mathematician, for example, will find that he has to have calculations ready in the same way as a Ford worker has to have the wheel ready for the car as it passes him on the production

line. Consequently we can say that the more technological change and computerisation enter into white-collar areas, the more workers in these areas will become proletarianised. The consequences of shift work will spread across the family, social and cultural life of the white-collar worker.

In a survey carried out in West Germany,[2] it was demonstrated that the ulcer rate of workers on a rotating shift was eight times higher than that of other workers.

> A higher proportion of night and rotating shift workers reported that they were fatigued much of the time, that their appetites were dulled and that they were often constipated.
>
> The most frequently mentioned difficulties in husband/wife relationships concerned the absence of the worker from the home in the evenings, sexual relations and difficulties encountered by the wife in carrying out her household duties.
>
> Another area of family life that seems to be adversely affected by certain kinds of shift work is the parent/child relationship.

I quote these extracts without making any judgement about the nuclear family. I am simply indicating that the nature of technology produces effects which spread right through the fabric of society to affect the way we live and the way we relate to other people.

The disruption of social life outside the family is also considerable. I was at one time acquainted with a suburban estate in west London where a number of mathematics graduates worked. They used to participate in activities like badminton, local operatics and a theatre group. When the large firm in which some of them worked introduced a computerised system, it required them to work on shift. Consequently their other activities were completely disrupted.

Thus, in practice, there are grounds already for suggesting that in white-collar work, far from humanising the nature of it, high-capital equipment is diminishing the quality of life of intellectual workers just as it has already done to shop-floor workers.[3]

VDUs

The tendency towards automation in offices leads to a reduction in the volume of paper, and to systems which are of 'high information density'. Micrographics systems are now commonplace peripherals to computerised systems. Complaints of eyestrain, visual discomfort, difficulties in reading and postural fatigue are now widespread. Östberg has described some of these difficulties in an important paper which contains eighty-four literature references.[4]

The effects of ageing are significant for the users of these micrographic systems. Typically, for a person sixteen years old with normal eyesight, about 12 dioptres of accommodation are available (the near point being 8 cm) of which only one dioptre (near point at 100 cm) remains at sixty. In consequence, employees over the age of fifty are frequently regarded as 'visually handicapped' and unsuitable for long term work with these systems. Increasingly (particularly in Sweden), trade-union and health and safety representatives are demanding that such systems should be designed to accommodate a wide age spectrum. These demands are part of the growing international insistence by workers on the right to be involved in the design of their jobs, work stations and wider working environment.

By 1980 there were between 5 and 10 million VDUs in use. They have since become commonplace in every office of significant size. Even so, the controversy still continues about the effects on the user – in particular of the low-level radiation emitted. This controversy has been going on for the past twenty years. In 1968, a meeting of over 100 European experts reached the conclusion that working with VDUs for eight hours causes fatigue, dizziness and, in extreme cases, claustrophobia. It recommended that the operator should have frequent rests.[5]

In 1976, an American report concluded that, based on measurements and the current standards together with the present knowledge of biological effects, the VDU did not present any occupational ocular radiation hazard.[6] However, a report from a 1985 Stockholm conference attended by 1200 participants, 'Scientists look again at VDU research', accepted that VDU screen operators suffered aches, pains and sudden bouts of sleep.

Some unions, like ASTMS in the UK, have agreements with individual employers that VDU operators who become pregnant will be given alternative work. Swedish trade unions specify rest

periods and other safeguards for all operators.[7] Far more important would be to insist on the redesign of the equipment. In Britain, trade-union concern has grown and many unions produce check lists for the installation and use of VDUs. These check lists were based originally on the recommendations of the International Federation of Commercial, Clerical and Technical Employees. They recommend regular eye checks at six-monthly intervals, specify frequency rates, luminance of the characters on the screen, character size, shape, form and height ratios. They also cover matters such as ambient lighting.

Far less research is devoted to the more subjective concerns of workers using VDUs. Journalists, for example, complained that the equipment gives them a feeling of isolation.[8] Managers using an electronic office system established by Citibank in New York regarded the software as 'hostile' when using advanced management work stations. When a redesign of the work station was undertaken, the philosophy was to keep existing procedures as they were and to build an electrical analogue of them. In this way, it is said, the receptivity of the users was greatly increased.[9]

More dramatic reactions by organised workers have been reported. In Norway, workers at NEBB made it quite clear to the management that they would ban a range of terminals the company intended purchasing because these could only be operated in a mode which was 'unidirectional', and hence not really responsive to the human being. Such a system, they pointed out, would be inherently undemocratic and was therefore unacceptable.

The employer purchased a different range of terminals as a result of the direct industrial and collective strength of these workers. It is quite conceivable that these workers would, in any case, have had a constitutional right to insist on such changes. An act in Norway which has been in force for seven years requires employers to provide 'sound contract conditions and meaningful occupation for the individual employee' and 'the individual employee's opportunity for self-determination'. 'Each employer shall cooperate to provide a fully satisfactory working environment for all employees at the workplace.'[10]

TAYLOR'S SCIENTIFIC MANAGEMENT

Central to the dehumanisation of work in the intellectual field, just as in the field of manual work, is the fragmentation of work into narrow, alienated tasks, each minutely timed. To reduce the worker to a blind, unthinking appendage of the machine is the very essence of 'scientific management'. Paradoxically, Taylor's scientific management, applied to the shop floor, initially increased the intellectual activity of the staff in the offices. In his book *Shop Management*, Taylor explained that his system 'is aimed at establishing a clear cut and novel division of mental and manual work throughout the workshops. It is based upon the precise time and motion study of each worker's job in isolation, and relegates the entire mental parts of the task in hand to the managerial staff.'

Timely warnings of these dangers came from nineteenth-century writers. 'To subdivide a man is to assassinate him. The subdivision of labour is the assassination of a people.'[11]

The notion of the division of labour and the efficiency which is said to flow from it is normally associated with Adam Smith.[12] In fact, Adam Smith's specific arguments were anticipated by Henry Martyn almost a century earlier.[13] However, the basic notion of the division of labour is so intertwined with Western philosophy and scientific methodology that it is identifiable as far back as Plato when he argues for political institutions of the republic on the basis of the virtues of specialisation in the economic sphere.

The division of labour and fragmentation of skills is of course absolutely rational if you regard people as mere units of production and are concerned solely with the maximisation of the profit you extract from them. Indeed, viewed from that premise, it is not merely rational but also scientific. The scale and nature of the deskilling which accompanies this scientific management has been graphically described by Braverman.[14] This deskilling stretches right through the intellectual field. One researcher who has examined the effects of automation in Swedish banks states, 'Increased automation converted tellers, who were in effect mini-bankers, into automatons.'[15]

It might be argued in defence of these developments that at least

in the 'occupational growth areas' associated with computing, those workers concerned with issuing instructions to the machines will be undertaking work of growing skill and creativity. To suggest this would be to fail completely to understand the historical tendency to deskill *all* work. Programming is itself being reduced to routines and 'the deskiller is deskilled' as structural programming breaks with the universal (if short) tradition of idiosyncratic software production.[16]

The use of this scientific management has seen the fragmentation of work occurring through the spectrum of workshop activity engulfing even the most creative and satisfying manual jobs (such as toolmaking). We are now, in addition, experiencing the same fragmentation in nonmanual jobs.

Up to the 1970s, most industrial laboratories, design offices and administrative centres were the sanctuaries of the conceptual planning and administrative aspects of work. In these areas, one spur to output was a dedication to the task in hand, an interest in it, and the satisfaction of dealing with a job from start to finish. Some observers, including the author, cautioned that the situation would soon be brought to an end as the monopolies, in their quest for increased profits, would bring their 'rational and scientific' methods into these more self-organising and comparatively easy-going fields. The objective circumstances for this were already set when in some industries 50 or 60 per cent of those employed were scientific, technical and managerial staff.

It was evident that the more science ceased to be an amateur gentleman's affair and was integrated into the productive processes, the more scientists and technologists would become part of the work force itself. It was even suggested that as high-capital equipment such as computers became available to scientists and technologists, they would be paced by the machine. Eventually, their intellectual activity would be divided into routine tasks and work study would be used to set precise times for its synchronisation with the rest of the 'rational procedure'.

Those scientists and technologists, particularly in the computer field, who look upon this view with derision, would be well advised to recall what the father of their industry, Charles Babbage, had to say on the matter. As early as the 1830s he anticipated Taylorism in the field of intellectual work. In a chapter entitled 'On the Division of Manual Labour' his message is clear: 'We may have already mentioned what may perhaps appear paradoxical to some of our readers, that the division of labour can be applied with equal success to mental as well as mechanical operations, and that it ensures in both the same economy of time.'[17]

THERBLIGS AND YALCS

In spite of these warnings and in spite of strikes by some white-collar unions against the use of the stopwatch in offices, these predictions were for the most part treated either as the scaremongering of slick trade-union leaders keen on increasing their flock, or as plain absurdity. 'That will be the day when someone tries to measure *my* intellectual activity' was a frequent reaction. Unfortunately, the day may be much closer than many would like to believe. In June 1974, there appeared in the publication *Workstudy*, 'A Classification and Terminology of Mental Work'. It suggests that much 'progress' has been made in this direction. Having identified the hierarchy of physical work – i.e. job, operation, element, therblig, it states:

> The first three of these are general concepts – i.e. they can be applied equally well to physical or mental work. The last term, the therblig, is specific to physical work. All elements of physical work consist of a small number of basic physical motions first codified by Gilbreth [Therblig is an anagram of Gilbreth] and later amended by the American Society of Mechanical Engineers and in the British Standard Glossary. The logical pattern would be complete if a similar breakdown of elements into basic mental motions – or Yalcs – were available. [Yalc is named after Clay.]

The paper describes how to classify yalcs into input, output and processing yalcs, and also how each of these can be subdivided into basic mental operations. It even draws a distinction between 'seeing', or the passive reception of visual signals, and 'looking', i.e. their active reception. Similarly it distinguishes between 'hearing', or the passive reception of audio signals, and 'listening', i.e.

their active reception. The paper implies that these techniques will be used in the more simple aspects of mental work. However it concludes by saying:

> We have tried to show that mental work is a valid and practical field for the application of workstudy; that basic mental motions exist and can be identified and classified in a meaningful way provided one does not trespass too far into the more complex mental routines and processes. A set of basic mental motions have been identified, named, described and coded as a basis for future work measurement research leading to the compilation of standard times. There are good prospects that such times could play a valuable part in workstudy projects.

It is clear, however, that these techniques *will* 'trespass too far' into the more complex mental routines and processes, just as they have in the case of highly creative manual work. Whether one regards this type of research as pseudoscientific or not, there can be little doubt about how it will be deployed. The employers of scientific, technical and administrative staff, including some forms of managerial staff, will see it as a powerful form of psychological intimidation to mould their intellectual workers to the 'mental production line'. It is perhaps a recognition of this tactical importance which prompted Howard C. Carlson, a psychologist employed by General Motors, to say: 'The computer may be to middle management what the assembly line is to the hourly paid worker.'[18]

'OBJECTIVE' SCIENTIFIC DECISION-MAKING

The computer is not only used as a Trojan horse for Taylorism in the fields of management and scientific work, even the university is no longer a sanctuary for non alienated work. Those academics engaged in the physical and pure sciences will be pleased to learn that these important issues of efficiency and optimisation will not be left to the subjective ramblings of the sociologist or the tainted ideology of the political economist. The full analytical power and neutrality of real science and the penetrating logic of mathematical method have been brought to bear. They will undoubtedly produce a completely 'objective' solution to the problem of university efficiency. For example, the notion of utilising factory models to optimise university and polytechnic productivity has been seriously proposed. We now have the rather ironic development in which some of those who, at university, helped to develop the scientific management production systems which made work so grotesque for those on the shop floor, may soon be the victims of their own repressive techniques. An article entitled 'College of Business Administration as a Production System'[19] is symptomatic of a general tendency. This article employs the terminology which describes academic features and activities in the form of a factory model. It is strongly indicative of the underlying philosophy.

Thus the recruitment of students is referred to as 'material procurement', recruiting of faculty as 'resource planning and development', faculty research and study as 'supplies procurement', instructional-methods planning as 'process planning', examinations and award of credits as 'quality control', instructor evaluation as 'resource maintenance' and graduation as 'delivery'. The professors and lecturers are of course 'operators' and presumably, as on the factory floor, only the effective operators will be tolerated. (Effective for what, and for whom, we may ask.)

The administrators' definition of effectiveness and competence makes it highly likely that many of the cherished academic freedoms of the university, whether real or imaginary, will be dented. In the not too distant future, many faculty members may well find themselves subordinated to the process in the interests of efficiency, as are workers on the shop floor. To get down to the real 'science' of it we can look at the proposals of Geoffrion, Dyer and Freiberg in 'An Interactive Approach to Multicriterion Optimisation, with an Application to the Operation of an Academic Department'.[20] They use the well known Frank-Wolfe algorithm and suggest that the multicriterion problem be reduced to the following expression:

> Maximise U [f_1 (x), f_2(x), ... fr (x)], subject to xeE where f_1,........fr are r distinct criterion functions of the decision vector x, X is the constrained set of feasible decisions, and U is the decision maker's overall preference function defined on the values of criteria.

Taking a specific department as an example, they define six criteria for it. The first three are the number of course sections offered by the department at graduate, lower-division undergraduate and upper-division undergraduate levels. Criterion four is the amount of teaching-assistant time used for the support of classroom instruction by the faculty. The fifth criterion is the regular faculty effort devoted to major departmental duties measured in equivalent course sections. Finally, criterion six is the regular faculty effort devoted to additional activities such as research, student counselling and minor administrative tasks, again measured in course sections.

Terms such as 'teaching time', 'teaching loads' and 'faculty effort' are used throughout. This will mean that whoever makes a decision about criterion weight must have very precise times for the different functions, and thus the basis is clearly set for work measurement not unlike that on the shop floor. The justification will undoubtedly be that such times are necessary to be fed into the computerised model for objective assessment.

However, despite the veneer of mathematical objectivity, it is the subjective judgement of the so-called decision-maker that determines the key U function. This decision-maker will be an administrator, not the academic staff themselves, who will consequently experience a loss of control over their work environment. If, for example, a faculty member is informed via the computer that he or she is taking too long on teaching or spending too much time in research, or has been rendered superfluous as a result of an optimisation routine (a function which mathematically illiterate workers call 'the sack'), it will be worth recalling that it is the U function that predominates.

In furtherance of this efficiency, a comprehensive faculty-activity analysis was prepared and developed by the University of Washington.[21] The percentage time devoted to each faculty activity is requested. All university activities, whether regular or irregular, are refined and coded. For example, code 501 (unscheduled teaching) includes thesis-committee participation, discussion with colleagues about teaching, guest lecturing in other faculty members' courses and giving seminars within the institution. Each activity is specified very precisely as it might be in a factory situation. Under the code 'Specific Scholarly Project' are listed: departmental research, sponsored research, writing or developing research proposals, writing books and articles and many others. Under 'General Scholarly Projects' we find: reading articles and books related to the profession, attending professional meetings, research-related discussions with colleagues, and reviewing colleagues' research work.

SOME CONSEQUENCES

There are some academics who hope that in projects of this kind educational requirements will outweigh mere productivity ones, but many feel the outcome will be a shrinking of facilities, as in the City University of New York where 700 faculty members were sacked.[22] In the United States, these programmes are in fact spreading rapidly as indicated by the scale of recent grants. In the California State university and college system a 'Centre for Professional Development' was set up with a grant of $341,261 from the Fund for the Improvement of Post Secondary Education in Washington. There is no doubt what the term 'improvement' is intended to imply.

This increased productivity, however, could have consequences much more widespread and subtle than the obvious ones of increased work tempo, loss of control, job insecurity and even redundancy. The impact this will have on the creativity of those involved is likely to be significant, for central to all optimisation procedures of this kind is the notion of specific goal objectives.

A vivid example of the need to avoid such an overconstrained work environment was the design of EMI's computer-controlled brain and body X-ray scanner. In his evidence to the Select Committee on Science and Technology, Dr John Powell, EMI's managing director, pointed out that the scanner was developed using unallocated funds as a by-product of work on optical character recognition. Dr Powell stated that had its inventor 'been constrained to follow a set objective on contract research funded by an operating division, he might have just produced another optical character-recognition machine'.

The inventor himself, Dr Godfrey Hounsfield, who received the 1979 Nobel Prize for medicine as a result of his work on the scanner, said about his habit of going for long walks, 'It is a time when things come to one, I find. The seeds of what happened came on a ramble.' He said also, 'I still feel quite a lift when I find that the machine is doing good.'[23]

Scientific and technical advance, in spite of its liberatory potential, brings also in its wake powerful tendencies of control and authoritarian organisational forms. Indeed, it has been suggested that 'control' has been as much a stimulus to technological change as has 'productivity'.[24] Some researchers pointed out as early as the fifties and sixties that computers increase the authoritarian control which an employer has over his employees, and strengthens the hand of those who support a tougher attitude to employees.[25]

The process is succinctly described by a writer fresh from an IBM customer-training course:

> Now an operating system is a piece of software functionally designed to do most efficiently a particular job – or is it? It gradually dawned on me that some rather obnoxious cultural assumptions have been imported lock, stock and barrel into IBM software. Insidious, persuasive assumptions which appear to be a natural product of logic – but are they?
>
> The whole thing is a complete totalitarian hierarchy. The operating system runs the computer installation. The chief and most privileged element is the 'Supervisor'. Always resident in the most senior position in the main storage, it controls, through its minions, the entire operation. Subservient to the Supervisor is the bureaucratic machinery – job management routines, task management, input/output scheduling, spares management and so on. The whole thing is thought out as a rigidly controlled, centralised hierarchy, and as machines get bigger and more powerful, so the operating system grows and takes more powers.
>
> One lecturer soared into eloquence in comparing the various parts of the operating system to the directors, top management, middle management, shop foremen and ordinary pleb workers of a typical commercial company. In fact, the whole of IBM

> terminology is riddled with class expressions such as master files, high and low level languages, controller, scheduler, monitor.[26]

The same writer then generalised some of the contradictions of centralised operating systems. These coincided closely with my own findings when I investigated the contradictions in the specific field of computer-aided design.

> The drawbacks of the centralised operating system are many. It is a constraining and conservative force. A set of possibilities for the computer system is chosen at a point in time and a change involves regeneration of the system. It imposes conformity on programming methods and thought. Another amazingly apt quote from an IBM lecturer was 'always stick to what the system provides, otherwise you may get into trouble'. It mystifies the computer system by putting its most vital functions into a software package which is beyond the control and comprehension of the applications engineer, thus introducing even into the exclusive province of data processing the division between software experts and other programmers, and reinforcing the idea that we do not really control the tools we use, but can only do something if the operating system lets you – a phrase which I am sure many of us have used. The system which results seems absurdly top heavy and complex. The need to have everything centrally controlled seems to impose an enormous strain.

Six

POLITICAL IMPLICATIONS OF NEW TECHNOLOGY

MALE/FEMALE VALUES

Niels Bjorn-Andersen and his colleagues of the information-systems research group at the Copenhagen School of Economics have named their latest joint computerisation project with the trade unions Daphne.

The name is an acronym in Danish, but it has a much more profound significance. You may recall that in Greek mythology Daphne was a nymph, the daughter of the river Peneius. She was the embodiment of what we would nowadays refer to as the historically determined 'female' characteristics, such as intuition, subjectivity, tenacity and compassion.

She was pursued by Apollo, the embodiment of the so-called male characteristics: logic, analysis, rationality, objectivity. Indeed, one might say, the god of computerisation.

When he failed to win Daphne's favours, Apollo applied the male logic of 'might is right' and decided to take her by force.

As he was about to rape her, she called on the venerable Gaea to help her. Immediately, the earth opened, Daphne disappeared, and in her place a laurel tree sprang from the ground.

Believing that male values have raped science and technology for long enough, Bjorn-Andersen pointed out that 'it was natural for us to choose the name Daphne'.

One of the major problems with Western science and technology is that they have the historically determined male values built into them. These are the values of the white male warrior, admired for his strength and speed in eliminating the weak, conquering competitors and ruling over vast armies of men who obey his every instruction. He makes decisions which are logical, rational and will lead to victory. Within this, there is little place for the attributes of Daphne.

The introduction of a computerised system is frequently used as a smokescreen to introduce a management control weapon which discriminates against women, that of job evaluation. Pseudo-scientific reasons are given for fragmenting jobs and slotting the subdivided function into a low level of the system's hierarchy with correspondingly low wages for 'appropriate' job grades. My experience of this in industry tends to show that it is frequently used to consolidate the unequal pay and opportunities for women. This is done either by implying, or by ensuring by structural means and recruitment, that the fragmented functions are women's work. This of course can no longer be stated openly since there is the sex-discrimination legislation to watch out for, but it still happens that women are recruited for the input of predetermined data, for example, whereas the higher-status jobs are offered to men.

When we looked over some past issues of the computing magazines covering a period of six months in 1983, 82 per cent of the advertisements that had one person in a photograph with the equipment showed a woman in some kind of absurd posture which was in no way related to the use of the equipment. There is a continual projection of the view, even in the most serious of journals, that women are to be regarded as playthings, draped around the place for decoration.

Not only that, but those who read these journals often do not notice the built-in assumption unless it is pointed out to them. They are conditioned to accept the presence of women in the servicing role, and the absence of women in the organising role, as being quite normal. Even women themselves quite often see nothing untoward in this.

Technological change is starved of values like intuition, subjectivity, tenacity and compassion. It would be an enormous contribution to society if more women were to come into the technological field, not as imitation men or honorary males, but to challenge the 'male' values which have distorted it for so long. It would be a contribution to science itself which would become more caring, liberatory, socially relevant and natural.

Women are going to have to fight, not only the traditional forms of discrimination, but much more sophisticated and scientifically structured ones. There is little indication, even in 1987, that the unions catering for women workers in scientific, administrative and medical occupations which are being restructured around computer-based equipment have really understood the nature and the scale of this problem. However, what we can do is change our attitude to these 'male' and 'female' values and thereby cease to place the objective above the subjective, the rational (mathematical) above the tacit (there are things we know but cannot tell) and the digital above analogical representation.

IS SCIENCE NEUTRAL?

Marxist critics of capitalist society have tended to concentrate, at least since the turn of this century, on the contradictions of distribution. This they have done at the expense of a thoroughgoing analysis of the contradictions of production within technologically advanced society.

This imbalance can hardly be attributed to a one-sidedness on Marx's own part. Central to volume I of *Capital* is the nature of the labour process and a 'critical analysis of capitalist production'. In this, Marx demonstrates that with the accumulation of capital – the principal motivating force – the processes of production are incessantly transformed. For those who work, whether by hand or brain, this transformation shows itself as a continuous technological change within the labour process of each branch of industry, and secondly, as dramatic redistributions of labour among occupations and industries.

That the overall development of production since then should accord so closely with Marx's analysis is a remarkable tribute to his work, bearing in mind the sparsity of occupations and industries then, compared with the proliferation of these today. Whether this Marxist analysis will be equally consistent and valid when applied to the science-based industries which have emerged since the Second World War is now a matter of considerable discussion. With the integration of science into the 'productive forces' this question is one of growing significance. In some large multinational corporations 50 per cent or more of all those employed are scientific, technical or administrative 'workers'. This has begun to question, in a very practical way, the relationship between science, as at present practised, and society.

THE USE/ABUSE MODEL

Up to the mid sixties, there hardly seemed any useful purpose in raising this question. At that time, there was hardly a chink in the Bernalian analysis of twentieth-century science. In this analysis, science, although it was integral to capitalism, was ultimately in contradiction with it. Capitalism, it was felt, continuously frustrated the potential of science for human good. Therefore, the problems thrown up by the application of science and technology were viewed simply as capitalism's misuse of their potential. The contradictions between science and capitalism were viewed as the inability of capitalism to invest adequately, to plan for science, and to provide a rational framework for its widespread application in the elimination of disease, poverty and toil.

The forces of production, in particular, science and technology, were viewed as ideologically neutral, and it was considered that the development of these forces was inherently positive and progressive. It was held that the more these productive forces – technology, science, human skill, knowledge and abundant 'dead labour' (fixed capital) – developed under capitalism, the easier the transition to socialism would be. Further, science is rational, and could therefore be counterposed against irrationality and suspicion.

Science had after all, through the Galilean revolution, destroyed the earth-centred model of the universe, and, through Darwin, had made redundant earlier ideas of the creation of life and of humanity. Science, viewed thus, appeared as critical knowledge, liberating humanity from the bondage of superstition – a superstition which, elaborated into the system of religion, had acted as a key ideological prop of the outgoing social order.[1] The past few years have seen a growing questioning of this rather mechanistic interpretation of the Marxist thesis. There is now a growing realisation that science has embodied within it many of the ideological

assumptions of the society which has given rise to it. This in turn has resulted in a questioning of the neutrality of science as at present practised in our society. The debate on this issue is likely to be one of major political significance. The question extends far beyond that of scientific abuses, to the deeper considerations of the nature of the scientific process itself. Science done within a particular social order reflects the norms and ideology of that social order. Science ceases to be seen as autonomous, but instead as part of an interacting system in which internalised ideological assumptions help to determine the very experimental designs and theories of scientists themselves.[2]

Failure to deal with these questions will mean that the anti-science movement of the 1970s, which had its antecedents in the anticulture movement of the 1960s, will not be developed beyond its initial and partly negative premise. In this, science is viewed as evil, totalitarian and devoid of those attributes which make it amenable to the 'human spirit'. This total rejection is now common among many young people. Indeed, in the early seventies the student population in the USA included the following words among those terms it regarded as 'bad': verification, facts, technology, statistical controls, programming, calculate, objectify, detachment.[3]

Not surprisingly, many of these students opt for the arts or social sciences where they feel (sometimes mistakenly) that more opportunity will exist for humanistic concerns.

Our Western scientific methodology is based on the natural sciences. Within this, relationships are mathematically quantifiable. There has been a tendency to suggest that if you cannot quantify something it really doesn't exist. This is not without its political significance, for if the mass of ordinary people are incapable of providing 'scientific reasons' for their judgements (which are based on actual experience of the real world), ruling elites can then silence their common sense with quantification. This has caused the brilliant French mathematician, Professor Jean-Louis Rigal, to observe, 'Quantification is the ultimate form of fascism.' Rigal's concern about quantification is even more relevant when applied outside the domain in which it evolved. Attempts to use this narrow, mathematically-based science in the much more complex and indeterminate social sciences and political activity give rise to very serious distortions, which are inevitable from the abstracted nature of the scientific method.

It is significant that those working in the scientific field are themselves beginning to raise these questions. Thus, Professor R. S. Silver says that there are risks

> in the scientific method, which may abstract common features away from concrete reality in order to achieve clarity and systematisation of thought. However, within the domain of science itself, no adverse effects arise because the concepts, ideas and principles are all interrelated in a carefully structured matrix of mutually supporting definitions and interpretations of experimental observation. The trouble starts when the same method is applied to situations where the number and complexity of factors is so great that you cannot abstract without doing some damage, and without getting an erroneous result.[4]

Those working in the field of cybernetics have also expressed their concern about this misuse of 'science'. 'There is no doubt that a very important influence nowadays is a revised reductionism within the theory of cybernetics. It reduces processes and complex objectives to black boxes and dynamic control systems. Not only in the natural sciences, but also in the social sciences.'[5]

To address these problems it will be necessary to challenge the idea of what constitutes scientific development. The role of science and technology in society will need to be recast and a social structure provided which will be capable of nurturing the coexistence of the subjective and the objective, of tacit knowledge based on contact with the physical world, and abstracted knowledge. More simply, a society and a culture which would reduce and gradually eliminate the divisions between hand and brain, and provide the stimulus, encouragement and infrastructure to permit human beings to develop in a well-rounded and heuristic fashion. This will mean challenging the fundamental assumptions of our present society and, indeed, the assumptions of societies in the so-called socialist countries. One of the important factors now

moulding the social forces to give rise to such a challenge is the contradictions of science and technology experienced by an ever increasing section of the population.

CONTROL THROUGH TECHNOLOGY

The elitist right of the scientific worker or researcher to give vent to his or her creativity will now be increasingly curbed by the system as it seeks to control human behaviour in all its aspects. This is part of the general attempt of the small elite who control society to gain complete control over all those who work, whether by hand or by brain, and to use scientific management and notions of efficiency as a vehicle for doing so. It will be seen, then, that the organisation of work, and the means of designing both jobs and the machines and computers necessary to perform them, embody profound ideological assumptions. So, by regarding science and technology as neutral, we have

> failed to recognise as antihuman, and consequently to oppose the effects of values built into the apparatus, instruments and machines of their capitalist technological system. So, machines have played the part of a Trojan horse in their relation to the Labour movement. Productivity becomes more important than fraternity. Discipline outweighs freedom. The product is in fact more important than the producer, even in countries struggling for socialism.[6]

It has been suggested[7] that by ignoring these considerations the Soviet Union was laying the basis for the present situation in which it would be hard to argue that a worker there enjoys the sense of fulfilment through his or her work envisaged by the early Marxists. It may well be that in merely trying to adapt forms of science and technology developed in the capitalist societies instead of developing entirely different ones, the Soviet Union has made a profound error. The development in that country must find part of its origins in the attitude of Lenin to Taylorism, which, he said,

> like all capitalist progress is a combination of the refined brutality of bourgeois exploitation, and a number of the greatest scientific achievements in the field of analysing mechanical

> motions during work, the elimination of superfluous and awkward motions, the elaboration of the correct methods of work, the introduction of the best system of accounting and control etc. The Soviet Republic must at all costs adapt all that is valuable in the achievement of Science and Technology in this field. The possibility of building socialism depends exactly on our success in combining the Soviet Power and the Soviet Organisation of Industry with the up-to-date achievements of capitalism. We must organise in Russia the study and teaching of the Taylor system, and systematically try it out and adapt it to our ends.[8]

Socialism, if it is to mean anything, must mean more freedom rather than less. If workers are constrained through Taylorism at the point of production, it is inconceivable that they will develop the self-confidence and the range of skills, abilities and talents which will make it possible for them to play a vigorous and creative part in society as a whole.

So it is that, in the technologically advanced nations, there are now beginning to emerge a range of contradictions which will necessitate a radical examination of how we use science and technology, and how knowledge should be applied in society to extend human freedom and development.

TECHNOLOGICAL CHANGE AND PROLETARIANISATION

The emergence of fixed capital as a dominant feature in the productive process means that the organic composition of capital is changed and industry becomes capital-intensive rather than labour-intensive. Human beings are increasingly replaced by machines. This in itself increases the instability of capitalism: on the one hand capitalism uses the quantity of working time as the determining element in production, yet at the same time it continuously reduces the amount of direct labour involved in the production of commodities. At an industrial level, literally millions of workers lose their jobs and millions more suffer the nagging insecurity of the threat of redundancy. An important new political element in this is the class composition of those being made redundant. Just as the use of high-capital equipment has spread out into white-collar and professional fields, so have the consequences of high-capital equipment. Scientists, technologists, professional workers and clerical workers all now experience unemployment in a manner that only manual workers did in the past. Verbal niceties are used to disguise their common plight. A large west London engineering organisation declared its scientists and technologists 'technologically displaced', its clerical and administrative workers 'surplus to requirements' and its manual workers 'redundant'. In other words they had all got the sack. In spite of different social, cultural and educational backgrounds, they all had a common interest in fighting the closure of that plant, and they did. Scientists and technologists paraded around the factory carrying banners demanding 'the right to work' in a struggle that would have been inconceivable a few years ago. Technological change was indeed proletarianising them. In consequence of the massive and synchronised scale of production which modern technology requires, redundancies can affect whole communities. During a recession in the American aircraft industry, a union banner read, 'Last out of Seattle, please put the lights out.'

Because of this change in the organic composition of capital, society is gradually being conditioned to accept the idea of a permanent pool of unemployed persons. In the United States, the 1970s saw some 5 million people permanently out of work in spite of the artificial stimulus of the Vietnam War. It is true that some of the more recent Reagan policies have resulted in job creation in limited sectors and small businesses. However, this may be more of a transitional phenomenon than one heralding the end of mass unemployment, and has been due partly to American external financial policies and at the expense of jobs in other countries. Japan and the United States have tended to export unemployment to maintain employment at home.

We have witnessed in this country the large-scale unemployment of recent years. Unemployment is considerable in Italy, and even in the West German miracle there are sections of workers, particularly over the age of fifty, who are now experiencing long terms of unemployment and there is no sign of this being reversed. (See Figure 15.) This unemployment itself creates contradictions for the ruling class. It does so because people have a dual role in society, that of producers and consumers. When you deny them the right to produce, you also limit their consumption power. In an attempt to achieve a balance, efforts are now being made to restructure the social services to maintain that balance between unemployment and the purchasing power of the community. In the United States, President Kennedy spoke of a 'tolerable level of unemployment'. In Britain in the 1960s, Harold Wilson, having fuelled the fires of industry with the taxpayers' money through the Industrial Reorganisation Corporation to create the 'white heat of technological change', spoke in a typical double negative of a 'not unacceptable level of unemployment' – a remarkable statement for a so-called socialist prime minister.

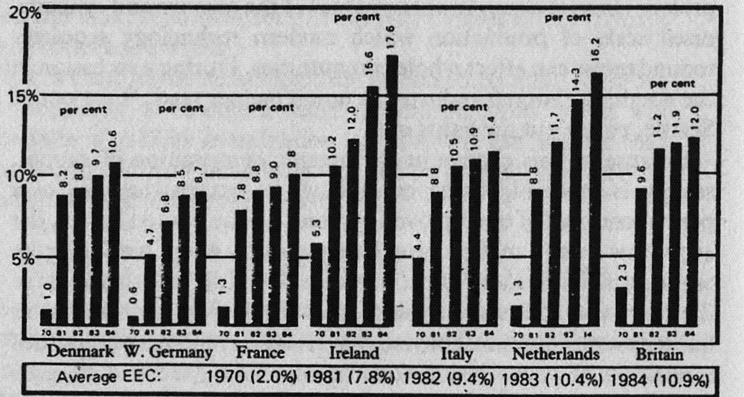

Fig. 15. Unemployment rates in the EEC.

This concept has now been extrapolated and developed by the Thatcher government to condition the population to accept that 3.5 million is a 'not unacceptable level of unemployment'. It is implied that those out of work have only themselves to blame, are scroungers or are too unimaginative, unwilling or downright lazy to avail themselves of leisure activities. Given the lack of infrastructure and resources, and the absence of job-sharing mechanisms with shorter working hours, those out of work experience not leisure but enforced idleness.

THE FRUITS OF EARLY OPTIMISM

The net result is that there is on the one hand an increased work tempo for those in industry and on the other hand a growing dole queue with all the degradation that implies. Nor has the actual working week been reduced during this period. In spite of all the technological change since the war, the working week in Britain for those who have the jobs is now longer than it was in 1946, if we include overtime, moonlighting and travel time. Yet the relentless drive goes on to design machines and equipment which will replace workers. Those involved in such work seldom question the nature of the process in which they are engaged. Why, for example, the frantic efforts to design robots with pattern-recognition intelligence when we have three million people in the dole queue in Britain whose pattern-recognition intelligence is infinitely greater than anything yet conceived even at a theoretical level?

The policies of the labour and trade-union movement have in the past been to accept redundancies and to cut expenditure on, for example, defence without any concrete proposals whatsoever about alternative work. The argument in support of this has been that defence cuts would release capital, which could then be used in the social services. It is of course then grudgingly admitted that there would be the residual problem of further unemployment.

This reveals the extent to which those of us in the labour movement have been conditioned by the criteria of the market economy. We see the freeing of capital as an asset, and the freeing of people as a liability. In doing this we ignore our most precious asset – people, with their skill, ingenuity and creativity. In the defence and aerospace industries we have some of the most highly skilled and talented workers in Britain. Yet, like the ruling class, we have thought of capital first and people last, and ignored the great contribution which their skill and ability could make to the wellbeing of the people.

Confronted with these contradictions, the bleating and whimpering of the European trade-union bureaucracies (to be contrasted with the creative Luddism of at least some sections of the Australian movement) has failed to disguise the reality that they have no independent view of how science and technology should develop. Indeed, when they are not demanding more investment in the same forms of technology that have given rise to the problems in the first place, they are making minor, pathetic, window-dressing modifications to the proposals of the vast multinational corporations. A more constructive trade-union response is illustrated in Figure 16.

Given the gradual incorporation of the trade unions through membership of state planning bodies, industrial sector strategy teams, co-determination in West Germany, and, in Britain, quangos (although this trend has been halted and somewhat reversed under Thatcher), this form of response is perhaps not so surprising. What is, however, disconcerting is the total disarray and confusion of the Marxist Left as the political pigeons of blind unthinking technological optimism come home to roost with a vengeance.

'USING' PEOPLE

The system seeks in every way to break down workers' resistance to being sacked. One of the sophisticated devices was the Redundancy Payments Act under the Labour government. Practical experience of trade unions in Britain demonstrates that the lump sums involved broke up the solidarity at a number of plants where struggle was taking place against a closure.

A much more insidious device is to condition the workers into believing that it is their own fault that they are out of work, and that they are in fact unemployable. This technique is already widespread in the United States, where it is asserted that certain workers do not have the intelligence and the training to be employed in modern technological society. This argument is particularly used against coloured workers, Puerto Ricans and poor whites. There is perhaps here fertile ground for some of the 'objective research' of Jensen and Eysenck.

The concept of a permanent pool of unemployed persons, as a result of technological change, also brings with it the danger that

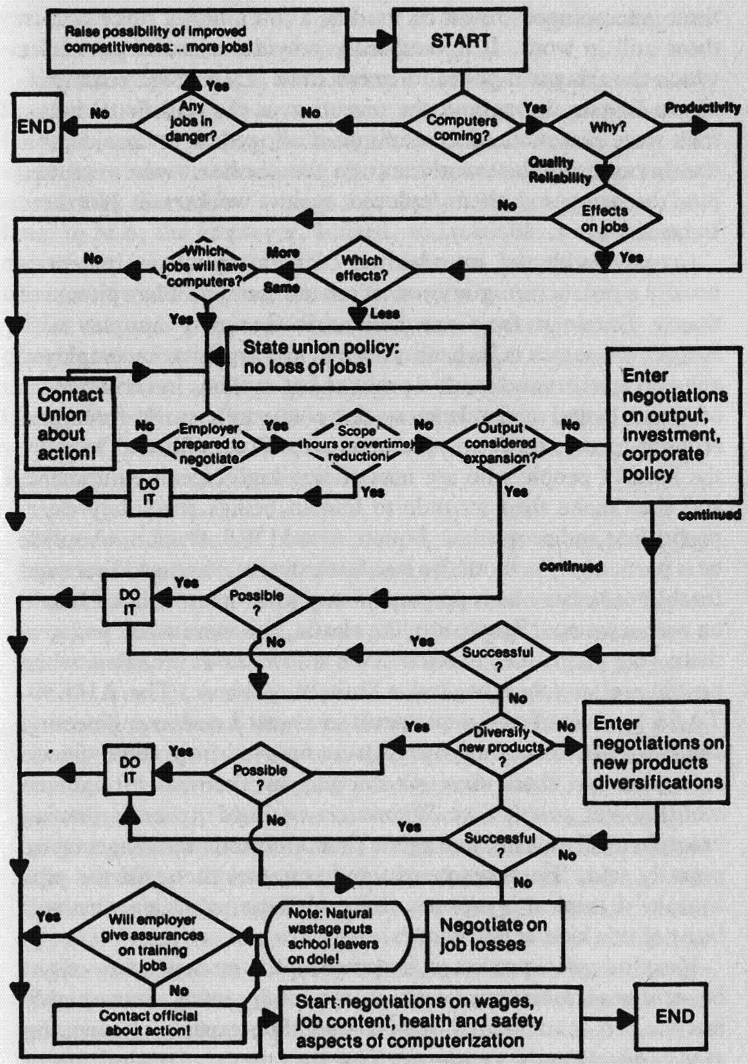

Fig. 16. A typical trade-union response to new technology.

those unemployed would be used as a disciplining force against those still in work. It undoubtedly provides a useful pool from which the army and police force can draw. During the redundancies in Britain throughout the seventies, as the traditional industries were restructured or eliminated altogether, a considerable number of redundant workers from the northeast were recruited into the army and then deployed against workers in Northern Ireland.

Coupled with the introduction of high-capital equipment is usually a restructuring known as 'rationalisation'. The epitome of this in Britain is the General Electric Company complex with Arnold Weinstock at its head. In 1968, this organisation employed 260,000 workers and made a profit of £75 million. In consequence of quite brutal redundancies, the company's work force was reduced to 200,000 yet profits went up to £105 million. These are the kind of people who are introducing high-capital equipment, and they make their attitude to human beings absolutely clear: profits first and people last. I quote Arnold Weinstock not because he is particularly heinous (he is in fact extremely honest, direct and frank) but because he is prepared to say what others think. He said on one occasion, 'People are like elastic, the more work you give them, the more they stretch.' We know, however, that when people are stretched beyond a limit, they break. The AUEW-TASS has identified a department in a west London engineering company where the design staff were reduced from thirty-five to seventeen and there were six nervous breakdowns in eighteen months. Yet people like Weinstock are held up as a glowing example to all aspiring managers. One of his senior managers once proudly said, 'He takes people and squeezes them till the pips squeak.' I think it is a pretty sick and decaying society that will boast of this kind of behaviour.

Most industrial processes, however capital-intensive they might be, still require human beings in the total system. Since highly mechanised or automated plant frequently is capable of operating at very high speeds, employers view the comparative slowness of the human being in his interaction with the machinery as a bottleneck in the overall system. In consequence of this, pay

structures and productivity deals are arranged to ensure that the workers operate at an even faster tempo.

For the employer it is like having a horse or dog. If you must have one at all then you have a young one so that it is energetic and frisky enough to do your bidding all the time. So totally does the employer seek to subordinate the worker to production that he asserts that the worker's every minute and every movement 'belong' to him, the employer. Indeed, so insatiable is the thirst of capital for surplus value, that it thinks no longer in terms of minutes of workers' time, but fractions of minutes.

The methods may vary from company to company, or from country to country, but where the profit motive reigns supreme, the degradation and subordination of the worker is the same. George Friedmann, that shrewd observer of industrial politics, has written of two different methods used by great French companies, Berliot in Lyons and Citroën in Paris:

> Why has the Berliot works the reputation, in spite of the spacious beauty of its halls, of being a jail?
>
> Because here they apply a simplified version of the Taylor method of rationalising labour, in which the time taken by a demonstrator, an 'ace' worker, serves as the criterion imposed on the mass of workers. He it is who fixes, watch in hand, the 'normal' production expected from a worker. He seems, when he is with each worker, to be adding up in an honest way the time needed for the processing of each item. In fact if the worker's movement seems to him to be not quick or precise enough, he gives a practical demonstration, and his performance determines the norm expected in return for the basic wage. Add to this supervision in the technical sphere the disciplinary supervision by uniformed warders who patrol the factory all the time and go as far as to push open the doors of the toilets to check that the men squatting there are not smoking, even in workshops where the risk of fire is nonexistent.
>
> At Citroën's the methods used are more subtle. The working teams are in rivalry with one another, the lads quarrel over travelling cranes, drills, pneumatic grinders, small tools. But the

supervisors in white coats, whose task is to keep up the pace, are insistent, pressing, hearty. You would think that by saving time a worker was doing them a personal favour. But they are there, unremittingly on the back of the foreman, who in turn is on your back; they expect you to show an unheard of quickness in your movements, as in a speeded-up motion picture! Within this context, the desire of companies to recruit only those under the age of thirty can be seen in its dehumanised context.[9]

Although this is the position on the workshop floor, it would be naive indeed to believe that the use of high-capital equipment will be any more liberating in the fields of clerical, administrative, technical, scientific and intellectual work.

Some scientists and technologists take the smug view that this can only happen to manual workers on the shop floor. They fail to realise that the problem is now at their own doorstep. At a conference on robot technology at Nottingham University in April 1973, a programmable draughting or design system was accepted by definition as being a robot. One of the manufacturers of robotic equipment pointed out, 'Robots represent industry's logical search for an obedient workforce.' This is a very dangerous philosophy indeed. The great thing about people is that they are sometimes disobedient. Most human development, technical, cultural and political, has depended on those movements which questioned, challenged and, where necessary, disobeyed the established order.

MINIMUM MAINTENANCE FOR THE HUMAN APPENDAGE

The controllers of production view all workers, whether by hand or brain, as units of production. Only when that reality has been firmly grasped can the chasm which divides the potentialities of science and technology from the current reality be understood. The gap between what is possible and what is actual widens daily. The latent capacities of science and technology grow exponentially at the same time as the plight of many ordinary people in the West and dramatically of those in Third World countries becomes relatively worse. Technology can produce a Concorde but not enough simple heaters to save the hundreds of elderly pensioners

who die in London each winter of hypothermia. Only when one realises that the system regards pensioners as discarded units of production does this make sense – capitalist sense. This is part of their social design, and from a ruling-class viewpoint it is quite 'scientific' and abides closely by the principles observed in machine design.

I know, as a designer, that when you design a unit of production you ensure that you design it to operate in the minimum environment necessary for it to do its job. You seek to ensure that it does not require any special temperature-controlled room unless it is absolutely essential. In designing the lubrication system you do not specify any exotic oils as lubricants unless it is necessary. You ensure that its control system is provided with the minimum brain necessary for it to do its job. You don't, for example have a complex CAD three-dimensional system if you can get away with a simple two-dimensional plotter. Finally, you provide it with the minimum amount of maintenance. In other words, you design for it the maximum life span in which it will operate before it fails. Those who control our society see human beings in the same way. The minimum environment for workers means that you provide them with the absolutely lowest level of housing which will keep them in a healthy enough state to do their job. The equivalent of fuel and lubrication for the machine is the food provided for a worker. This is also kept at a minimum for those who work – and is completely inadequate for those who cannot work.

In the early 1970s Oxford dietitians were telling pensioners precisely how much margarine and which scraps of meat to purchase so that they could survive on £2 worth of food per week. Despite the stir this caused at the time, the amount which working-class pensioners have available today for food is relatively unchanged in terms of actual purchasing power.

The minimum brain is provided for the worker by an educational system which imparts enough knowledge to be of use to the industrial system, and which trains him or her to do the job, but does not educate the worker to think about his or her own predicament or that of society as a whole.

The minimum maintenance is provided through the National

Health Service, which concentrates on curative rather than preventive medicine. The harsh reality is that when workers have finished their working life they are thrown on the scrap heap like obsolete machines.

If all this sounds like an extreme position, it is worth recalling the statement of the doctor at Willesden Hospital who said there was no need to resuscitate National Health patients over the age of sixty-five. (The doctor himself was sixty-eight.) When a barrage of protest was raised, the statement was hurriedly withdrawn as a mistake. The real mistake he made was to reveal in naked print one of the underlying assumptions of our class-divided society. Science and technology cannot be humanely applied in an inherently inhuman society, and the contradictions for scientific workers in the application of their abilities will grow and, if properly articulated, will lead to a radicalisation of the scientific community.

NEED FOR PUBLIC INVOLVEMENT

Any meaningful analysis of scientific abuse must probe the very nature of the scientific process itself, and the objective role of science within the ideological framework of a given society. As such, it ceases to be merely a 'problem of science' and takes on a political dimension. It extends beyond the important but limited, introverted soul-searching of the scientific community, and recognises the need for wider public involvement. Many 'progressive' scientists now realise that this is so, but still see their role as the interpreters of the mystical world of science for a largely ignorant mass which, when enlightened, will then support the scientists in their intention 'not to use my scientific knowledge or status to promote practices which I consider dangerous' (as correctly advocated by some members of the British Society for Social Responsibility in Science).

Those who in addition to being 'progressive' have political acumen know that a Lysistrata movement, even if it could be organised, is unlikely to terrify international capital into applying science in a socially responsible manner. Socially responsible science is only conceivable in a politically responsible society. That must mean changing the one in which we now live.

One of the prerequisites for such political change is the rejection of the present basis of our society by a substantial number of its members, and a conscious political force to articulate that contradiction as part of a critique of society as a whole. The inevitable misuse of science, and its consequent impact on the lives of an ever growing mass of people, provides the fertile ground for such a political development. It should constitute an important weapon in the political software of any conscious radical.

Even Marxist scientists seem to reflect the internal political incestuousness of the scientific community, and demonstrate in practice a reluctance to raise the issues in the mass movement. Thus the debate has tended to be confined to the rarefied atmosphere of the campus, the elitism of the learned body or the relative monastic quiet of the laboratory.

Clearly those who control the vast multinational corporations, who have never harboured any illusions about the ideological neutrality of science, will not be overconcerned by this responsible disquiet. The Geneens of ITT and the Weinstocks of GEC do not tremble at the pronouncements of Nobel laureates. It is true, of course, that the pronouncements of the ecologists have reverberated through the quality press and caused some concern – not all of it healthy – in liberal circles. But ordinary people – those who have it within their power to transform society, those for whom such a transformation is an objective necessity – have not yet been really involved. Yet their day-to-day experience at the point of production brutally demonstrates that a society which strives for profit maximisation is incapable of providing a rational social framework for technology (which they see as applied science).

Socially irresponsible science not only pollutes our rivers, air and soil, produces CS gas for Northern Ireland, defoliants for Vietnam and stroboscopic torture devices for police states. It also degrades, both mentally and physically, those at the point of production, as the objectivisation of their labour reduces them to mere machine appendages. The financial anaesthetic of the 'high-wage (a lie in any case), high-productivity, low-cost economy' has demonstrably failed to numb workers' minds to the human costs of the fragmented, dehumanised tasks of the production line. Although the organisation of work seeks to reduce them to zombies, they develop coping mechanisms, sometimes through compensation outside work in the form of hobbies, frequently through trade-union activity and making plans for the day when they will 'escape' from the production line altogether.

There are growing manifestations in the productive superstructure of the irreconcilable contradictions at the economic base. The sabotage of products on the robot-assisted line at General Motors' Lordstown plant in the US, the 8 per cent absentee rate at Fiat in Italy, the 'quality' strike at Chrysler in Britain and the protected workshops in Sweden reveal but the tip of a great international iceberg of seething industrial discontent. That discontent, if properly handled, can be elevated from its essentially defensive, negative stance into a positive political challenge to the system as a whole.

The objective circumstances for such a challenge are developing rapidly as the crushing reality is hammered home by the concrete experience of more and more workers in high-capital, technologically based, automated or computerised plants. In consequence, there is a gradual realisation by both manual and staff workers that the more elaborate and scientific the equipment they design and build, the more they themselves become subordinated to it, that is, to the objects of their own labour. This process can only be understood when seen in the historical and economic context of technological change as a whole.

FUNDAMENTAL DIFFERENCE

The use of fixed capital, that is machinery and, latterly, computers, in the productive process marked a fundamental change in the mode of production. It cannot be viewed merely as an increase in the rate at which tools are used to act on raw material. The hand tool was entirely animated by the workers, and the rate at which the commodity was produced – and the quality of it – depended (apart from the raw materials, market forces and supervision) on the strength, tenacity, dexterity and ingenuity of the worker. With fixed capital, that is, the machine, it is quite the contrary in that the method of work is geared to profit and the convenience of the machine. The scientific knowledge which predetermines the speeds and feeds of the machine, and the mathematics used in compiling the numerical control program, do not exist in the consciousness of the operator; they are external to him and act upon him through the machine as an alien force. Thus science, as it manifests itself to the workers through fixed capital, although it is merely the accumulation of the knowledge and skill now appropriated, confronts them as an alien and hostile force, and further subordinates them to the machine. The nature of their activity, the movements of their limbs, the rate and sequence of those movements – all these are determined in quite minute detail by the 'scientific' requirements of fixed capital. Thus objectivised labour in the form of fixed capital emerges in the productive process as a dominating force opposed to living labour. We shall see subsequently, when we examine concrete situations at the point of production, that fixed capital represents not only the appropriation of *living* labour but in its sophisticated forms (computer hardware and software) appropriates the scientific and intellectual output of white-collar workers whose own intellects oppose them also as an alien force.

The more, therefore, that workers put into the object of their labour, the less there remains of themselves. The welder at General Motors who takes a robotic welding device and guides its probes through the welding procedures of a car body is building skill into the machine and deskilling himself. The accumulation of years of welding experience is absorbed by the robot's self-programming systems and will never be forgotten. Similarly, a mathematician working as a stressman in an aircraft company may design a software package for the stress analysis of airframe structures and suffer the same consequences in his job. In each case they have given part of themselves to the machine and in doing so have conferred 'life', in systems terms, on the object of their labour, but now this life no longer belongs to them but to the owner of the object.

Since the product of their labour does not belong to the workers, but to the owner of the means of production in whose service the work is done, and is used in his interests, it necessarily follows that the object of the workers' labour confronts them as an alien and hostile force. Thus this 'loss of self' of the worker is but a manifestation of the fundamental contradictions at the economic base of our society. It is a reflection of the antagonistic contradiction between the interest of capital and labour, between the exploiter and the exploited. Fixed capital, therefore, at this historical stage, is the embodiment of a contradiction, namely that the means which could make possible the liberation of the workers from routine, soul-destroying, backbreaking tasks is rather the means of their own enslavement.

IS 'POLITICAL' CHANGE ENOUGH?

It will therefore be necessary to change the nature and the ownership of the means of production, although this of itself will by no means be adequate. In addition there is the question as to whether there is a contradiction (non antagonistic) between science and technology in their present form and the very essence of humanity. It is quite conceivable that our scientific methodology, in particular our design methodology, has been distorted by the social forces that have given rise to it. The question is therefore whether the problems of scientific development and technological change, which are *primarily* due to the nature of our class-divided society, can be solved solely by changing the economic base of that society.

The question is not one of mere theoretical and academic interest. It must be a burning issue in the minds of those attempting to build a people's democracy. It must be of political concern to them to establish if Western technology can be simply applied to a socialist society. Technology, at this historical stage, is the embodiment of two opposites: the possibility of freeing workers and the actuality of ensnaring them. The possibility can only become actuality when the workers own the objects of their labour. Because the nature of this contradiction has not been understood, there have been the traditional polarised views, 'technology is good' and 'technology is bad'. These polarised views are of long standing and not merely products of space-age technology. As far back as 1642, when Pascal introduced his mechanical calculating device, he expected it to free people to engage in creative work. Only forty-six years earlier, in 1596, an opposite view was dramatically demonstrated when the city council of Danzig hired an assassin to strangle the inventor of a labour-saving ribbon-loom. This reaction has been repeated time and again in various guises during the ensuing 500 years to resolve a contradiction at an industrial level when only a radical political one would suffice. That contradiction manifests itself in industrial forms even to this day.

THE DEDICATED APPENDAGE

It has been common for some time to talk about 'dedicated machines'. It is now a fact that when defining a job function, employers define a dedicated appendage to the machine, the operator.

Even our educational system is being distorted to produce these 'dedicated men for dedicated machines'. People are no longer being educated to think, they are being trained to do a narrow, specific job. Much of the unrest amongst students is caused by recognition that they are being trained as industrial fodder for the large monopolies in order to fit them into narrow fragmented functions where they will be unable to see in an overall panoramic fashion the work on which they are engaged.

In order to ensure that the right kind of 'dedicated product' is turned out of the university, we find the monopolies attempting to determine the nature of university curricula and research programmes. Warwick University was a classic example. In particular, at research level, the monopolies increasingly attempt to determine the nature of research through grants which they provide to universities or research projects undertaken in their own laboratories. Many research scientists still harbour illusions that they are in practice 'independent, dedicated searchers after truth'.

The 'truth' for them has to coincide with the interests of the monopolies if they are to retain their jobs. William H. Whyte Jr pointed out in 1960 that in the United States, out of 600,000 persons then engaged in scientific research, not more than 5000 were allowed to choose their research subject and less than 4 per cent of the total expenditure was devoted to 'creative research' which does not offer immediate prospects of profits. He recognises the long-term consequences of this and concludes, 'If corporations continue to mould scientists the way they are now doing, it is entirely possible that in the long run this huge apparatus may actually slow down the rate of basic discovery it feeds on.'[10]

PROBLEMS FOR THE EMPLOYER

I have up to now concentrated on the contradictions as they affect the worker by hand or brain. There are of course problems for the employer and an understanding of some of these is of considerable tactical importance.

One of the contradictions for the employer is that the more capital he accumulates in any one place, the more vulnerable it becomes. The more closely he synchronises his industry and production by using computers, the greater becomes the strike power of those employed in it. Mao Tse Tung once said, in his military writings, that the more capitalised an army becomes, the more vulnerable it becomes. This was demonstrated in Vietnam, where a National Liberation Front cadre with a £1.50 shell could destroy an American aircraft with an airborne computer costing something like £2.5 million.

A Palestine guerrilla with a revolver costing perhaps £20 can hijack a plane costing several million dollars and destroy it at some airfield. High-capital equipment, although it appears all-powerful and invincible, always has a point of vulnerability and possibilities for sabotage and guerrilla warfare are considerable. A quite small force can destroy or immobilise plant equipment or weapons costing literally millions. The capitalisation of industry also produces an analogous situation. In the past, when a clerical worker went on strike it had precious little effect. Now, if the wages of a factory are carried out by a computer, a strike by clerical workers can disrupt the whole plant. It is also true on the factory floor that in the highly synchronised motorcar industry a strike of twelve workers in the foundry can stop large sections of the entire industry.

The same is happening in the design area. As high-capital equipment, through computer-aided design, is being made available to design staffs, it proletarianises them, but it also increases

their strike power. In the past when a draughtsman went on strike he simply put down his 6H pencil and his rubber, and there was unfortunately a considerable length of time before an effect was felt on production, even when the manual workers were blacking his drawings. With the new kind of equipment described, where control data is being prepared or where high-capital equipment is used for interactive work, the effects of a strike will in many instances be immediate, and production will be affected in a very short time.

PARITY WITH THE MACHINE

While the introduction of fixed capital enables the employer to displace some workers and subordinate others to the machine, it also embodies within it an opposite in that it provides the worker with a powerful industrial weapon to use against the employer who introduced it. This will apply equally to hosts of other jobs and occupations in banking, insurance, power generation, civil transport, as well as those more closely connected to industry and production.

This is even the case when industrial action short of strike action is taken. As I have pointed out, the activity of the worker is transformed to suit the requirement of fixed capital. The more complete the transformation, the greater is the disruptive effect of the slightest deviation by the worker from his predetermined work sequence. Industrial militants with an imaginative and creative view of industrial harassment have been able to exploit this contradiction by developing techniques like 'working to rule', 'working without enthusiasm' and 'days of noncooperation'. These techniques can reduce the output of both manual and staff workers by up to 70 per cent without placing on the workers involved the economic hardship of a full strike.

Since much of the sophisticated equipment I have described earlier is very sensitive and delicate in a scientific sense, it has to be handled with great care and is accommodated in purpose-built structures in conditions of clinical cleanliness. In many industries the care the employer will lavish on 'his' fixed capital is in glaring contrast with the comparatively primitive conditions of 'his' living capital. The campaign for parity with equipment, which perhaps started facetiously in 1964 with a placard at Berkeley which parodied the IBM punchcard ('I am a human being: Please do not fold, spindle or mutilate'), has now assumed significant industrial dimensions. In June 1973, designers and draughtsmen, members of AUEW-TASS employed by a large Birmingham engineering firm, officially claimed 'parity of environment with the CAD equipment' in the following terms:

> This claim is made in furtherance of a long-standing complaint concerning the heating and ventilation in the Design and Drawing Office Area going back to April 1972. Indeed to our certain knowledge these working conditions have been unsatisfactory as far back as 1958. We believe that if electromechanical equipment can be considered to the point of giving it an air-conditioned environment for its efficient working, the human beings who may be interfaced with this equipment should receive the same consideration.

It is an interesting reflection on the values of advanced technological society that it subsequently took three industrial stoppages to achieve for the designers conditions approaching those of the CAD equipment. The exercise also helped to dispel some illusions about highly qualified design staff not needing trade unions.

Scientists must now begin to learn the lessons of such experiences, and to understand that their destiny is bound up with all those 'moulded' by the system. They must attempt to understand that the products of their ingenuity and scientific ability will become the objects of their own oppression and that of the mass of the people until they are courageous enough to be involved in political struggle with them. It is the historical task of the working class to effect a transformation of society, but in that process scientists and technologists can be powerful and vital allies for the working class as a whole. This means that scientists will have to involve themselves in the political movement.

> When the enslaving subordination of the individual to the division of labour, and with it the antithesis between mental and physical work has vanished, when labour is no longer merely a means of life but has become life's principal need, when the productive forces have also increased with the all-round development of the individual, and all the springs of cooperative wealth flow more abundantly. Only then will it be possible completely to transcend the narrow outlook of the bourgeois right, and only then will society be able to inscribe on its banners – 'From each according to his ability, to each according to his needs'. Then, and then only will scientists be able to truly give of their ability to meet the needs of the community as a whole rather than maximise profits for the few.[11]