IT IN MANUFACTURING -
THE MAP TO A NEW SOCIETY

INAUGURAL LECTURE

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by

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In this Inaugural Lecture, the rapidly changing industrial scene is viewed from both a local and an international perspective. The Paper insists that the adoption of high technology manufacturing methods is no longer optional, but forms part of a critical strategy for the survival of any country. The base for this claim is that technology has now become universally available and whoever employs it, wins! To highlight this, the Paper provides a background to the information revolution and to the role that IT is playing in manufacturing. Information Technology is seen to be the convergence of the technologies of digital computing and digital communications, which have come together to form a technology which is already having all-pervasive impacts on every aspect of our lives. Together with advances in transportation, IT has clearly brought about the move towards a world economy. However, the wonders of this new world order have to be viewed against the realities of immense population increases and the essential fact that high-technology manufacturing undoubtedly (and despite all the claims to the contrary) results in major job losses, be they on a local scale or of a global nature.

1 INTRODUCTION

"The industrial environment is changing at a speed and on a scale never before witnessed... driven by rapid developments in new technologies, as well as by new production management techniques that exploit these new technologies... and these advances are available world-wide" - Sir Edwin Nixon, Chairman of IBM (UK)[1].

The health of each and every nation throughout the world has been dramatically affected by technological changes over the past few decades. Advances in medicine, prolonged life expectancy and decreased infant mortality have resulted in frightening population growths. Spiralling industrialization has led to overuse of scarce natural resources - which has directed us towards greater efficiency in production and the reduction of waste. Increased communication facilities have opened the eyes of millions in the economically under-developed countries to the riches which the developed nations have - with a consequent demand for a share in them. Improved world-wide transportation has resulted in the ease of movement of manufactured goods on a previously unimaginable scale - so that a country's economically strategic industry may be devastated overnight by imported goods.

The concept of a world state - dreamt of by philosophers down the ages and so dramatically predicted by H. G. Wells in his classic discourse at the Royal Institution in January 1901[2] - is closer now to reality than ever before; brought about by communication technologies, both electronic and physical. A prime result of this is the rapid move towards a world economy, and this could not have been more dramatically illustrated than during the recent stock market crash, in which virtually no country's economy was left unaffected by a crisis which had its origins in Wall Street. Exciting and welcome as the moves towards the arms limitation treaties between the East and the West may be, they can be viewed as inevitable when considered against the backdrop of an emerging world economy. However much credit the leaders might claim, one could say that they are simply riding their respective horses in the directions which the horses wish to take.

The global issue which must be faced, however, in this move towards a world economy, is, will it indeed be "a great world state that will purge from itself much that is mean, much that is bestial, and much that makes for the individual dullness and drearyness, greyness and wretchedness in the world of today" - as predicted by Wells[2]?

Every country, province and indeed town, will have to decide where its place will be in this world. "Technology is global, but implementation is local, the only variables are product design and management skills".[3] It is simply no use claiming that we can choose

to go about our lives as we did in the past, and act like the Luddites (as Lord Byron put it, in the House of Lords in 1812, "In the blindness of their ignorance instead of rejoicing at these improvements in art, so beneficial to mankind conceive themselves to be sacrificed to improvements in mechanisms") by attempting to smash the machines[4]. History has taught us that this simply leads to self-destruction. In principle, of course, we can choose, but only if we are isolated from the deeds and actions of our neighbours. And in this world state, and with communications improving every day, our "neighbours" can be across a street or across a continent.

The decline during the past three decades in the manufacturing capacity of many traditionally industrialised nations bears testimony to the problem. It is simple to understand: we manufacture for consumers, be they individuals, companies or countries. These consumers will make their choices simply on the basis of cost, quality and functionality; if they know about alternative sources, and have access to them, they will seek them out. So unless there are artificial barriers imposed on free-trade, we will sell our products only if they are better - in terms of cost, quality and functionality!

Japan has illustrated this simple economic fact of life. To penetrate the lucrative American and European markets, it had to compete under the most unfavourable of conditions. Not only had it to come in with products cheaper than locally made ones but, with the growing appreciation of quality, had to compete in terms of improved quality and a higher degree of functionality. That the Japanese succeeded, there can be little doubt, and the fact that in the process, they changed the world's approach to manufacturing, is illustrated by the many countries whose manufacturing industries lie rotting and devastated. To do this, Japan had to develop a new approach towards manufacturing - one which ensured the highest possible reliability and quality, offering designs to meet the fashions and trends of the day. This required the introduction of highly flexible manufacturing techniques - large batch runs of many months were no longer acceptable, and the mass-production lines, pioneered by Henry Ford, simply had to disappear. Japan had to strive towards the hitherto-impossible task of a batch size of one - even in the most involved processes such as white-goods or car manufacture. In addition, it had to ensure quality at every stage. It was soon appreciated that complex systems cannot normally be fully tested when fully assembled and, even when this is feasible, it consumes vast resources to carry out. The only solution lies in ensuring that each and every component, and each and every operation in manufacturing, is completely error-free - hence the concept of "zero-defect" manufacturing was born. This has reached the point where, indeed, the final inspection of many products is now totally eliminated. The responsibility for quality is placed on the shoulders of the factory workers, be they human or automata.

But this new quality in manufacture had to be achieved at costs which were lower than those of locally-made products. The classic manufacturing equation of

SELLING PRICE = MANUFACTURING PRICE + PROFIT

had to be changed. The selling price was now fixed by the competition, so that profit became redefined as

PROFIT = SELLING PRICE - MANUFACTURING PRICE.

Hence the only possible way to make a profit was to reduce the manufacturing costs!

Together, then, with the move towards high quality and flexibility, this need to reduce manufacturing costs led to a completely new philosophy of manufacturing. This implied that each and every aspect of the operation of a factory, or process, had to be examined and optimised on a cost basis. Clearly, any wastage had to be eliminated as it was soon realised that this was simply "money down the drain". Likewise, to produce any article without a guaranteed market, was highly questionable. Management therefore needed to have rapid access to information relating to market sizes and requirements, user demands and raw material availability, as well as precise surveys of shopfloor activities. It was soon recognised that technology could play a critical role in meeting these new manufacturing challenges, not only to provide the information, but also, where necessary, to ensure higher quality control, and hence to eliminate wastage and improve consistency. It could not be argued that a robot would perform better than a highly skilled craftsman, but it was very clear that the robot could perform as well as a reasonably skilled craftsman, and could consistently produce goods of the same quality - day in and day out.

In summary, the new manufacturing industry had to strive for

- Standards of quality and consistency which exceeded their competitors'.
- Total flexibility, so that new and improved products could be introduced with lead-times which were superior to competitors'.
- Higher productivity, reduced cost, reduced wastage, reduced energy utilisation.
- Better service for customers, both before and after sales.

Indeed, we are moving rapidly towards these manufacturing goals - again, simply witness the turnabout in the balance of the industrial power in the world. Within a few decades Japan, closely followed by other Eastern countries, entered and rapidly dominated hosts of industries, ranging from electronics and white goods, through to transport and into industrial machinery. From power station generators to portable radios, in a few short years markets were captured with clinical precision. The next target is aerospace!

Of course, it must be acknowledged that in many cases the clinical precision was a result of government policy and backing. The ruthlessness of the marketing strategies

which have to be adopted to capture world domination in a particular market sector is now beginning to be recognised. It might require, for example, government support for anything up to five years before the fledgling industry becomes the world dominating factor, and in order to produce articles more cheaply than the competitors, government aid might well be initially required - especially in research and capital investment. Having achieved the domination in the market, however, the rewards are great. The truth of the Japanese domination is that a clear-cut government policy was necessary to tear the world's economies to pieces. In a relatively short period, the Japanese economic policies have succeeded in imposing an economic supremacy on the world such as has rarely been achieved through any military intervention!

The only way to counter the real threat of economic world domination by Eastern countries, is clearly through the use of the same tools which they have exploited so well. We simply have no choice. At the same time, however, we have to acknowledge that this new industrial revolution, which indeed is only just beginning, will have consequences for our society more profound than could have been imagined. We must understand the technology and its inevitability and, against this backdrop, must strive towards shaping the society of the future - one which we want. The choice is clear: "Either we will have a future in which human beings are reduced to a sort of bee-like behaviour, reacting to the systems and equipment specified for them; or we will have a future in which masses of people, conscious of their skills and abilities in both a political and technical sense, decide that they are going to be architects of a new form of technological development which will enhance human creativity and mean more freedom of choice rather than less" - M. J. E. Cooley[5].

In the rest of this Paper, we will review the technology which is so fundamental to this industrial revolution which we have embarked upon; we will look at its consequences for the manufacturing industry, and finally take a glimpse at some of the already perceived effects which it is having on our society.

2. INFORMATION TECHNOLOGY

Fundamental to the restructuring of industry and, indeed, to the emergence of a world economy is information - its acquisition, processing and transmission. It was Lord Kelvin who said, "If I can measure and express numerically, some feature of an object or process, I will know something about it"[6]; and if you know something about it, you can, in most cases, have an influence on it. Control theory, the corner-stone of automation, is all about exerting an influence on a process - controlling it according to some desired pattern.

IT - Information Technology - is the handling of information - its capture (be it entered by keyboard or as a scene viewed by a camera); its transmission to one or more information-processing units (computers); the actual processing (be it according to some predefined control algorithm, or the insertion of data into a table of figures); and finally, the sending of information back to the user or to the process under control.

In IT, the convergence of various technologies is evident - the most obvious being digital computer techniques and digital communications. These two technologies have, and will continue to have, impacts on all aspects of our existence. The communications market alone is confidently predicted to be expanding at a rate of at least 30% per annum, and this will be maintained for at least the next ten years. A conservative estimate is that by 1990, over 50% of all employed persons in the developed countries will be active within the information industry.[22] That we are moving towards an "information society" cannot be doubted. Information is becoming a commodity and those who can produce and handle it will be the wealth generators of the future decades.

Behind this dramatic converging of the two technologies are the strides made in digital electronics and digital computers; no other market has had the impact or the sheer growth which has been experienced by digital electronics. Not that digital electronics has any theoretical advantage over analogue electronics - in fact it has many disadvantages - but digital electronics allows the mass production of microminiature devices which do not have to be inherently accurate in themselves to handle, in a rather clumsy fashion, highly accurate information. It is rather ironic that one can achieve incredibly accurate arithmetic using devices which themselves have characteristics which can vary by up to 100% of their designed values.

The epitome of digital electronics is naturally the digital computer. One must sympathise with Physicist Douglas Hartee when he was quoted in 1951 as saying, "We have a computer here in Cambridge; there is one in Manchester and one at the National Physics Laboratory. I suppose there ought to be one in Scotland, but that's about all"[7]. Who could have predicted that within two decades a computer would cost less than a television set, and that we would be carrying them around on our wrists or in our pockets? At that time, one simply could not perceive the fact that a technology would emerge which would allow the implementation of millions of active electronic devices on a mere few square centimetres of a substance as common as silicon. Not only that, but with reliability and a reproducability which must surely outstrip any other invention of mankind's. We can now produce electronic devices which are so complex that they cannot even be fully tested. In fact, it was calculated by one of the manufacturers that it would take them two million years to test fully, all the possible operations of one of their own microprocessor chips[8]!

Microelectronics technology has pervaded virtually every aspect of our lives. Focussing back on Information Technology, it has obviously brought about the availability of extremely powerful computing devices, available for use wherever decisions have to be made or information handled, stored or processed. Not that the industrial engineer has had an easy path in adopting the technology; to have it accepted on the factory floor, General Motors had to get the computer manufacturers to produce a series of computers which did not look anything like computers! This gave rise to the ubiquitous programmable logic controller (PLC or, more correctly, PC - since PLC is a registered trademark) - a computer which resembles a set of relays and which is programmed in a format familiar to generations of Electrical Technicians.

With the arrival of the mini-computer, the computer began to move out of the hallowed temples of air-conditioned computer centres - together with their great High Priests, the Computer Centre Directors and Data Processing Managers - and became available to the engineer to exploit for uses other than scientific or data processing. The huge leap forward, however, came when it was decided that the time was right to make the computer a consumer item and the "Personal Computer Era" was born. The mystique of the computer was dispelled forever, and at last it had become viewed as it should - a processing "box" which can take in information, process it according to some algorithm and produce appropriate outputs.

Of course, recognising that we humans appear to have many computer-like abilities, there is much interest in developing computers which exhibit a degree of inherent intelligence. In 1950 the legendary A.M. Turing stated that ".... by the year 2000 computers would be created which could imitate human intelligence perfectly"[9]. Turing, of course, was the creator of the concept of artificial intelligence - essentially a computer that thinks. This is not the place to enter into a debate about the potentials of artificial intelligence and whether in fact we can achieve a truly thinking machine - but if we accept as a conservative estimate that the human system probably has some 10^{21} parallel computing elements, each of which has features which we have still not been able to replicate, then the magnitude of the engineering problem becomes evident! However, let us not forget the Hartee comment, made only thirty-seven years ago about the need for just four computers in the United Kingdom! It is critical though, to recall the words of Norbert Wiener, the Father of Cybernetics: "Computers perform no work themselves - they direct work - the technology of command and control"[10], in other words, computers are of little value unless they have something to control.

Returning to the other side of IT - communications - here the influence of digital electronics (and, again, the computer) has been immense. Developments in high-speed communications, satellite communications, optical fibre technology and indeed, improved analogue microelectronic devices, taken together with the widespread acceptance of digital transmission techniques, have opened up a wide spectrum of communication facilities. At the user level, this is demonstrated by the amazing development in international telephone facilities. Other critical developments have included the rapid switch to digital exchanges - essentially, replacing the classical electro-mechanically-based systems with digital ones. Once this had occurred, the potentials of having computer-based exchanges became evident and the wide range of facilities now offered became achievable.

The advantage of digitally-based technology soon became evident and with the emergence of high-speed low-cost digital computing devices, a whole wide range of totally new devices became possible. Thus we have seen the arrival of facsimile machines, of intelligent telephone units, of operatorless exchanges and, more recently, of cellular telephones (and soon, of digital television). Of course, the computer industry also saw the benefits of having computers "talking" to each other and, based on the wide range of communication facilities rapidly becoming available, computer networking, both country- and continent-wide, soon became a reality. As the potential benefits of such computer communications became realised, so the demand for better and better services, embodying faster, higher data rates, etc., increased.

Where is this leading us? The way is, at least for the next five to ten years, fairly clear - hence the projected 30% increase in the communications industry! The trend must be towards Integrated Services Digital Networks (ISDN) - networks which allow computer speech, video, telex facilities, etc., all to live side-by-side in a unified system. Not that the final technology is yet clear; promising European experiments with ISDN systems make use of a mixture of actual carrier mechanisms, but other rival technologies exist, such as BISDN (Broadband ISDN) - in which a single carrier medium is used, possibly running over a high-speed fibre-optical link. But whatever it is, there is no doubt that within five to ten years we will have a digital communication system in our homes and in our factories into which we can plug a telephone, a computer or a television unit and over which we will receive, on request, selected video programmes, database information, the morning newspaper, the book of our choice or even a telephone call from Mum!

3. I T IN MANUFACTURING

Free competition in a world which has shrunk, in economic terms, in a mere few decades, has resulted in the situation previously referred to in which virtually any country or any company can compete on equal terms - whatever its geographic position. Technology can be bought - an advanced machining centre can work equally well in Swansea or in Bulawayo. To win markets, products must be produced when required, at the right price and with the desired functionality. To have any edge over one's

competitors, one must be better in each category and this can only be achieved by better prediction of market requirements, better design and better management of the whole manufacturing process. In his Inaugural Lecture, Professor David Morris covered the aspect "Better Design"[11] - the key lying in the exploitation of new materials and in producing designs which will ease the manufacturing task. The key, too, lies in the full utilisation of computer-based tools, such as CAD, Simulation and Modelling, to bring new designs to fruition as quickly as possible.

It is clear that successful management, be it of an International Corporation, the economy of a Country or the machining of a single component, can be achieved only by the availability of information - not only about the process involved (leading to a full understanding of that process) but also as a picture of what is happening at any specific moment in the operation of the system. This information must be timely - there is no point in having elaborate data acquisition equipment to measure, say, the performance of a rolling mill, if the information obtained cannot be used in time to prevent the mill producing more than a single defective item at a time. Whilst historic data is useful in looking back at the past performance of a system, and might be required for legal reasons, information which is not used, is useless and (like any other commodity) information costs real money.

The exploitation of IT in Manufacturing implies the provision of such information, aimed specifically at permitting the making of better decisions and giving the company a competetive edge. To achieve this, IT must affect all aspects of manufacturing, and control must be intensified along the whole production chain - from marketing through research to production. Manufacturing is increasingly becoming market driven - the product being produced only if there is a customer. Long-term projections are essential, and models of markets are critical, particularly to direct research. However, in the end a company must respond only to a real demand, and once the demand is detected, all resources must be co-ordinated to determine appropriate price structures and delivery terms. To satisfy an order, lead times must be as short as possible to back up the promises which secured that very order! On the shopfloor, raw materials and bought-in components must be available as and when required; their quality must be ensured and the manufacturing process must be as effective and reliable as possible. The final products must be shipped as rapidly as possible - so close co-ordination with the transport operations are critical. Throughout, any overhead costs must be reduced to a minimum - an item stored costs money, material wasted is money down the drain and any error simply reduces the profit. The earlier a problem is detected, the cheaper it is to rectify.

From the earliest days of computers, they were exploited in the industrial sector - typically in the data-processing arena where they were used for accounting, personnel records, forecasting production scheduling, etc. On the shopfloor, PLCs were rapidly introduced to replace relay-based control systems, and closed-loop controllers (initially based on analogue techniques) were rapidly replaced by microprocessor-based units with added flexibility and additional functionality. As microprocessor technology charged ahead, it was exploited in new fields and, for example, the industrial robot became a reality, as did advanced automatic test equipment and various inspection aids. Robot technology, which had been waiting in the wings for decades for the arrival of cheap, robust miniature computers, was initially seized upon as the panacea to all manufacturing evils. The incredible market forecasts which showed growth rates of 20-40% however, were not realised, and led to much disillusionment, and in many ways, the bottom rapidly fell out of the robot market! This was not a function of the robot's incapacity to fulfil its destiny, but rather of the lack of appreciation that the robot is merely an advanced materials-handling implement, which, to be fully utilised, must be incorporated in a total system solution.

As a direct result of the need in the DP industry for computers to be able to share data etc., computer networks rapidly became commonplace in office environments. The office automation scenario has been critical in the history of computing, as it first posed the problem of developing networking systems in which computers, possibly from different vendors, had to communicate over relatively small distances (up to one or two kilometers) at very high rates of data exchange, and making use of communication facilities which did not exceed the cost of the actual computers. The techniques of Local Area Networks (LANs) came into being and the need for the standardisation of these networks became apparent - since it was critical to allow one specific network to carry information generated by, or received from, a wide range of different vendors' computers, using a range of different software.

LANs soon found their way into the offices of manufacturing companies and into the drawing offices, where they allowed Computer-Aided Design (CAD) systems to share information. Significantly, with the move towards vendor-independent networks, it became feasible to choose computers from more than one vendor. Therefore, the classic "IBM-shop" in which only IBM computers could ever be used because of compatibility problems, started to disappear. In manufacturing this was a particularly important step, as computers were being used in applications (and associated with equipment) in which traditional companies, such as IBM, DEC etc., had no experience.

At the same time, the Programmable Logic Controller manufacturers realised that there was a need for their PLCs to talk to each other and to exchange data to provide much wider control. The development of office-based LAN systems is of growing interest to PLC manufacturers, in their search for low-cost, standardized, solutions to their own

networking problems.

To summarize, then, since the development of the computer, there have been major moves to exploit the technology in virtually every aspect of the manufacturing chain - from networks of CAD computers, to microprocessors in robots, programmable logic controllers controlling the production line, mini-computers supervising warehouses and, of course, extensive networks of computers in the traditional data-processing areas. However, to achieve the degree of total control required, we must bring all these so-called "islands of automation" together. If a computer is to assist in planning production, it needs to have access to current shopfloor activities and raw materials holding, as well as current orders, etc. It also needs to have access to the expected delivery times of suppliers. In a similar way, the CAD system designing the programmes for a numerically-controlled milling machine, can advantageously be linked directly to that particular machine. In essence, of course, we are doing nothing more than moving information electronically - the point is that we can do it much faster and more securely than on paper - and with a much-reduced chance of error. Also, with a bit of imagination, we can provide the information right where it is needed most. Why, for example, send a printed order to one's suppliers? Why not let them see your requirements and schedule their production to meet your needs? It is all about information sharing - which, in turn, is all about information transmission.

This, then, is Computer Integrated Manufacturing - the integration of computers in manufacturing - or rather, the integration of the information available in those computers. CIM should allow anyone in an organisation who needs information, to have access to it when they need it most. This need not necessarily be restricted within a single company! One major car manufacturer, for example, never starts a production run (of 1) until an order has been placed - anywhere in the world. That order is fed into a computer which schedules the production run, informs suppliers of the exact requirements and ultimately sends, via other computers, information to the shopfloor to permit production of the specified vehicle.

This applies not only in the car industry: a Japanese white-goods manufacturer now schedules each and every washing machine assembly as an individual event, initiated only when an order is received. A major Italian clothing manufacturer similarly produces T-Shirts only on demand.

As a leading Economist wrote in the Harvard Business Review - "It's time to turn another page in the chronicle of the Computer Revolution. Imaginative companies are creatively applying the speed and flexibility of low-cost data processing and communication systems to the control function and the results have been astounding. .... They have found ways to channel the power of information to the muscle of their corporations. As a result, they have boosted their efficiency and overall competitive position".[12]

4. MAP - THE WAY TO THE PROMISED LAN?

CIM involves moving information between the various constituent components involved in the manufacturing process - from the uppermost levels of strategic planning right down to the shopfloor. The information must be available, not only where it is most needed but when. In fact, this last aspect has often been forgotten, and much of the disillusionment with highly computerised applications has come about because users ultimately discover that the information provided by their multi-million-pound computer investment, arrives too late to be of value. The question of the Real-Time aspects of information is critical, and must always be a major design consideration[13].

Fundamental to the provision of appropriate information are the mechanisms installed to move the data around - often called the "glue" of CIM. Clearly the problem is one of complexity - a single sensor device can provide thousands of bytes of data every second and a single CAD file, describing one component to be manufactured, might contain a million characters. We have to decide at an early stage, not only what information we require and where, but how to get it there. In tackling problems of this complexity we simply have to break the problem down into sensible chunks - the principle of "divide and conquer". In a CIM system a reasonable starting point is to divide the total plant or process into logical layers and there is general agreement about the model shown in Fig. 1[14].

The first layer is often referred to as the Information Processing Layer, which typically involves large computer data-processing type tasks, running functions such as materials planning, corporate order processing, financial control, company-wide production planning, strategic planning, etc.

The second layer of the five-layer model is often termed the Plant Layer, and is concerned with anything that is plant-wide in terms of scope, including management of facilities, production scheduling and plant-order processing.

Next down comes the Area Control Layer, where the concern is with aspects that might be specific to a given area of the plant - such as one complete production line.

The fourth level down is the Cell Control Level. A cell is typically regarded as a group of machines which co-operate on a close, Real-Time basis. Such a cell could consist of, say, a collection of robots feeding a numerically controlled machine, together

with the appropriate inspection and materials-handling equipment. In many cases, a cell would be configured to produce one particular product at a particular time and then re-configured for an alternative product. It is clearly characterised by the high amount of Real-Time interaction which occurs between its various components.

The lowest layer of the architecture covers the automating devices themselves, including the controllers, robots, automatic guided vehicles, etc., as well as a host of sensing and actuating devices.

On studying these layers, it becomes clear that the amount of information which has to be communicated amongst them changes as one moves up the conceptual architecture. For example, at the lowest level the data volume might be relatively low (if appropriately processed at the source at which it is created) but it must be communicated at very high rates, since it is required to co-ordinate high-speed Real-Time processes. A cell controller might, for example, be responsible for co-ordinating the activities of a robot with those of a numerically-controlled machine. At this level, therefore, it becomes absolutely crucial that Real-Time effects are considered. Further up the architecture, if the CIM system is required to co-ordinate the activities of two or more cells, then Real-Time can play a critical role. At the upper layers, however, although high volumes of data will now be handled, it might not be serious if some delay occurs.

It therefore becomes clear that a single networking approach, into which all these devices can fit, will be inappropriate in all but the most trivial of plants. At each level of the conceptual architecture described, networking requirements will differ and many appropriate solutions can therefore be adopted - typically based on available networks used in other data-communication fields (see Fig. 2). However, when such integration is attempted, at least two major problems are apparent. (Although with a bit of imagination, and some "bit-fiddling" expertise by the engineers concerned, these problems can be overcome, generalised solutions rarely emerge.) In the first place it has not been in the interest of computer manufacturers to produce hardware which is compatible with their competitors' - therefore the manufacturer of computer system XYZ has no enthusiasm whatever about arranging for an inter-connection to company PQR's range of machines. The second difficulty lies in the structuring of the data which, it is proposed, will be shifted around the various computers. Again, each manufacturer or software system design house has done it their own way. They have produced software systems which are, undoubtedly, highly effective on their own computers, and have done everything possible to keep their programmes running as fast as possible. In doing this they have optimised their data structures to suit their own needs. Therefore, virtually no standardisation has occurred! Even some ten years after it was first proposed to introduce CAD design files which could be shared between systems, no really widely adopted international standards have emerged. Clearly, standardisation tends to be seen as contrary to the interests of the manufacturers!

It has taken the users of systems to try to achieve some degree of standardisation. In the general office-automation Local Area Network field, the IEEE-sponsored exercises, for example, have gone a long way towards producing hardware and software specifications - the 802 Committee standards. Vendors are encouraged to produce hardware and software which is compatible with these standards. In theory, a user can purchase components for his system from a variety of vendors, provided they adhere to the agreed standards. In the broader data-communications field, the International Standards Organisation (ISO) has also been very concerned about standards in computer communication and developed the so-called "Open Systems Interconnection" (OSI) Reference Model. Although ISO were targeting the more general field of commercial data-communications, in view of the size of that market when compared with the process control market, the use by the latter community of standards produced by larger organisations makes a good deal of sense.

Similar exercises have been undertaken in other fields but until recently, very little was happening in factory automation. Indeed it took one of the biggest users of such systems, General Motors, to start the ball rolling, and this should ultimately be to the benefit of the whole manufacturing and production community.

General Motors had estimated that over 50% of automation costs were going into communication functions, and the continual lack of well-defined standards was seen as simply adding to the cost of producing CIM solutions. Recognising this, GM set up various working groups in late 1979, their prime function being to investigate and identify common communication standards for plant-wide systems. This led to the establishment of the so-called MAP (Manufacturing Automation Protocol) Task Force in November 1980, with a brief to prepare a specification that would allow easy communication between a wide range of computer-based devices in a cost-effective and consistent manner. The overall objectives were

- to identify a MAP message standard to support application-to-application communications
- to identify application functions to be supported by the messages conforming to this standard
- to recommend communication protocols that would meet the functional requirements.

The first MAP document, published in October 1982, laid down general networking considerations, as well as some implementation information. The second issue of MAP documents arrived in 1984 and was expanded in February 1985. Version 2.1 added

inter-networking facilities and provided additional functions. The latest Version, proposed for final release in 1988, upgrades most of the protocols and adds certain high-level features[15]. A final MAP-based plant could well end up with a collection of network systems, each designed to meet the specific needs of an area in a factory, in accordance with a particular MAP specification - as illustrated in Fig. 3.

Having established the activity, General Motors attempted to take a back seat and to hand over the activities in the USA to the MAP Users Group (MUG) and in Europe to the European MAP Users Group (EMUG), while playing an important role as an major user of the activity. International interest is running high, and at the last reported count over 600 vendors and users in the USA alone were actively involved in MAP. In Europe a significantly large community is involved with EMUG. However, despite extensive support from the DTI, interest within the United Kingdom is not as widespread as originally hoped for.

Alongside MAP came TOP - Technical and Office Protocol - which had had a similar history to MAP's but with the aerospace manufacturer Boeing as originator. The first TOP specification was published in 1985. TOP is intended to cover office functions in manufacturing companies, and is identical to MAP in most respects, except for the types of cable and some of the network structures.

Despite the hotly debated issues relating to the pros and cons of various aspects of MAP and TOP, there is no doubt that their claims for serious consideration are well founded.

- They are becoming widely supported and are clearly backed by many vendors and associated organisations. In the United Kingdom, for example, the DTI has much faith in MAP, and was a prime sponsor of the CIMAP Exhibition held in Birmingham, which brought together over 60 manufacturers of computer-related equipment.

- Products are beginning to become available and certain items of software are being delivered. Alternative suppliers of the network technology, and of interfaces to many popular computers, are now being identified. A few major silicon manufacturers are committed to producing MAP-based products, and this will eventually begin to bring the cost down.

- MAP and TOP are clearly driven by major users and are aimed specifically at providing standards which are applicable in factory and office networking. They are true multi-vendor standards, which should ultimately lead to the interconnection of devices regardless of the source of manufacture.

In addition, most vendors of CIM-related technology feel that they cannot afford not to be involved in the MAP/TOP exercise. Therefore, there is much activity by vendors, either bringing their new products in line with MAP proposals, or at least providing the means of inter-connecting their own proprietary products with the MAP system. Whilst one cannot claim that MAP is cheap (indeed at the moment, is virtually the most expensive inter-connection strategy one can adopt!), there can be little doubt that it does offer much for the future. Indeed, the importance of the MAP exercise is probably not going to be whether the lowest-level standards adopted are the best, but rather the fact that a standard, application-level interface will be developed which will allow for data compatability between various computing systems. Issues relating to the selection of the lowest-level protocol will probably prove to be totally irrelevant, and a variety of solutions will ultimately be offered, with the user choosing the most appropriate to his data requirements, in terms of both volume and Real-Time needs.

In summary, then, the issue of moving data around a plant is by no means a trivial one, or one that can be delegated to a single engineer, or indeed to a single supplier. The first stage in any CIM implementation must undoubtedly involve an extensive investigation into the precise data needs of the various users of the CIM system. It must be decided where data is needed, why it is needed and when it is needed. Based on this, appropriate networking strategies can be adopted. The problem, of course, is made even more complex by the fact that CIM is, of necessity, an evolutionary technology. When a CIM strategy is developed, many pieces of the solution will already be in place, because manufacturing has developed via a series of islands of automation. The critical point, though, is to establish a strategy, and evolve towards the ultimate requirements in a step-by-step fashion - choosing the most appropriate (from an economic added-value point of view) aspects to be integrated first. Above all, CIM is an economic strategy and it has to be accepted that information is extremely expensive - to acquire, to process and, of course, to transmit.

5. TOWARDS A NEW SOCIETY

As Engineers, we have traditionally been seen as being so devoted to our wonderful technologies that we ignore the world around us (as the environmentalist so often would say) to its detriment. This might well be true, but I often wonder if this is not a two-way problem. Engineers find it extremely difficult to find a Sociologist who has taken the trouble to find out about our technology, so that together we can look at the problem with mutual understanding. Too often the standpoint is taken that technology is not inevitable and that societies are planned in isolation from the realities of world

economies. As I have tried to stress in this paper, technology is now universal and if we don't exploit it, our "neighbours" will!

But let us not be blind to the consequences of advanced manufacturing methods. Statements such as "Japan has one of the lowest unemployment rates in the world" are often used to support the theory that advanced manufacturing does not result in job losses. Just stop however, and think of the millions of people in other countries who have been put out of work by cheaper, higher-quality imported goods from the East, or by other technological advances. Think of the hundreds of devastated fishing villages scattered down the coast of Africa, which have lost their traditional industries, gutted by the highly-effective, highly-automated fishing fleets from the East or from the Soviet Union. Think of that once-proud manufacturer of radios in Bulawayo, which formerly employed thousands of workers assembling radio sets for export throughout the world, reduced now to importing robot-assembled circuit boards from Japan and employing a mere handful of persons to insert them into boxes for retail to a few surrounding countries.

Let us take a cold and unemotional look at the facts - not to pose any solutions, but to highlight the fact that we do have a major problem in that our society is going to go through upheavals possibly greater than ever before felt.

At the beginning of the 18th century, 92% of the total labour force worked on farms to feed the other 8%. Today it needs only 2 or 3% to feed the rest. With high technology agriculture, the only reason for peasant farming to continue is to provide a job for the peasants - and at that, it has to be subsidised[16]. Employment patterns are shown, for example, for the USA in Fig. 4[22]. We see here the change in other sectors - especially critical is manufacturing, where from a high of some 40% in 1950, a steady decline began. According to eminent Sociologist Tom Stonier[16] this position will continue, and by early in the next century we will see no more than 10% of the labour force involved in manufacturing! There is no doubt that these predictions are well in line with other surveys - the most important probably being an extensive report prepared for the Financial Times in 1986 by Gallup, and covering the five major economies of the world, the USA, Japan, West Germany, France and Britain. In each case, about 200 companies were surveyed at random, together with the leading major multi-national technological companies[17]. Focussing just on the UK, the report found that between 1980 and 1986 72% of the companies surveyed in the UK had introduced new technology and that this had had a definite effect on the employment policies. Between 1986 and 1990, 59% of the companies planned further introductions. Of importance was that the companies surveyed included not only manufacturers but also those operating in the service sector! Also, it is critical to highlight that the job growth in the companies which had used the new technology had been 16% on average, whereas the national average for companies was some 20%. In the UK, 77% of companies projected job losses directly as the result of the introduction of new technology.

But the cry goes up, of course, that those who lose their jobs will be employed elsewhere, particularly as the overall wealth of a nation rises. There is no doubt that the wealth will rise, and indeed this is the only strategy for survival - but according to the OECD Report, entitled "Microelectronics, Robotics and Jobs"[18] only 60% of jobs lost through new technology will emerge elsewhere - and only then for those who have been retrained.

The facts keep staring us in the face. In 1981, using high technology, Nissan could assemble a car in Japan using 51 labour hours at a total cost of some $1,484; Ford in the USA took 84 labour hours at a cost of $3,048.

Of course, one can use the Japanese model and simply <u>export unemployment</u> - and this is probably the only way ahead in the immediate future for countries such as those in the developed world. For example, Volkswagen's plant in Wolfsburg, one of the most automated plants in Europe, calculated that in theory 1,000 jobs were lost in the process of automation - but because of increased production these persons were re-employed elsewhere[17]. But markets are finite - so where did the extra cars manufactured go? Textile firms in developed countries have been very successful in meeting the challenge of imports from Third-World countries by introducing, once again, high-technology manufacturing methods but the clothing barons of the developed countries are not likely to employ the hundreds of Bulawayo clothing-industry workers who have, in turn, lost their jobs through a decreasing export market. Will the wealthy mining magnates be willing to finance the small African countries whose major source of income is the wages (typically paid in gold) earned by the mining workers in the South African goldmines? Over 1 million persons are employed in the mining industry in Southern Africa and there is no doubt that they work in conditions, many kilometers underground, which few would regard as appropriate for human endeavour. Desirable as automation in this industry clearly is, the social consequences are of a magnitude which exceeds anything seen during the first Industrial Revolution.

The argument is naturally put forward that jobs will emerge in the service sector - but is this really true? I cannot help wondering about this, especially when I see many countries investing heavily in robotics, where the object is to develop systems which perform housework, assist in health care, carry out security patrolling tasks at night, and trundle around highly-automated factories and attend to the servicing requirements of large machine tools. Work has also advanced in producing a robot which cleans windows!

How long will it be before we take the obvious and technically-feasible step of dictating directly into the wordprocessor?

The problem must also be viewed against the global situation. According to an OECD Report[20] we already have 31 million people unemployed in the developed countries of the world. By the year 2000 the workforce in these countries alone will increase by 10%, but in the same time period, the workforce in Asia and the Pacific will increase by 55% and in Latin America and Africa, by an incredible 80%. It has been calculated that in Sub-Saharan Africa alone, 300 million additional jobs will be required by 2015[21].

From a local point of view, it is critical, though, that we realise that we have no other route to follow but to go down this very road. Of course, we have already gone a long way and here in South Wales, we have seen the beginnings of a turnabout in our economy as high technology is adopted. Within 50 miles of Swansea we have some of the most advanced plants in the world. Up the road, a manufacture of video-tapes has what must be the most automated production line anywhere. Just outside Newport is the world's most advanced surface-mount device operation with multiple, virtually totally-automated, production lines, producing goods whose quality exceeds all others. Nearby are machining centres which rank amongst the most advanced to be found anywhere. To support this growth we have to realise that there are major changes in employment patterns. Job losses will <u>not</u> just be at the highly skilled craftsman or at the very low unskilled level. Many mid-management jobs will undoubtedly go, as management functions are performed more and more by computers. As the quality produced by machines improves, and as manual operators become more quality-conscious, the role of the Quality Inspectors will disappear. Moves to techniques such as Just In Time will mean that the need for storage in warehouses will decline, and persons operating in this area will simply become redundant. Draughtsmen will have to become Computer Operators, and above all there will be an increasing demand for persons who are highly computer-literate and are capable of designing and maintaining highly-sophisticated integrated computer systems.

In view of this, thoughts of reducing or rationalising (that famous word for cutting-back) tertiary education are unbelievably naive and show forethought similar to that of the Luddites. What we have to do is to ensure that we literally double the number of persons who are emerging with appropriate qualifications and to do this we must provide Universities, Polytechnics, Colleges of Further Education etc., with the right feedstock. A prime investment in our future which we must make at this moment lies in Primary Education. Indeed, the key to the future wealth of this nation does not lie in the hands of the business executive or the computer engineer; it lies in the hands of the schoolteacher, for unless we can at least double, within the next few years, the number of persons capable of handling modern technology, then those countries who have set their sights on doing just that, will simply seize the world markets and we will have lost forever, that narrow window which is left for us to re-establish this country as a major force in the world economy.

Manufacturing is all about wealth generation and not the direct creation of employment opportunities. The more we automate, the more wealth we generate and it is this wealth which must then be distributed to make this a better and more civilized world. If we don't, as a country, seize the opportunity to generate that wealth, then the universality of technology will ensure that we hand over that role to whoever has the initiative to grab it!

6. ACKNOWLEDGEMENT

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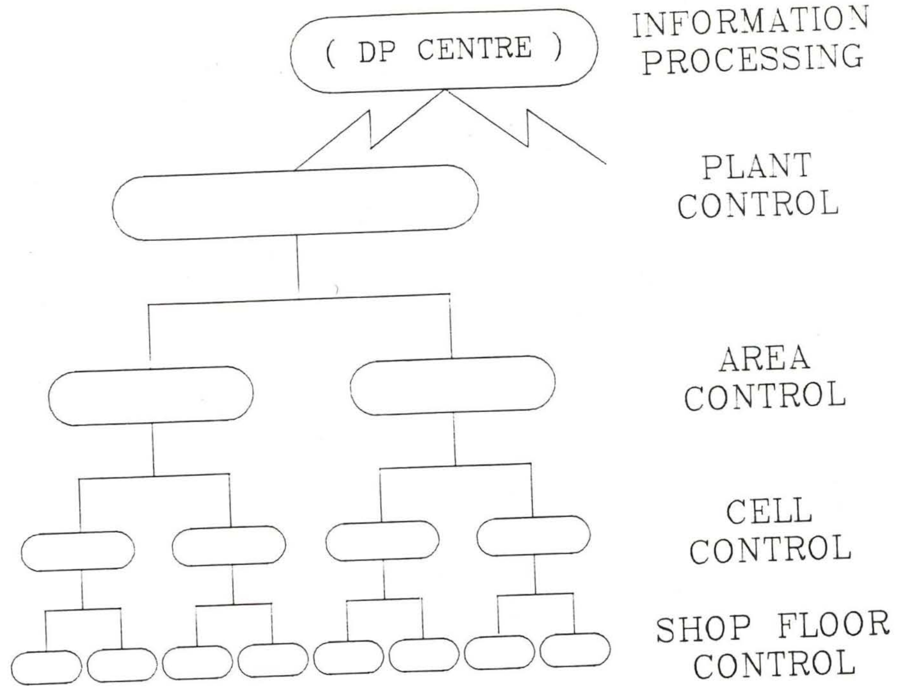

Fig 1: LOGICAL LAYER MODEL FOR CIM SYSTEMS

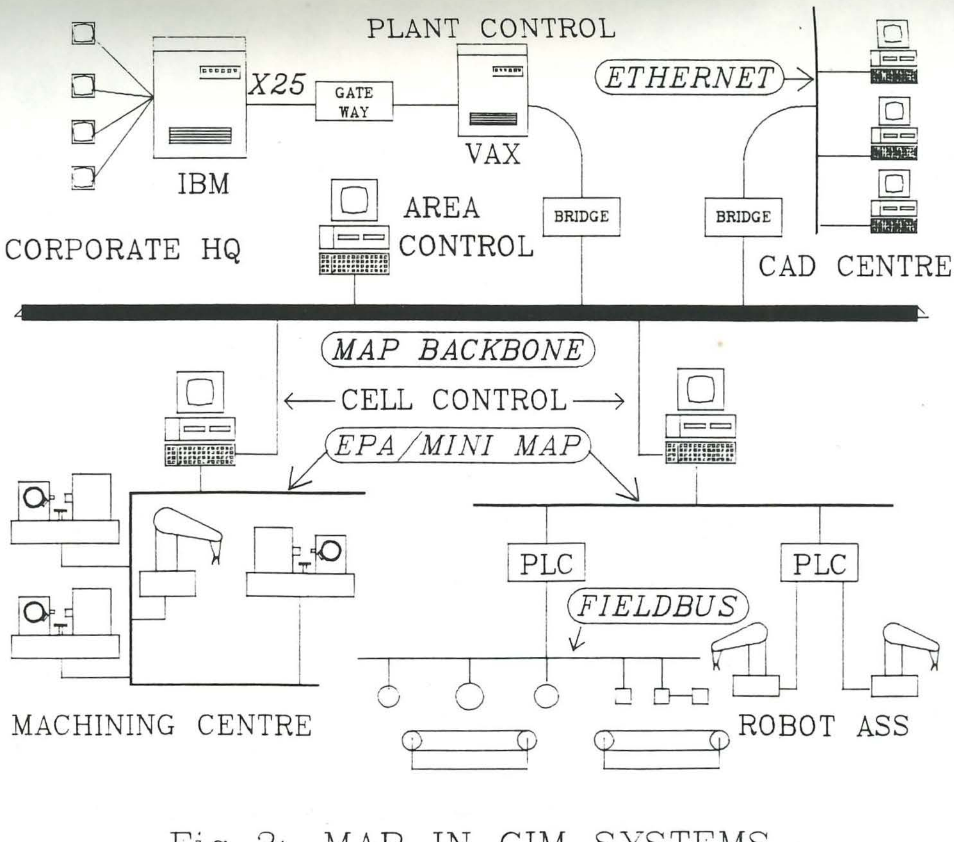

Fig 3: MAP IN CIM SYSTEMS

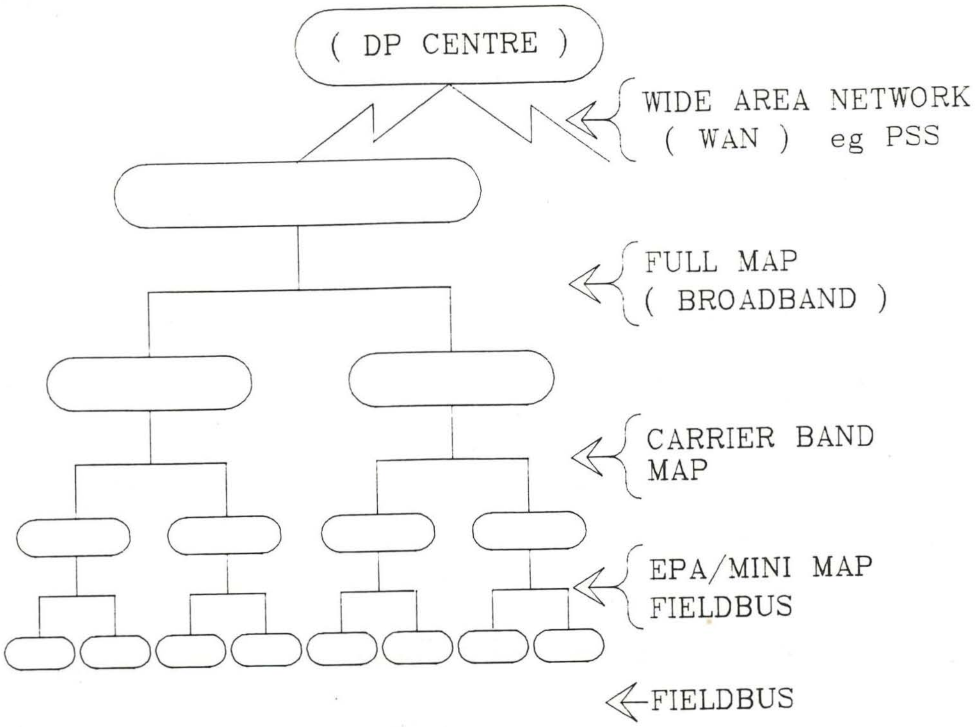

Fig 2: NETWORKING STRATEGIES FOR CIM

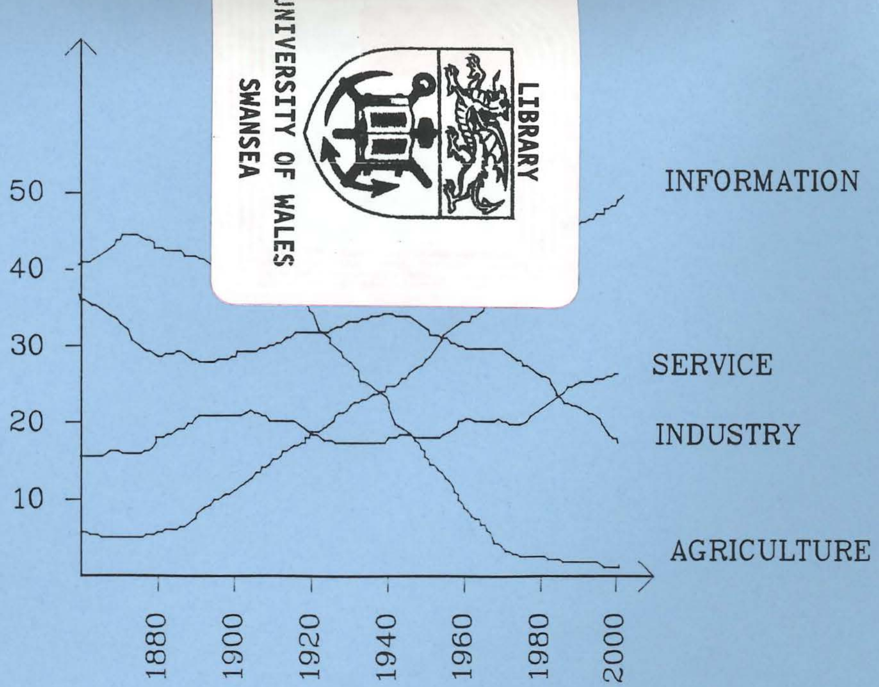

Fig 4: EMPLOYMENT TRENDS IN USA