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MICROELECTRONICS MONITOR

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Starting with this issue the Microelectronics Monitor comes to you with a new cover page which our colleagues in the printing shop have designed and produced and which, we hope, our readers will find attractive.

Superconductivity: a new magic word that describes a phenomenon which has been known since 1911, when a Dutch scientist found that some metals lose their electrical resistance if cooled to near absolute zero. It was first observed at minus 452 Fahrenheit or four points above absolute zero on the Kelvin scale (4 K). However, the real excitement began last year when reports arrived of materials becoming superconductors at 40 and 30 K.

More on this subject, which may be one of the biggest breakthroughs of the century, inside these pages.

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I. UN NEWS AND RECENT EVENTS

UN system communications under study

The possibility of making the UN computerized telecommunications network accessible to other UN system agencies is now under study. To be addressed are such issues as the types of legal, operational and technical infrastructure arrangements necessary to make the network more widely accessible.

The United Nations has requested that all specialized UN agencies complete a questionnaire on actual and projected communications traffic requirements between main offices, subsidiary offices, and other offices vital to operations. The initiative for planning and the network architecture of the proposed UN system network have been undertaken by the UN Communications Service jointly with the International Telecommunication Union (ITU).

The UN telecommunications network is currently operational between New York, Geneva, Nairobi, Bangkok, Santiago and Vienna. Facilities for computerized document exchange are also being used.

Impetus for the present study came from a 1985 Joint Inspection Unit Report (85/6) that recommended developing a proposal to extend to the specialized agencies the use of the UN telecommunications network, and presenting this proposal to the Administrative Council. Acting on this recommendation, the 40th session of the ITU Administrative Council authorized its Secretary-General to study the matter.

In previous years, ITU Plenipotentiary Conferences have held that the UN point-to-point telecommunications network should not be used by the specialized agencies. Should the present efforts be successful, the UN system will be able to take a major step toward the full use of the telecommunication and automated management information systems which the Member States have provided. (ACCIS Newsletter 4, (6) March 1987, page 3)

Training activities of United Nations University

The broad goal of UNU training is to alleviate the isolation of third world scholars and help the international academic community strengthen the ability of third world institutions to play a significant role in national, regional and global development.

The UNU does not have a central campus, but carries out its activities through a world-wide network of institutions. Training, coupled with research projects whenever appropriate, is provided through fellowship programmes which are designed to match the needs of the home institutions of participating individuals and the research aims of the UNU.

One focus is microprocessor-based devices and systems, including microcomputers and the associated software. Activities in this area have involved the organization, in co-operation with the International Centre for Theoretical Physics in Trieste, Italy, of regional seminars, such as the Asian regional seminar held in Colombo, Sri Lanka, in 1984, and the Latin American regional seminar held in Bogota, Colombia, in 1985. Related on-going projects are now under way in Malaysia and Colombia.

The UNU also undertakes projects to create microprocessor-support units and upgrade local facilities, especially laboratories, for high-level training and research. Through the projects, research centres and universities in industrialized countries, such as France and the United Kingdom, have provided experts to, and accepted scholars from, selected universities in Africa and Asia. Hopefully, institutions in Latin America will be taking part soon. (Bulletin IBIPRESS 125, 26 April 1987)

The relaunching of IBI

Professor S. Venceslai was appointed by consensus to assume the functions of Director-General of the Intergovernmental Bureau for Informatics (IBI). This event and the new ideas for relaunching, recently discussed by the management committee, constitute the solution to the crisis which led to the resignation of the Director-General, Professor F. A. Bernasconi, after 17 years of service at the head of IBI and its predecessor the International Computation Centre.

IBI, like other international organizations, has encountered financial and economic problems, which have led to difficulties in carrying out co-operation programmes for the developing countries and to their expressing dissatisfaction. These factors created serious divergences, resulting in the notice of withdrawal of certain countries, such as Italy and Spain, which up to then had expressed interest in and provided significant financial support to the organization.

No longer having the necessary consensus, Professor Bernasconi resigned on 26 February 1987. The executive council, then meeting in extraordinary session from 24 to 26 February, accepted this resignation and set up a management committee composed of five member countries: Argentina, Cameroon, Italy, Spain and Tunisia. Professor S. Venceslai was made provisional chairman of this committee and, at the same time, was entrusted with the functions of Director-General *ad interim*. (Bulletin IBIPRESS 122, 29 March 1987)

International symposium-workshop on silicon technology

The National Institute of Silicon Technology (NIST) of Pakistan is organizing an international symposium-workshop on silicon technology development and its role in the sun belt countries, which will be held at Islamabad on 14-16 June 1987. The symposium is organized in conjunction with the Clean Energy Research Institute (CERI), University of Miami, USA and is sponsored by the Ministry of Science and Technology, Pakistan and the National Science Foundation, Washington, D.C., USA.

The objectives of the symposium are to provide the latest knowledge on the technology and utilization of silicon in photovoltaics and transistor applications. It is intended to be of interest to those involved in research and development of silicon technology, in photovoltaics and other semiconductor devices. Information on the symposium and on papers submitted can be obtained from: Dr. Atique Mufti, Director-General, National Institute of Silicon Technology, No. 25, H-9, Islamabad, Pakistant.

Last year's databooks

In issue No. 17, page 5 we published a request for "last year's databooks" which had been suggested to us by Mr. Yin Sein of the Burma Broadcasting Service, Information and Broadcasting Department, Ministry of Information, Government of Burma. Mr. Sein's proposal was that companies, university institutes or government departments in developed countries would make available manuals, surveys, databooks etc., which are no longer up to date and would only be discarded, to interested individuals or institutions in third world countries.

Mr. Sein has written to us again still hoping that his scheme would become reality. As a first step, interested donors may wish to contact Mr. Yin Sein, Super Engineer (Plan/Dev), GPO Box 199, Myodaw Rangoon, Yangon Taing, Union of Burma. The Microelectronics Monitor will also help by publishing a list of available "old databooks".

UNIDO assists in Trinidad and Tobago workshop

As already mentioned in the previous issue of the Monitor, UNIDO assisted Trinidad and Tobago by sending two international consultants to lecture at a workshop on microelectronics organized by the National Institute of Higher Education, Research, Science and Technology (NIHERST), which was held at Port-of-Spain on 10-12 February 1987. The report of the workshop is now available. The workshop had brought together experienced practitioners in the field drawn from the manufacturing and extractive industries, the service sectors, the public sector and the University. The workshop developed a number of recommendations to the government emphasizing the need for applications research and training which could lead to improved growth in this sector. First, electronics should be declared a "strategic" industry. Secondly, there should be an institutional monitoring/co-ordinating mechanism for the development of microelectronics in Trinidad and Tobago. Thirdly, consideration should be given to exploring the role of private foreign investment. Finally, public policies should be geared towards the following: creating massive literacy in microelectronics; making the country attractive as a host country for microelectronics manufacturing; developing a world class software industry; fostering an indigenous capability for upgrading industry and the service sectors; standardization of hardware and, to a lesser extent, software; the development of an efficient service and maintenance capability and the provision of a number of fiscal incentives. NIHERST is looking towards UNIDO for further assistance in the implementation of the recommendations of the workshop.

Spotlight on industrial automation at Hanover Fair

At the Hanover Fair (FRG) which took place on 1-8 April 1987 an exhibit sector this year called "Intermatic" focused on process controls. Some 400 companies had gathered their products in the field of process controls; sensors; production data acquisition equipment; quality assurance; CAD and CAM; software and consulting services. The range of exhibits at Intermatic attempted to cover universal industrial applications. They included routing and control systems; machine and plant control systems; computer-aided development from design to engineering, manufacturing, quality control and logistics; on-and off-line programming systems, and more.

In addition to Intermatic and the sectors mentioned above, the Hanover Fair mounts separate exhibit halls for equipment in: electronics and electrical engineering; microelectronics; fluid power and power transmission; research and technology; custom manufacturing/subcontracting; tools; cleaning technology (waste removal and property management).

In 1988 the Fair will include sectors on energy, new materials, factory equipment, and surface treatment while some of the 1987 sectors will not be held again until 1989. (Excerpted from Industrial World, March 1987)

II. NEW DEVELOPMENTS

Superconductivity

Journals during the last few months reported on exciting developments in the search for a superconducting material that works at temperatures that would allow commercial applications. In the following some recent review articles are reprinted.

The superconductor comes in from the cold

At unthinkable temperatures below -260°C, something miraculous happens to electricity. Kept this cold, some materials conduct electric current with virtually no loss of energy: they superconduct. But after years of searching, most scientists have reluctantly concluded that superconductors exist only at temperatures so low that they are inaccessible for most practical purposes. They are wrong.

Researchers at the University of Texas at Houston are about to divulge a big secret: how to make a superconductor that works at around -180°C. As a result, many applications of superconductivity that previously seemed far-fetched promise to make commercial sense: from magnets for levitating trains to transistors for ultra-fast computers.

The cost of keeping materials below the temperature where they superconduct has until now exceeded the savings to be had from resistance-less wires. The 80°C increase in this critical temperature from -260°C to -180°C makes all the difference, for two reasons.

First, the only medium that can be used as a fluid coolant below -260°C is liquid helium; all other elements freeze at such low temperatures. Helium is found in high concentrations only in a few natural gas reservoirs in the United States and Canada and its drawback is that it is expensive as well as scarce. One litre of liquid helium from these reservoirs costs about $2. And extracting the gas from the atmosphere, where it makes up just one part in 200,000, or from radioactive materials, would cost much more. Liquid hydrogen is not an acceptable alternative. Although it is cheap and can be used to keep materials at temperatures as low as -250°C, it has a nasty habit of exploding when it leaks into warm air. At -196°C or above, a new coolant enters the picture: liquid nitrogen. It costs a mere nickel a litre and is abundant. Every breath you take is 78 per cent nitrogen.

Second, it takes a lot of energy to keep something cold: the colder you want to keep it, the more power you need. A refrigerator uses at least 25 times more power to extract a unit of heat energy from an object at -269°C (the boiling point of liquid helium) than from one at -196°C (the boiling point of liquid nitrogen). Combining a cheap coolant and a big saving in power consumption promises to revolutionise superconductor technology, in much the same way as a seawater-fuelled engine would rock the motor industry. But for the past 75 years, nothing has looked more unlikely.

In 1911, a Dutch physicist, Heike Kamerlingh Onnes, discovered that mercury superconducts at -269°C. Since then, the record for the highest temperature superconductor has climbed a measly 0.3°C a year before levelling off a decade ago at -250°C. This was for a compound of niobium and germanium.

The beginnings of a breakthough came last June (1986) when Dr. George Bednorz and Dr. Alex Müller at IBM's research laboratories in Zürich saw some confusing signs of superconductivity in a compound of lanthanum, barium and copper oxide. In December, scientists at the University of Tokyo and at AT&T's Bell Laboratories in New Jersey reported superconductivity at -237°C with a crystalline compund of lanthanum, strontium and copper oxide. In a flurry of one-upmanship, the Japanese and American teams have been busy beating each other's records. At the beginning of this month, the record stood at -233°C, with hints of better to come.

This week, Dr. Paul Chu and colleagues in Houston announced that they had made a material that is fully superconducting at -179°C, well above the boiling point of nitrogen (-196°C). Dr. Chu is in no hurry to disclose his secret formula: once the -196°C barrier is broken, scientists shut up and patent lawyers take over.

Before investing in Superconductors Inc. consider the problems that scientists must solve in order to get their compounds out of the laboratory and onto the market. Magnetic fields can "switch off" a superconductor and different materials switch off at different magnetic field intensities. All of which is more than a nuisance because many potential applications of superconductivity involve using a coil of superconducting material to produce a strong magnetic field.

The good news it that it seems that the new compounds can withstand the strongest magnetic fields scientists can produce at about -268°C. The bad news is that as a superconductor approaches its critical temperature - the maximum temperature at which it superconducts - the strength of the magnetic field that switches it off falls rapidly.

This means that, to be useful, a superconductor cooled by nitrogen to -196°C will have to stay a superconductor at much higher temperatures. A rule of thumb says that if a compound remains a superconductor up to -123°C, then - at the boiling temperature of liquid nitrogen - it could withstand magnetic fields powerful enough for the most demanding applications, such as nuclear-fusion reactors. But even if the superconductor's critical temperature cannot be raised above around -173°C, that would still be good enough for less demanding uses.

Making wires out of the compound will tax the ingenuity of metallurgists. For most applications, the superconducting wire has to be a good normal conductor at room temperature. To achieve this, it is necessary to mix the insulating compound with a good conductor. That risks destroying the superconductivity of the compound.
Dr. Douglas Finnemore and his colleagues at the Ames Laboratory in Iowa have mixed the compound with copper and other wires. Preliminary results suggest that the wires behave just like the pure compound.

Scientists have yet to discover exactly how far up the temperature scale they can take their new superconductors. A small risk remains that they are guilty of some oversight and that their results so far will prove a wild goose chase. But there is another intriguing possibility: that no upper limit exists for the temperature at which a superconductor stops working. Now that the -196°C barrier seems to have been broken, allowing the use of cheap and plentiful nitrogen as a coolant, scientists will try every trick they know to push the maximum temperature higher. They have a hundred elements to play with, and as many fabrication techniques.

So a small chance exists that scientists will achieve superconductivity at room temperature. That would rival most technological breakthoughs of this century. But do not hold your breath. (The Economist, 21 February 1987, pp. 87-88)

The new world of superconductivity

... The idea that it may soon be economically feasible to put superconductivity to work in myriad uses is sparking development projects at hundreds of companies worldwide. The payoffs would be enormous. And if room-temperature superconductors are ultimately discovered, the world could be transformed. Such "hot" materials could provide new tools for every technology related to electricity. But just the prospect of superconductivity at liquid-nitrogen temperatures is enough to excite most industrial engineers.

Practical nitrogen-cooled superconductors could save the utilities billions - and save enough energy to put 50 or more power plants in mothballs. Copper wires may be the conductor of choice now, but they lose a lot of power. The copper soaks up 5 per cent to 15 per cent of the electricity flowing through long-haul transmission lines, and still more disappears in local distribution lines.

Interest in using powerful superconducting magnets to build high-speed trains that levitate above their tracks has also flagged in the US, because of high capital costs. That interest, too, could be reviving. But the eventual builders of these so-called maglev trains are more likely to be in either West Germany or Japan, which have continued to fund serious research, or Canada, which still supports a modest effort. ...

America's best shot at exploiting the new technology is probably in electronics. There, superconductivity will usher in what Sadeg M. Faris calls "the third age of electronics", after vacuum tubes and transistors. Faris worked on superconducting microchip devices known as Josephson junctions at IBM. When Big Blue decided in 1983, after 14 years of work, that the technology was a no-go, Faris left and founded Hypres Inc.* In February 1987, less than four years later, Hypres unveiled the first system based on Josephson junctions. Now, Faris asserts that Hypres will be the first to build chips using the new materials, because "no one else in the world has a manufacturing line producing JJ chips". That distinction isn't likely to last long. Major electronics companies, from IBM to Varian Associates, are racing to explore the new superconductors. Westinghouse wants to use Josephson junctions, which are up to 1,000 times faster than conventional silicon transistors, to build radar systems it believes would outperform any now available. At Varian, a leading maker of equipment used in semiconductor fabrication, a crash effort is under way to verify the work on superconducting thin films being done at nearby Stanford University. Such films could be the starting point for tomorrow's superchips. Health care is another area where superconductors could have an early impact. Nuclear magnetic resonance (NMR) scanners rely on powerful superconducting magnets to produce unprecedented views of the body's organs. The new materials promise magnets 10 times more powerful than those now used. And if NMR machines shed the cost and bulk associated with their present cooling systems for helium, the market for them could be a lot bigger. "You could site NMRs in smaller hospitals, even clinics," says Dr. Paul Winson, director of business development at Britain's Oxford Instruments Group PLC, the leading supplier of NMR magnets. Diasonics Inc., which has sold more than 100 NMR scanners, estimates that cooling with liquid nitrogen might save $100,000 per year in operating costs per machine.

The new superconducting materials may also produce magnets that give theoretical physicists a closer look inside atomic particles. Just eliminating the helium needed to cool the 10,000 giant magnets in the proposed superconducting supercollider would lop $160 million off the projected $4.4 billion cost of the atom smasher - plus cut energy usage by 25 per cent. Researchers argue that waiting for the ability to eliminate helium should not hold back the project, which earned a green light from the President early this year, but they say the possibility of replacing those magnets should be kept open.

Ultimately, physicists hope the new superconductors will hold the key to practical nuclear fusion. Such reactors need powerful magnets to contain the intense heat of the reaction, which will be even hotter than the sun. The US magnetic fusion effort has been trimmed by 20 per cent since 1985, to $345 million this year, and Princeton University's Plasma Physics Laboratory, the site of the major US fusion project, is being outspent by rival projects in Europe and Japan. The new superconductors, hopes Robert M. Hill, a senior scientist at SRI International, could revive fusion's prospects.

They may even boost Star Wars. The Strategic Defense Initiative Organization's Office of Innovative Science & Technology has already marked $500,000 for

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* See article on superconducting switches on page 4.

superconductor research this year and plans to buck it to $2 million next year. The interest is easy to fathom. After all, space-borne systems built with superconductors wouldn't have to be cooled: in space, "room temperature" is even colder than liquid nitrogen. (Reprinted from the 6 April 1987 (pp. 59-60) issue of Business Week by special permission, (c) 1987 by McGraw-Hill, Inc.)

Superconductors and the superchip

Researchers at Stanford University in California have developed a thin film using high temperature superconductors and made crude electronic devices from these. This could pave the way for a new generation of superconducting chips, the researchers claim.

The scientific community is still buzzing with excitement four weeks after what has been described as the most extraordinary scientific meeting in living memory. In March scientists converged on New York to a conference called by the American Physical Society. They were there to find out about newly discovered high temperature superconductors that are about to revolutionise electronics and computing.

The tremendous excitement was over the development of new superconducting materials which have no electrical resistance and so can conduct electricity in a circuit forever.

Until a few weeks ago superconductivity was only possible in a few materials at a few degrees above absolute zero, -273°C, the temperature of liquid helium. The newly discovered materials, however, superconduct at much higher temperatures, -180°C, the temperature of liquid nitrogen. Because of the difficulty and expense of maintaining conductors at liquid helium temperatures their use has been restricted to a few exotic research applications. But now, with the discovery of high temperature materials they can be used in all sorts of everyday applications.

Their use will radically change the world in which we live and they will change electronics and computing more than a transistor did in the 1950s.

Unlike the older superconductors the new materials are not metals but made from complex ceramic compounds. The highest temperature superconductor made so far has been made from a compound of yittrium, barium, copper and oxygen.

The material was first made by Paul Chu of the University of Houston and Dr. Man Kuen Wu of the University of Alabama towards the end of January. At first the material could superconduct at -193°C but within a matter of weeks the two men raised the temperature of the material to -179°C.

Wu is certain that temperatures can be raised further, even up to room temperatures.

"There are all kinds of things we can do to the material to increase its temperature," says Wu. "I am very confident that by adapting the material in the right way we can get the material to superconduct at room temperature."

But even if there is no improvement on present temperatures it will still be economical to use these materials, according to professor Malcolm Beasley, head of the applied physics department at Stanford University in California.

"Liquid nitrogen is as cheap as beer and as plentiful as air," he says. "It is now possible to have CMOS circuitry working at liquid nitrogen temperatures. This is an incredible stroke of luck since it means that the new high temperature superconductor materials can be used in electronic circuitry from today."

Beasley's group has developed a thin film from the material which can be used to provide chip interconnectors. Using this thin film the group has developed what is believed to be the world's first crude electronic device. The device, called a tunnel junction, is the basic component of a subpico second switching device called a Josephson junction.

IBM has tried and failed to develop these devices which could improve switching times in computers by three orders of magnitude.

Beasley's device comprises an insulating layer sandwiched between a thin film of lead and a thin film of the new compound. Because part of the device is made from lead it can only work at liquid helium temperatures. However, Beasley is confident of getting temperatures up to about -190°C, "very, very soon". If Beasley is successful it will soon be possible to fabricate chips that can work between 1,000 and 10,000 times faster than they can now.

Already several US companies are investigating these devices for use in their products. AT&T's Bell research laboratory in New Jersey has developed a flexible tape made from the material which can be used to conduct electricity much more efficiently than copper. A company spokesman stressed that the tape is still at research stage but admitted that products could be made from the tape very soon.

Researchers at Westinghouse, the giant US electrotechnical corporation, are attempting to make a cable out of the material to distribute for electricity distribution. Resistance in power cables results in only 70 per cent of generated electricity reaching consumers. A power cable made from superconducting wires could slash electricity costs by between 10 and 20 per cent, according to Westinghouse researcher, John Gavalar. Gavalar's initial research has shown that at liquid nitrogen temperatures the current carrying capacity of these materials is between 100A to 1,000A per square cm. This effectively rules out their immediate use for elecricity distribution and other heavy current applications such as magnetic levitation for transport.

"Electronics is likely to be the first area the material is likely to have an impact," says Gavalar. "Devices using superconducting devices could be available in a year or so."

The most exciting development in the technology was announced in Japan two weeks ago at a meeting held by the Japanese Physical Society where a group from the Chinese Academy of Sciences claimed they had developed a material that could superconduct at near room temperatures, nearly +14°C.

Superconducting technology is set to turn the electronics industry on its head. As is always the case when an industry-changing technology arrives, those that will do best will not be the slow ponderous established companies, but those that are able to adapt most rapidly to the new technology. Unless the top semiconductor companies and computer companies are fast off the mark in exploiting the new technology their present market leadership will be short lived. From today nothing will ever be the same again in the electronics industry. (Electronics Weekly, 8 April 1987, p. 14)

Superconducting switches find their way into a commercial instrument

Superconducting switches are making it into the real world. Hypres, an American company based in New York, has announced the first commercial instrument - an oscilloscope - that takes advantage of the extremely high speeds of superconducting switches known as Josephson junctions. These electronic switches have allowed Hypres to develop a new system for examining ultrafast events such as the switching time in electronic components.

The "rise time" of the signal - the time it takes to rise from zero in the instrument - is just 5 picoseconds (million millionths of a second). The rise time is important because no instrument can record an event if the event is shorter than the time it takes to record it. Hypres claims that this is five times faster than anything else ever made. It also says that its instrument is 50 times as sensitive as conventional oscilloscopes. The new instrument relies on Josephson junctions operating at the relatively low temperature of 4 K, cooled by liquid helium. Although the temperature is not quite as glamorous as recent stories of breakthroughs in superconducting materials, the achievement is still impressive.

A novel cooling system sprays liquid helium on the corner of the chip that most needs cooling, rather than immersing the whole chip in liquefied gas. This makes the technology more practical, but the instrument is still massive. It is closer to the size of a small desk than to the typewriter proportions of conventional oscilloscopes.

Hypres was founded in 1983 by Sadeg Faris, who left the computer giant IBM when the corporation abandoned its research into Josephson junctions.

IBM was interested in designing fast computers around the fast switching speeds of the junctions. Some Japanese companies are still working towards that goal. Faris was involved in the work at IBM's Thomas J. Watson laboratories in nearby Yorktown Heights. With backing from venture capital, he set to work on the more modest goal of high-speed instrumentation. Now his main problem may be price: from June, the oscilloscope will sell for around £80,000. (This first appeared in New Scientist, London, 25 April 1987, the weekly review of science and technology)

Japan edges up in the superconductor race

The West may have taken the lead in the race to develop new superconductors, but the Japanese are catching up fast. Just how fast became evident recently when Toshiba announced that it had developed a ceramic superconductor and fashioned the material into tapes and wires. The ceramic, like that made by other research groups around the world, is a compound of yttrium, barium, copper and oxygen. In bulk form, the transition to superconductivity begins at 100 degrees above absolute zero (100 K), and the ceramic loses all electrical resistance at 93.7 K. In wire form, the figures are respectively 93.5 K and 87 K. In either case, the material will superconduct when immersed in liquid nitrogen rather than the much more expensive liquid helium that conventional superconductors require.

Superconductors are important because they have no resistance to electrical currents. Until last September, scientists had observed superconductivity in materials only at temperatures 20 degrees above absolute zero. Then, scientists began reporting that some ceramic materials exhibited superconductivity at 100 K. Japanese researchers then began an intensive effort to reproduce these results.

Toshiba moved ahead of its rivals in the Japanese heavy electrical industry - such as Hitachi, Japan's largest maker of semiconductors - for two reasons. First, for the past five years the company has worked with Shoji Tanaka's group at the University of Tokyo, the leading Japanese researchers in the field. Secondly, processing technology for fine ceramics is one of Toshiba's strong suits. ...

As elsewhere, superconducting ceramics are the centre of a frenzy of activity in Japan. Announcements of developments have also come from groups at five Japanese universities as well as three national laboratories.

The Japanese Government's Science and Technology Agency is currently working out how to co-ordinate the efforts in industry, universities and national laboratories. Tentative plans call for the establishment of a new superconducting materials research association and, perhaps, an associated laboratory. (This first appeared in New Scientist, London, 16 April 1987, the weekly review of science and technology)

Molecular-beam GaAs leaves the lab

A seven-person French start-up is pushing molecular-beam-epitaxy production of advanced gallium arsenide out of the laboratory and into mass production. The company, Picogiga SA, is already shipping wafers to component makers in the US, Canada, and Europe.

Linh T. Nuyen, company president and former chief of the Thomson CSF team that in 1981 came up with the high-electron-mobility transistor, estimates the worldwide market for wafers in military, telecommunications, supercomputer and consumer-product applications to reach about $150 million by 1990. Picogiga's objective is to capture 10 per cent; estimated first-year sales are $1.5 million. "There are about 60 gallium arsenide programmes, and we have about 12 as customers," says Nuyen.

Picogiga opened a subsidiary last month in Oxnard, Calif., in an attempt to further penetrate the US market, especially in the military area. "We are going in the same direction as the [Defense Department] - higher speed," says Nuyen. "If you can detect your signal even one second before your enemy, you have the chance to send up a lot of missiles."

Nuyen insists that his process involves no secrets - it was simply a question of "very, very hard work". He adds: "We have so far increased by a factor of three what could be done in the research state," which means 80 wafers a month. The throughput is expected to double each year, along with sales.

He calls the wafers he is producing "second-generation GaAs". That, he says, is to differentiate them from "the thick-layered ordinary GaAs wafers people are making today". Picogiga's wafers are a complex heterostructure of GaAs and gallium-aluminium-arsenide with very thin layers.

Nuyen proved the effectiveness of thin layers while working at Thomson CSF in Orsay. His research group deposited an undoped-p-type GaAs layer 1-μm thick, an undoped GaAlAs layer 60 Å thick, and a silicon-doped GaAlAs layer 700 Å thick on a chromium-doped substrate. The researchers cut the wafer in half, left one half intact, and etched some 200 Å off the other.

Devices were fabricated identically on both halves - gold over germanium nitride for the source and drain contacts, and aluminium deposited directly on the top epitaxy layer without any recess for the gate. The thinned-down devices out-performed the others.

For production wafers, Picogiga uses molecular beam epitaxy to get the very thin layers - 1μm undoped p-type GaAs, 5-to-60 Å undoped GaAlAs, and 500-to-1,000 Å silicon-doped GaAlAs - on a semi-insulating substrate. Cost is the key. Molecular-beam-epitaxy machines cost about $800,000, Nuyen says, making them prohibitively expensive for part-time use. Picogiga exploits its machine fully, turning out six wafers a day. "Our wafers cost 10 times more than conventional GaAs wafers but make our yield much higher, so the cost of the device is much lower," he says.

"The cost for GaAs-on-silicon wafers is not less expensive because it's the epitaxial growth procedure that makes the price high," he adds. "Other techniques for expitaxy will have the same costs." Nuyen says the cost of the wafers will decrease by a factor of three or four in a few years. (Reprinted from Electronics, 5 March 1987, (c) 1987, McGraw Hill Inc., all rights reserved)

Japanese link on biochip R&D

Eight leading Japanese electronics firms are to join forces to develop a biochip, the key to the potential development of organic computers. The companies have been selected by the Industrial Technology Council, an advisory body to Japan's Ministry of International Trade and Industry (MITI). MITI will invest some Yen 5 billion in the venture over the next 10 years.

The eight firms - Mitsubishi Chemical Industries, Fujitsu, NEC, Hitachi, Mitsubishi Electric, Sanyo Electric, Sharp and an R&D subsidiary of Matsushita Electric Industrial - will set up a committee and invite researchers at various institutions to take part in the venture. (European Chemical News, 5-12 January 1987)

The knowledgeable computer

By the end of the year, computers will be available that can "learn" from the engineers who put together the tortuously complex design of chips.

The design engineers will be working at computers that contain a database of rules and examples of how various electronic tasks can be implemented on silicon. Such a database is called a knowledge base. Silicon Compilers Systems, based in California, is developing the software for such a knowledge base. It is called the intelligent compiler.

The designer will feed a schematic diagram of the chip into the computer; the diagram includes information about the chip's function. In addition, the designer tells the computer how much the chip should cost, how fast it should operate, what size it should be and how important each of these factors is for a particular design.

Armed with these details, the computer will search its knowledge base to see if it contains a better way of carrying out the chip's functions than the designer's diagram suggests. If the computer finds a better method it substitutes that for the designer's. If it does not, the computer follows the designer's schematic, and then adds the schematic to its knowledge base for future applications. In this way, the computer acquires knowledge from the designer for that designer or others to benefit from when carrying out future jobs.

The intelligent compiler is a development of another type of aid for engineers designing chips - the silicon compiler. The design engineer feeds a schematic of the chip into the machine. The silicon compiler contains a database of elements that make up a chip. Unlike the intelligent compiler, though, this software cannot accumulate knowledge as it is used for more and more designs. (This first appeared in New Scientist, London, 16 April 1987, the weekly review of science and technology)

Machine intelligence

It ought to be possible to make a computer intelligent in the same way that you make a child intelligent: by educating it. "Expert systems", briefed this way, become quite good at a few tasks like medical diagnosis, but they are by no stretch of the imagination intelligent. For those aspects of human intelligence that people take for granted - recognizing a face in the crowd, interpreting the words of a telephone conversation - it is impossible to teach a computer the rules humans use, because humans do not know what rules they use.

The old solution to this dilemma is to seek rules that work. From time to time, though, a more seductive approach is aired: simply to build a computer that looks like a brain and make it learn by itself. This approach is called connectionism, neural networks or neurocomputing. Not everybody is seduced. Dr. Tommy Poggio, who divides his time between the Massachusetts Institute of Technology and a company called Thinking Machines, jokes about a virus that infects brain scientists, starting a new epidemic every 20 years. The epidemic takes the form of uncritical enthusiasm for a new idea. In the 1920s, the idea was gestalt phychology; in the 1940s, cybernetics; in the 1960s, perceptrons. In the 1980s it is connectionism.

Connectionists have four articles of faith. First, they believe in parallel computers: machines that do lots of things at once. Second, they believe that intelligent computers should resemble the networks of cells of which brains are made. In other words, the processors themselves should be like neurons (brain cells) and the connections between them like synapses (cell junctions). Third, connectionists believe that such a computer's programs should consist of varying the strengths of connections between processors, just as brains seem to work by varying the efficiency of synapses. Fourth, and most boldly, connectionists believe that, given certain conditions, the "programs" (rules, solutions, whatever) will somehow emerge within the machine. It will organize itself.

The first claim is uncontroversial. Almost everybody agrees that a brain is a parallel computer whose processing power is dispersed throughout its network of cells. The second claim, that computers should be built of neuron-like objects, is in some ways peculiar. Compared with the transistors on chips, neurons are big and slow. Transistors switch perhaps 1m times as fast. But whereas a transistor is an on-off switch, a neuron is subtler. Neurons add up the signals they receive, and, depending on whether the sum reaches a threshold, decide whether to send on a signal themselves - like sluice gates that open when all the streams leading to the dam reach a certain height.

AT&T's Bell Laboratories in New Jersey have built "neurons" from silicon. Their most complicated circuit has 512 "neurons" on a single chip. Each one is an amplifier and it is connected to others by resistors. The resistance in these varies with use, which is a direct emulation of the synapses between neurons. Studies of learning in rats and slugs have suggested that learning consists principally of improving the efficiency of synapses as they are used more. In other words, a slug that learns to avoid something nasty is improving the efficiency of the connection between the cell that detects the nastiness and the cell that initiates evasive action.

That leaves the connectionists with their most startling claim: that such neural networks will not have to be programmed. Set up in the right way, they will learn by themselves. The claim is not quite as mystical as it sounds. After all, brains compute and they were not programmed. They evolved the means to learn.

Evolution is not a bad metaphor for what goes on inside a learning "neurocomputer", of the kind connectionists would build. It would try different connection strengths, reject those that are bad and select those that are good. "Good" can mean one of several things, depending on whose machine it is. Dr. John Hopfield and Dr. David Tank of AT&T's Bell Laboratories use the criterion of energy - when the condition of the whole computer is at lowest energy, the connection strengths are closest to solving the problem. Others, such as Dr. David Rumelhart of the University of California at San Diego and Dr. Geoffrey Hinton at Carnegie-Mellon University in Pittsburgh, use the "back-propagation" of errors as their criterion for success. This method compares each solution with the expected answer, corrects the errors, sends those corrections back to "hidden" processors in the machine and tries again.

Some of the people who might be thought most likely to be connectionist are not. Two examples are Dr. Danny Hillis and Dr. Tommy Poggio, who both work at Thinking Machines. Dr. Hillis invented the company's product, the Connection Machine - which, with its 64,000 interlinked processors, is a good machine to do connectionist things on. Yet the coincidence of the names is an embarrassment to him. Dr. Poggio works on the most parallel of the brain's functions - vision.

He and Dr. Hillis take issue with two things. First, that neurons are anything special. Intelligence, they believe, can be independent of the machinery in which it resides. They, too, are interested in enabling machines to learn. But they do not treat the computer as a black box. Where a connectionist would tell the computer to find out some way of combining 2 and 2 to end up with 4 ("and don't bother me with the details"), a "computationist" like Dr. Hillis or Dr. Poggio would also want to work out what method the computer had hit upon and then see where else this new trick called addition might prove useful.

The connectionists, by evading the step of understanding how the computer solves the problem, avoid two difficulties: that you may not know the mathematical formula that works, and that you can solve problems that are intractable to ordinary mathematics. One such is the travelling-salesman problem. A salesman wishes to visit 50 cities. He does not mind in what order he does so, but he would like to spend the least time travelling. To work out his shortest route takes conventional computers forever. A connectionist device has solved the problem fairly quickly. Dr. Hopfield and Dr. Tank programmed a neural network with the basic rules - forbidding the salesman to visit a city twice and forbidding more than one city from being, say, the tenth city visited. It starts with a random route and is told that whenever it finds a shorter route, it is to strengthen the connections that gave it that route and weaken the others. Eventually, it ends up with a good solution.

A good solution, but not the right one. The computationists are not impressed. Dr. Poggio points out the conventional computers can also arrive at second-best solutions to the problem fairly easily: it is the right answer that is hard to get. Anyway, is the travelling salesman an interesting problem? It is clearly one suited to parallel computers, since many different legs of the journey have to be juggled at once. It is also of possible practical use. Airlines, for instance, may find it helpful to solve such a problem. But it is in danger of becoming an obsession with computer scientists.

To the computationists, understanding how the machine works is the interesting part: after all, real brains are black boxes and brain scientists devote their careers to making them less black. Dr. Andras Pellionisz of New York University straddles the divide between connectionism and computationism. He is interested in the control of movement. It teaches him the importance of parallel devices linked up by programmable connections, but it also teaches him how to program those connections by working out what the brain is computing.

Move your head from side to side. Did your eyes move, too, or did they remain fixed on the paper? The instinct that holds a gaze steady despite movement in the head and the rest of the body is a remarkably strong reflex, and one whose circuitry is well known. In the ear is an organ of balance, consisting of three semi-circular canals at right angles to one another. Around the eyes are six sets of muscles that control its angle. Between them is a network of nervous connections that automatically ensures that every change registered by the balance organs causes a compensating movement in the eye. Some of the connections are stronger than others, so that, for example, an up-and-down movement of the head causes the muscles controlling the vertical angle of the eye to change more than the other muscles.

That much has been known for decades. What Dr. Pellionisz and his colleague, Dr. Rodolfo Llinas, realized is that that network is doing a simple mathematical trick that could apply to all movement control within the body. The trick is called tensor analysis.

The position of an object in space can be identified in several different ways. The standard one is Cartesian co-ordinates: measuring from, say, the corner of the room, the object is x feet away, y feet up and z feet to the left. There are all sorts of others. The object's position can be described as the six instructions given to the six eye muscles to make the eye look at the object, or the many instructions given to the muscles of the arm to make the arm reach out and pick up the object. Tensors convert one set of co-ordinates into another.

Dr. Pellionisz thinks that all the connections between the balance organs and the eye muscles are doing is to execute a tensor transformation. He believes that this is also the function of the cerebellum, the separate organ at the back of the brain. The cerebellum has only four kinds of cells and throughout the organ they are repeated endlessly in the same pattern. It is, says Dr. Pellionisz, like a crystal. Or like a connectionist device. His approach, though, has been to understand its computations, not to treat it as a black box.

Several companies are already trying to market products based on connectionist ideas. Among the most ambitious is Synaptics, a company founded on the man who tracked down memory in the rat's brain, Dr. Gary Lynch of the University of California at Irvine, and a guru of chip design, Dr. Carver Mead of the California Institute of Technology. Synaptics has a device that imitates the retina of the eye. Its aim is to make neural chips.

Less ambitious but further forward is a small company in Providence, Rhode Island, called Nestor. Founded in 1975 by two physics professors from Brown University, Dr. Leon Cooper and Dr. Charles Elbaum, Nestor has invented, among other things, a device that reads handwriting directly into a computer.

The NestorWriter is presently being tested with insurance companies in France and America, and the company expects to be selling the product for $1,500 apiece by the end of May. But do not throw away your keyboard yet. NestorWriter's abilities are still fairly limited. It can learn to read an individual's way of writing single letters either as they are written or after the event. Joined-up writing is still beyond it, and the price does not include the special pen and pad required (though the company has also learnt how to incorporate the pad into the screen of a portable computer).

That limits the product's usefulness, but Nestor hopes to succeed in several markets, where scribbled but brief notes are a big part of the job. One is insurance, where agents fill in forms "in the field"; another is Japanese word-processing; a third is stock trading. The trader (always on the telephone, so unable to dictate) scribbles down on a slip each transaction; it is then transcribed and typed into a computer. Both these steps could be cut out by a machine.

Reading hand-writing is a game that Nestor has largely to itself. Recognising speech is one where it has some competition. Yet connectionists admit that this is the task in which neurocomputers must win their spurs: it requires parallel processing of lots of different kinds of data (pitch, volume, harmonics, context) and it is something at which brains are patently brilliant. Yet no human knows how he does it, so a computer cannot be programmed in the same way. It is the ideal task for neurocomputers, which would learn by simply trying lots of examples of spoken words.

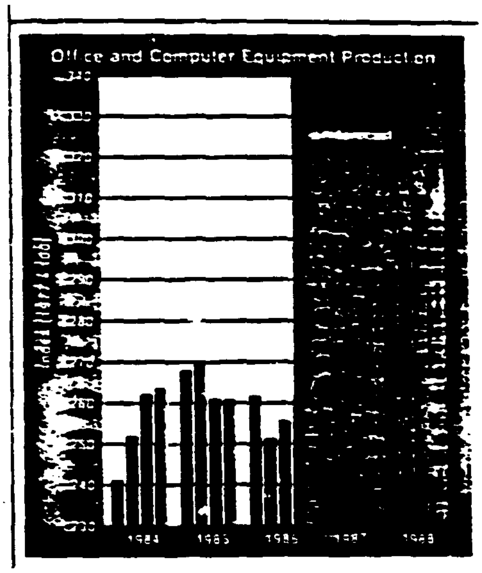
The trouble is that the computational approach is already doing well. Several small companies are on the point of launching devices that enable computers to take dictation. IBM is even further ahead technically, though not ready to sell anything. They all use the computational way: figuring out what rules might work for interpreting speech - grammatical and acoustic - and then programming them into the computer. Can the neurocomputers learn better rules? Japan's Asahi Chemicals may soon know the answer. The company plans to sell a speech recognizer that is based on connectionist principles. It was invented by Dr. Teuvo Kohonen of the Helsinki University of Technology, an early connectionist.

The purest form of connectionism is a dream: that you can put together a million-neuron network and set it free to organise itself into intelligence. It will get nowhere. Some kind of programming of the structure is necessary. But most connectionists are more realistic. They believe that there will be parts of parallel computers whose workings will somehow be hidden from scrutiny because they learn from examples using rules that humans cannot decipher. In that, they are likely to be right. (The Economist, 2 May 1987, pp. 86-88)

III. MARKET TRENDS AND COMPANY NEWS

US computer industry begins gradual recovery

Business conditions in the US computer industry began to improve in late 1986. Production levels, which had tumbled 5.6 per cent during the first six months of the year, rose steadily during the second half and managed to recoup the entire loss. Despite this recovery, the industry posted a decrease of 2.7 per cent in production for the year. Although capital spending within the US will remain lukewarm during early 1987, several factors should enable the market for computers and related equipment to improve throughout the year. These include: new product introductions, increased export sales and rapid growth in the areas of factory and office automation. Look for production to climb 6.5 per cent this year and 11.3 per cent next year.



Historical data: Semiconductor Industry Association

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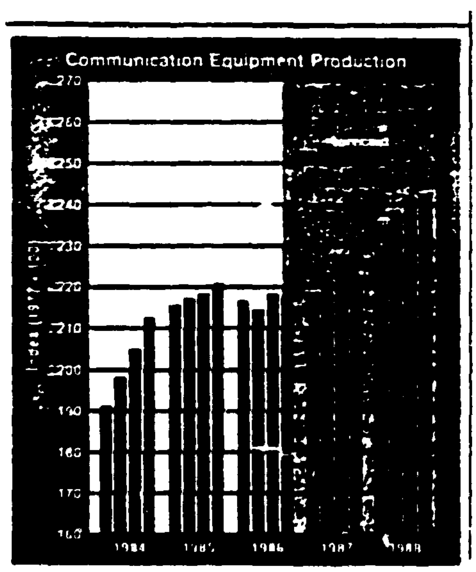
Slow growth ahead for communications market in US

Manufacturers of communication equipment maintained, but did not improve, their production rates between early 1985 and the end of 1986. This period of stagnation resulted from three factors: reduced spending by US businesses for computers and other types of capital equipment; maturation of some product areas such as voice-switching systems; and the current slowdown in defense-related procurement. The communication equipment market is expected to remain stagnant into this spring, but a recent improvement in demand for telecommunications products suggests that growth will accelerate gradually this year. Production will post a slim gain of 3.3 per cent in 1987, and more than double in 1988, reaching 7.1 per cent. (Reprinted with permission from Semiconductor International Magazine, March 1987. Copyright 1987 by Cahners Publishing Co., Des Plaines, Il., USA)



Gallium arsenide on silicon: the growth of something big

Research centres around the world are scrambling to put gallium arsenide (GaAs) on silicon (Si). And with good reason. As soon as technical and manufacturing issues are sorted out, it means an abundance of cheap GaAs - an increasingly important material for strategic, high-performance and optoelectronic integrated circuit (IC) applications. It means GaAs wafers resistant to breakage, inviting automated handling for improved yields.

Most important, perhaps, GaAs on Si means the marriage of two semiconductor materials, each with its own set of superior physical and electronic properties. This, in turn, could spawn intelligent sensors, super efficient "tandem" solar cells and data processing circuits with integral optical interconnects.

Longer-term, additional important compounds and alloys that now defy large-scale bulk growth will wind up as epitaxial layers on simpler, lower defect materials like silicon. Already Ford Aerospace, for instance, is growing mercury cadmium telluride (HgCdTe) on CdTe on GaAs on Si for infrared detector applications. Probable follow-ons include silicon carbide (SiC) for blue light-emitting diodes and lasers, and perhaps even diamond on a suitable substrate for high-speed, very high temperature ICs.

The precursor to heteroepitaxy on silicon was, ironically perhaps, silicon on sapphire (SOS). The lacklustre penetration of SOS into the commercial marketplace tempts the conclusion that GaAs on Si, too, will be limited to narrow niches. But such an analogy is dangerous to draw. Touted as the ticket to ultrahigh speed, the performance of SOS was beaten out by bipolar, and now, by advanced CMOS bulk processes. Predicted to be cheap, the price of SOS remains dear. In short, SOS has been relegated to specialized, defense-related, radiation hard applications, and consumer chips simply do not need rad-hardness.

True, GaAs ICs are used today largely in government-sponsored programmes, but commercial and industrial applications will demand GaAs and related compound semiconductor materials. Heteroepitaxy onto silicon is a likely vehicle for large substrates and low prices. In Japan, for example, the push for inexpensive lasers in compact disk players has been fueling the commercialization of GaAs technology for several years. And count on it - mainframe and business computers, and high-volume microwave and millimeter wave applications will follow. Texas Instruments recently flaunted a fully functional 1K static random access memory built in GaAs on Si. A current General Motors advertisement even suggests an automotive night vision system for spotting animals and pedestrians through thick fog. Such a system could not be fabricated on silicon.

Apart from laboratory efforts, a few companies are on the verge of introducing GaAs on Si substrates to compete with bulk grown GaAs. Technical challenges once thought to be insurmountable are being overcome thanks to ingenuity and advanced epitaxial procedures. GaAs and Si present a 4 per cent lattice mismatch and a 200 per cent thermal mismatch; Si is nonpolar but GaAs is polar, and Si oxidizes easily. Any of these differences could lead to a crystal defect.

But the lattice mismatch problem is being solved through strained epitaxial layers and growth on specific crystal orientations. The thermal mismatch problem may never be solved, but it is not as pronounced as once anticipated, and vacuum chucks on processing equipment may render the effect insignificant. Antiphase domains caused by polar-nonpolar interactions are being overcome by low temperature arsenic-only nucleation, and acute attention to cleanliness and detail is sufficiently limiting the formation of oxides and other detrimental compounds.

GaAs on Si will not replace GaAs. Certain types of solar cells and minority carrier devices such as heterojunction bipolar transistors may suffer due to excessive traps generated at the GaAs-Si interface. It may also be difficult to grow high-quality semi-insulating GaAs on Si, which will limit frequency response and keep the highest performance components on bulk GaAs substrates. But many, if not all of the remaining applications could exploit GaAs-on-Si technology, and judging by the growth of GaAs applications, this could be the growth of something big. (Reprinted with permission from Semiconductor International Magazine, March 1987, Copyright 1987 by Cannors Publishing Co., Des Plaines, Il., USA)

Gene Amdahl puts future in silicon

Gene Amdahl, father of the IBM mainframe, doubts that either gallium arsenide chips or hypercube computer architectures are going to have much impact on general-purpose computing.

Speaking to a London audience recently that included UK luminaries such as Inmos's Iann Barron, Amdahl was dismissive of two of the computer industry's brightest hopes for future advances.

Amdahl said gallium arsenide has been touted as the semiconductor material to replace silicon. But he said the 30-year-old silicon bipolar technology, ECL, still matches the best laboratory bench-marks for gallium devices.

He expects mainstream computers to be built of silicon for the foreseeable future.

At a lecture sponsored by the Institution of Electrical Engineers (IEE), Amdahl also gave reasons why massively parallel computer architectures are unlikely to revolutionise everyday tasks.

Amdahl said that even if the software existed to break up programmes into many parallel tasks, the pay-off from adding extra processors to the system falls off fast. And even with a task divided into 100 pieces, very little is gained by using more than 18 processors.

Amdahl said experimental parallel architectures such as hypercubes can theoretically tie together an infinite number of processors. But for general-purpose computing, he sees practical limits on using more than about 20. (Computing, 5 March 1987)

The European software market

According to a study carried out by the survey company Input, the European market for software and data services will grow at an annual rate of 20-23 per cent during the next four years. By 1991, it will have exceeded US$50,000 million. The survey included the total user costs, that is it included both the software from specialized companies and the software provided by computer manufacturers. (Bulletin IBIPRESS, No. 127, 10 May 1987)

Factory automation sales

High-tech factory automation sales are estimated to total $18.5 billion for 1986, and may increase 2X by 1992. The $600 million robotics market, however, is floundering, and growth for CAD/CAM spending, which totaled $3.3 billion in 1986, has been virtually cut in half. The latest trend in factory automation is being called computer-integrated manufacturing (CIM), a catch-all acronym for totally integrated factory automation, consisting of computers, workstations, terminals, CAD/CAM/CAE systems, floor automation, robotics, programmable controllers and sensors and other assorted products. The outlooks for both manufacturing resource planning (MRP) software and manufacturing automation protocol (MAP) networks are good, with MRP sales expected to total $300 million in 1986 and $900 million/year by 1990, while MAP sales are expected to grow to $350 million/year by 1990. (High Tech Market, February 1987, pp. 48-53)

Arab informatics imports

The Gulf Organization for Industrial Consulting has drawn up a study on the hardware imports in the Arab countries belonging to the OECD. This study shows how the fall in the price of oil and the conflicts in some of these countries have stabilized the informatics procurement figures of these countries. Hence, in 1980, the Arab countries imported US$299.4 million, and in 1984 this figure amounted to only US$304 million. The negative factors therefore counteracted and neutralized the trend of a general growth in the informatics market, which has shown increases even in economies affected by the crisis.

Years showing a large decrease in buying - as in 1981 with a total of US$227.5 million and 1984 with US$308 million - are balanced by years with an almost equal increase: such was the case of 1982 with imports of US$308.3 million and 1983 with US$363 million. Overall, during these five years, some countries showed a decrease in buying: Algeria passed from US$36.7 million to US$17 million, Libya from US$20.9 million to US$6.3 million, Lebanon from US$8 million to US$7.7 million, Iraq from US$61.8 million to US$16.6 million, South Yemen from US$0.96 million to US$0.72 million, the United Arab Emirates from US$20 million to US$15 million, Qatar from US$3.1 million to US$2.1 million, Oman from US$6.75 million to US$6.15 million. It must be noted that the fall in imports in Algeria is exceptional since this is due to the development of its own output.

As regards the growth in imports, a case apart is Saudi Arabia which passed from US$71.6 million in 1980 to US$133.8 million 1984. These figures alone enabled the Arab countries to avoid closing the period with a significant decrease. Other countries also had large increases, such as Tunisia (from US$2.78 million to US$11.6 million); Sudan (from US$0.56 million to US$1.55 million); Mauritania (from US$0.25 million to US$0.64 million); Syria (from US$4.5 million to US$9 million); Bahrain (from US$5.3 million to US$12.45 million); Jordan (from US$5.2 million to US$7.3 million); and Yemen (from US$1 million to US$1.8 million).

In the five-year period from 1980 to 1984, the worst year as regards figures for imports was 1981: only Tunisia, Sudan, Mauritania, Syria and Bahrain showed an increase. Noteworthy are the cases of Tunisia and Syria with increases of 165 and 338 respectively. All the other countries experienced a decline in their imports that year: Algeria passed from US$36.8 million to US$6.8 million; Iraq from US$61.8 million to US$35.4 million; Libya from US$20.9 million to US$10.6 million; Lebanon from US$8 million to US$4.8 million; and United Arab Emirates from US$19.9 million to US$11.6 million.

At the other extreme the best year was 1983, especially due to Saudi Arabia's imports which reached an amount of US$190.4 million. (Bulletin IBIPRESS, No. 126, 3 May 1987)

CADCAM market in the UK

All in all, 1986 was a dismal year for the CADCAM industry. Growth was down yet again, to an estimated 14 per cent rather than an expected 30 per cent, and, to top it all, another report has concluded that UK users are less than satisfied with what the vendors have to offer. Breakthroughs in technology too have been few and far between; although most microsystems now go to 3D, and some of them are even solid modellers. Prices continue to fall; performance to rise - but not so much as to cause a revolution in take-up. But watch out, Japan has been keeping a very low profile in CADCAM so far, restricting its impact to niche market hardcopy devices such as thermal transfer plotters. There are now signs that a change is on the way.

According to US analysts Daratech, only two of the top five CADCAM vendors ended 1986 in the black, presumably IBM and Intergraph who account for 23.9 per cent and 14.8 per cent of the world market, respectively. Neither IBM, nor GE Calma nor McDonnell Douglas issue figures, or if they do, their CADCAM activities are hidden among other revenues. But none of them dispute their placings in the turnkey league tables. The only dissenter is McDonnell Douglas's Alan Haffenden who was surprised to be behind GE Calma and thinks the former ARC architectural business may not have been considered in the totting-up.

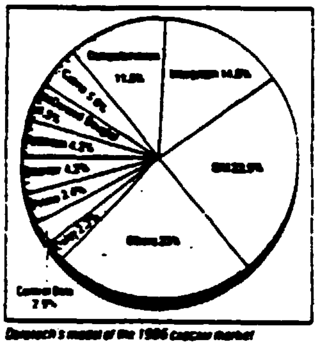
The final countdown goes like this: IBM (with CADCAM turnover estimated at around $1,000 million), followed by Intergraph, Computervision, GE Calma, McDonnell Douglas, Applicon, Mentor, Prime, Control Data and Daisy. This means there was no change in the top five since 1985: Daisy has fallen from last year's number six to this year's ten, neatly swopping places with Applicon whose figures are boosted by last year's merger with sister Schlumberger company MUSI. All the others held the same positions. 'Others', of which there are many, still account for 23 per cent of the world market.

Only IBM, McDonnell Douglas, Mentor and Applicon gained market share last year, according to Daratech. And before arguments start about who should and who should not be included in the charts, here are a few qualifying statements. The CADCAM vendors are taken to be suppliers of turnkey systems (although IBM has never admitted to selling a turnkey), and do not include software suppliers such as MDSI, MCS or Pafec. Racal-Redac which always claims to be up there in the number four or five slot always seems to be excluded for the same reason. Microsystem vendors are also shut out, despite Autodesk's meteoric rise. With 1986 revenues of $48 million, a growth rate of 80 per cent/year and over 180,000 PC-based systems sold so far, this company should at least be awarded a footnote to the tables.

DEC and Apollo also deserve a mention. Not selling own-make systems precludes them from being listed. However, most of the top ten are big users of their kit - Intergraph is DEC's largest single original equipment manufacturer and Mentor is Apollo's largest customer. Sun, too, is a name to conjure with. Computervision's renaissance has been built upon the Sun-based Caddstation, and ICL last year finally dropped the Perq workstation in favour of the Sun3. If 1986 was the year of the PC and Micro Vax, 1987 will be the year of the workstation.

In Daratech's report this time last year, 1985 was quoted as being 'the most turbulent year for CADCAM vendors in recent memory', with growth slowing to 24 per cent, compared with 56 per cent in the heady days of 1984. This year's shortfall - most industry watchers were counting on a recovery of around 30 per cent - surprised everyone. The major reason seems to be of the suppliers' own making - the promotion of computer integrated manufacturing (CIM) strategies.

CIM seemed to frighten most CADCAM users, who had only just got used to glass drawing boards in the design officer. The simultaneous entry of new buzzwords by the vendors, notably CIM (the Department of Trade and Industry had its own version. AMT (Advanced Manufacturing Technology)] and MCAE (standing for mechanical computer-aided engineering and encapsulating concept design using solid modelling and finite-element analysis) stunned the customers into a state of shock.



Dataquest's model of the 1986 CAD/CAM market

Leading CAD/CAM suppliers by revenue. Software-only and hardware-only suppliers are not included

(Engineering, March 1987)

Customized chips: more bits, fewer pieces

Intel, Motorola and Fairchild Semiconductor are among the big chip-making companies in America that are challenging each other to produce the most powerful version of a new generation of customized silicon chips. BIS Mackintosh, a market-research outfit, thinks that by 1991 chips designed specifically for their users will account for 20 per cent of the world chip market, up from 12 per cent last year.

New 32-bit chips are attracting the most interest. These can process 32 bits of information at a time - giving personal computers as much brainpower as many mainframe computers. Apple and Compaq already make PCs fitted with 32-bit chips. On 2 April, they were joined by IBM, which is hoping to thwart its "clone-making" competitors by using customized chips in its range of new PCs.

National Semiconductor has taken the technology of designer chips a stage further. Although available as a single component, its new 32-bit chip is designed as a "core" processor, able to link up with a library of other circuit designs. It hopes that customers will incorporate the chip within other circuits to produce a single, customized chip. That chip can then replace dozens of standardized ones, including some of the commodity chips which Japanese companies have over-produced.

Common operating standards and the need for computers to talk to each other through shared software are encouraging chip makers to make more of their products to order. Designer chips work faster than systems fitted with off-the-shelf chips. Their assembly is easier; and the circuits of computers that use made-to-order chips are less easily copied (one reason that IBM is using them for its range of new PCs).

To speed development, American manufacturers are clubbing together. Last year, Intel and IBM set up a technology pact. National Semiconductor has links with Xerox and Delco, the parts division of General Motors. A new pan-European company called European Silicon Structures (with a start-up capital of $60 million) is specializing in customized chips; its production centre is at Aix-en-Provence in southern France. The company's co-founder, Mr. Robb Wilmot, a former chief executive of Britain's ICL, reckons that customized chips give at least four times the performance of circuits made from standard chips. Thanks to new manufacturing techniques, it may soon make as much sense for users to order a handful of customized chips as it does to order 10,000 or so standardized chips.

Japanese chip makers are fighting back with their own designs of customized chips. About 50 Japanese companies are supporting a national operating system called TRON, developed by Dr. Ken Sakamura of Tokyo University's Department of Information Science. His aim is that TRON, which stands for The Real-time Operating system Nucleus, should be incorporated into the circuits of Japanese designer chips. Toshiba and Matsushita Electric are already developing personal computers using TRON, while Hitachi and Fujitsu have teamed up to produce a new 32-bit chip. (The Economist, 11 April 1987)

Linear integrated circuits

The eyes of Texas Instruments Inc. are focused on a major new thrust into advanced linear integrated circuits - a relatively calmer market that has been more resistant to the cutthroat competition that has bloodied the players in the digital chip arena. A critical part of TI's effort involves the creation of computer-aided-design tools, the lack of which has so far hampered linear's growth. The right tools could cut in half the time it takes to bring complex analog chips to market, the Dallas chip maker claims.

TI, which has been active in linear chips since the early 1970s, is now focusing on a number of different linear components. Among them are single-chip front-end peripherals to digital signal processors, speedy flash converters, self-calibrating analog ICs with on-board digital control logic, high-performance op amps, video digital-to-analog converters, analog-to-digital circuits, and new high-voltage flat-panel display drivers.

Work on the linear programme actually started last year, and the first advanced analog ICs are now waiting for formal introduction. For example, prototypes of a single-chip DSP front-end peripheral have been given to some customers. It is believed to be one of the most complex linear ICs available.

"The linear market has characteristics not found in others," says Tom Engibous, TI vice president for linear products. "It is probably more defensible against global competition. It's certainly a market where design expertise is a larger portion of the product's value. That expertise will mean fast-turnaround capabilities. For chips that are not too complex, we are looking at doing designs and getting parts to customers in less than 120 days. The days of having 18 months to design a part are over."

TI is not alone in its attempts to grab more of a steadily growing analog-IC market. Recent startups and other US electronics giants are also viewing the analog arena as a sanctuary from the intense competition that has driven profits out of many digital commodity markets. Market researcher Gnostic

Concepts Inc. of San Mateo, Calif., predicts that US linear IC production will continue a steady march from $1.8 billion in 1987 to $3.18 billion in 1993.

One reason for the new interest in linear ICs, oddly enough, is the relative shortage of design and testing tools. The need for talented engineers and internally developed CAD tools has raised the price for entry into the field.

The trick is dealing with the shortcomings in analog CAD and testing tools.

Another problem is that with analog there are so many modes of operation and so many unknowns. You don't often find out about them until you start evaluating the actual circuit. No matter how good simulation is on complex circuits, a few things will always be missed.

However, some progress is being made. Work on TI's advanced-linear design system started last year, and some pieces are being used. Crystal's Eric Swanson (Austin, Texas) says his analog designers can now work on ICs with three times the complexity of five years ago. But, he says, "the gap is still widening between digital and analog CAD. Analog suffers from a double problem because it is a smaller market [than digital] without the big dollars focused on it by CAD suppliers. And it is a much more difficult problem to solve compared with digital designs."

Micro Linear Corp. in San José, Calif., has been working on design tools for its semicustom chip customers. Today, its library of cells is available on CAD workstations from Daisy Systems Corp. and Analog Design Tools Inc. Still missing, however, are simpler user interfaces, faster work-station processing speeds, and better methods of converging simulations from linear-circuit equations, notes Ken Fields, Micro Linear's marketing manager.

In Colorado Springs, Colo., Honeywell Inc.'s Signal Processing Technologies venture is crafting engineering tools that speed simulation of digital circuits residing on analog ICs. Traditional methods based on Spice models are too slow, says Reddy Penumalli, technology director. Honeywell aims to speed up digital simulation on analog ICs by 40 to 50 times. It is also developing an analog functional simulator that, unlike transistor-level simulators, works on standard cells. In the layout area, it is writing auto-placement and routing software for interconnection of analog macro-cells.

Expert systems grow

Expert systems activity in UK firms is set to double over the next three years, according to a survey carried out by PA Computers and Telecommunications (Pactel).

Today more than 40 per cent of firms surveyed are using or developing expert systems: by 1990 83 per cent expect to be involved. Most think expert systems will be vital, or at least useful, for the future of their organisations.

The picture is a very different one from that which emerged two years ago, when Pactel found that only 10 per cent of firms were using expert systems. Competitive pressures may have been an important factor in persuading others to introduce systems.

Distribution of expertise, improved products and services, as well as improved management decisions are seen as the main benefits of using expert systems.

However, nearly half the firms said they were worried about development costs and lack of in-house expertise necessary to exploit the technology.

Systems are mainly being used in financial management, administration, sales and marketing, and design; there is little activity in leading edge applications such as real time process or factory control. It is mainly professional staff or line management who are using them rather than DP departments.

The personal computer is the main machine used; less than a quarter of firms are using dedicated workstations and the picture looks unlikely to change in the next three years. (Computer Weekly, 12 March 1987)

300 US companies now do AI

Recent estimates peg the number of companies developing artificial intelligence products at about 300. Most of these companies are less than five years old and employ between 10 and 50 people.

This is one result from a recent study by DM Data Inc. The commercial AI companies provide products that can be categorised as expert systems, natural language interfaces, voice recognition, machine vision, AI programming languages, and AI hardware such as symbolic processors. The largest number are in either machine vision or expert systems. Over half the companies are in California and Massachusetts. Cambridge, MA, has the largest single concentration of AI companies with more than a dozen. That is more AI companies than can be found in 46 of the 50 United States.

The company also notes that notifications of new AI firms or divisions being formed are coming in at a rate of about two per week. (Machine Design, 11 December 1986)

PC-CAD boom forecast

The use of personal computers (PCs) for computer-aided design (CAD) will grow in Europe tenfold by 1990, according to a report by market analysts.

The European PC-CAD market was worth about $157 million last year and will be worth $1,500 million a year by 1990 with a cumulative market of about $3,500 million, says the report from JJ&J Consultants and Technology & Business Communications in Massachusetts. (Electronics Weekly, 18 March 1987)

Company mergers:

The first informatics multinational takes off

Honeywell, Bull and NEC have very recently signed a final agreement which, according to those responsible, will enable the official launching of the first informatics multinational operating in all the electronics and telematics fields thanks to the use of American, European and Japanese technologies.

The new joint venture named Honeywell, Bull Inc. will be located in Minneapolis and its initial capital will be held in equal stakes of 42.5 per cent by Honeywell and Bull, with a 15 per cent stake from the Japanese group NEC.

Despite its apparent multinationality, Honeywell intends to reduce the current control of 42.5 per cent to 19.9 per cent at the end of 1988 and is to grant the difference to Bull which will become the major shareholder with a 65 per cent share. NEC however should not change its degree of participation in the new company.

The three parties have had long-standing collaboration relations. NEC in fact produces the central processor of the DPS-90, the Honeywell computer which is in direct competition with the IBM Sierra series. Bull, on the other hand, has for many years been distributing the American firm's products on the European market, whilst Honeywell markets in the USA the DPS-7, the medium capacity Bull computer. (Bulletin IBIPRESS, No. 125, 26 April 1987)

British collaboration in the Telit

The Italian Fiat and Stet groups - the subsidiaries of which Teletra and Italtel are near to concluding an agreement for setting up the new Telit - have begun talks with some British firms to establish collaboration agreements in the fields of research, marketing and distribution.

The official constitution of the Telit, which is the fruit of the joint venture between Teletra and Italtel, should come about shortly.

It is the founders' intention that Telit should become a company working in the field of telephone switchboards and data transmission. Fiat and Stet will participate with a 48 per cent holding each, while the remaining 4 per cent will remain under the control of the Mediobanca, a public financial institute. The search for British allies by Stet and Fiat is seen as the simplest way to obtain that critical mass necessary for competing on the international market with the other major European telecommunications giants. (Bulletin IBIPRESS, No. 123, 5 April 1987)

Ericsson wins the CGCT

The French authorities, after approximately a year of negotiations, have finally agreed to sell the Compagnie Générale de Construction Téléphonique (CGCT) to the Swedish firm Ericsson which was chosen as the buyer following its recent partnership with the French company Matra.

Ericsson will directly absorb 20 per cent of the CGCT capital, as foreseen under the French laws on the privatization of public companies, with the participation of foreign companies. The recent agreement with Matra will, however, enable the Swedish company to control, through Matra, an additional 50.1 per cent share of the CGCT. The remaining 29.9 per cent will be acquired by a French holding company comprising, among others, the Swedish group as a shareholder. (Bulletin IBIPRESS, No. 127, 11 May 1987)

Siemens joins the select 4-Mb DRAM club

Add Siemens AG to the short but growing list of companies that have produced working 4-Mb dynamic random-access memory chips. Siemens, the first European company to break the 4-Mb barrier, will join the likes of IBM Corp. and Texas Instruments Inc. in this select club when it announces on 1 April at the Industrial Fair in Hanover, FRG, that it has built laboratory samples of the 4-Mb devices. The announcement is the latest result of Siemens' "Megaproject", in which the company has been rushing to climb the learning curve in high-density silicon technology. The devices use 0.8- m CMOS technology and measure only 91 mm^2 - less than twice the size of Siemens' 54 mm^2 1-Mb DRAM. The 4-Mb chips employ trench-type cells that extend about 4 m deep. Siemens says the three-dimensional design helps keep the cell surface small, at just 5 m^2. Siemens says samples may be available by the end of next year. (Electronics, 19 March 1987)

IBM to fund research into AI

IBM has invested over £600,000 to develop artificial intelligence (AI)-based manufacturing systems. The company aims to install these systems at its Greenock plant in Scotland within two years.

According to IBM's UK strategic planning manager, John Smith, these systems promise to dramatically reduce the number of faults that occur in automated production lines and make automatic testing and inspection methods more reliable.

"AI has a big untapped future in manufacturing," says Smith. "And it will undoubtedly form the next stage in our manufacturing strategy. We hope to have our production monitored by expert systems and three-dimensional AI-based vision systems in two years."

IBM is sponsoring a £613,000 project at Heriot-Watt University to apply the latest AI techniques to manufacturing situations. The aim of the project is to develop a robot manufacturing cell which can cope with unexpected changes in production. Even the most advanced automation systems are unable to do so, since they can only cope with situations they are programmed to deal with.

The research will be carried out in Heriot-Watt's Intelligent Automation Laboratory which was opened on Monday. The ultimate goal of the two-year project is to construct a working manufacturing cell with three robots assembling a hydraulic pump. (Electronics Weekly, 4 March 1987)

ASIC centre goes on stream for Intel

Sub-nanosecond gate delays on semi-custom chips will be generally available on the UK market for the first time this month, according to Intel.

Intel has built a dedicated ASIC fab in Santa Clara and has linked it directly to its new ASIC centre at Swindon which was opened last week.

The company is offering the usual ASIC services such as custom, gate array and standard cell but with the addition of erasable programmable logic based on EPROM technology which it develops with, and manufactures for, Altera.

The semi-custom technology on offer is 1.5-micron, two-layer CMOS. It allows gate arrays of up to 19,000 gates, and standard cell with 3.2 transistors per sq. mil, to be made with typical gate delay of 0.7 ns and 65 MHz clock rates.

The largest EPROM-based programmable logic device has 1,800 gates. Intel does not expect to have a bigger part until it gets it onto a 1-micron process. That is not expected for at least six months. (Electronics Weekly, 25 March 1987)

Polycrystalline silicon plant

Nippon Kokan K.K. is currently planning to construct a polycrystalline silicon production plant in Millersburg, Oregon. The Japanese company has already purchased the Oregon site, where silicon production will begin in 1988. Silicon is the basic building block of semiconductors and other high technology products, and polycrystalline silicon is used for the production of silicon ingots.

This plan of Nippon Kokan, however, is raising concern in the US that Japanese firms may come to dominate silicon manufacture in the future. Japanese firms held 21 per cent of the US silicon market, US producers 56 per cent, and European producers 22 per cent in 1985, according to Dataquest Incorporated, an American high technology information service company. Three Japanese companies held 46 per cent of total global sales, with only one US manufacturer, Monsanto Electronics Materials, among the top five in sales. International Business Machines Corp., Texas Instruments Inc. and Motorola Inc., etc. make their own silicon.

Nippon Kokan K.K. acquired the Great Western Silicon plant in Chandler, Arizona, from General Electric Co. in January, and set up a new silicon service centre at its facility in Toyama, Japan, in June. It hopes to become a world-leading polycrystalline silicon producer and supplier. In 1986, Kawasaki Steel Corp. purchased NBK Corp. of Santa Clara, California, which is a small silicon manufacturer. Also Mitsubishi Metal Corp. purchased Siltec Corp. of Menlo Park, California, a silicon wafer producer.

The move of Nippon Kokan follows a trend by main Japanese steelmakers to diversify into non-steel operations. Japanese steelmakers have entered new businesses, faced with decreasing steel production due to low domestic demand, the yen's appreciation against the dollar and competition with South Korea, Brazil, Taiwan, etc. Japan's crude steel production in fiscal 1986 is expected to drop from the 104 million tons of the previous year to 96 million tons.

In the past two years, eight Japanese companies have invested a total of $293.6 million in plant projects in Oregon. Nippon Kokan chose Oregon partly because of lower power costs there, about one tenth of those in Japan. (Chemical Economy & Engineering Review, December 1986)

Oxford wins first with Clipper supermicro

A small Oxford company has become the first in the world to put Fairchild's fast 32-bit chip, the Clipper, into a general purpose multiuser micro. High Level Hardware claims the new version of its Orion supermicro will operate at five Mips, roughly equivalent to the power of a DEC Vax 8600 minicomputer.

The University of Kent is the first customer. It ordered a single machine after a private showing to existing Orion users by High Level Hardware in January.

High Level's managing director, David Small, expects 75 per cent of initial sales will be for universities and the rest to industrial research departments. The company evaluated other 32-bit chips for the Orion, including Intel's 80386, Motorola's 68020 and National Semiconductor's 32332, before settling on the Clipper.

The Clipper is the beginning of a new dynasty of chips, says Small. Most rival chips have grown from eight and 16-bit predecessors and are "hampered by a millstone of compatibility", he says.

A partial reduced instruction set (Risc) approach, coupled with parallel processing of integer and floating point units on the same chip, makes the Clipper several times faster than its rivals, according to Fairchild.

Fairchild says it has closed the gap between microprocessor design and the multiuser architectures of mainframes and supercomputers. (Computer Weekly, 2 April 1987)

IBM PC set to go back to school

IBM is expected to introduce a new low-end personal computer in April primarily aimed at the important education market. Industry sources report that IBM's micro, the IBM PC ET (Educational Technology), will be announced in time to take advantage of buying cycles in the US education sector.

The IBM PC ET is expected to be based on Intel's 8086 16-bit microprocessor rather than the slower 8088 microprocessor that runs the current IBM PC. It will feature a 3 1/2 inch floppy disk drive rather than the older 5 1/4 inch drive. IBM will also offer diskless machines to be used in local area networks. The ET is expected to cost $799 but educational institutes will buy at a 20 per cent discount. It will directly replace the discontinued IBM PCjr which is still sold at a major markdown to clear IBM's inventories. The IBM PC ET will also have to compete with a similar machine manufactured by Tandy, the Tandy 1000 EX. Tandy last year overtook IBM in PC sales.

IBM is also expected to introduce a range of second generation personal computers later this year. This will include semi-custom chips adding new graphics capabilities to the entry level machines and a new high end 32-bit 80386-based system. (Computing, 5 March 1987)

Clone repellent

Once personified as a wandering tramp, IBM's personal computer has rejoined the family fold. The line of PCs just announced includes the first examples of new software standards which Big Blue hopes eventually to extend from the smallest PC to the largest mainframe. In the mean time, the machines also have a series of jazzy new (and mostly proprietary) features to beat the clones.

The Personal System/2, the inelegant name for the new line, faces a daunting task. When IBM launched the original PC in 1981, it went on to win over half the personal-computer market. Today, IBM's share has been cut to less than a quarter (see chart) by machines which can do everything it can - but faster and cheaper.

The first strand of IBM's strategy to restore its personal-computer fortunes is simply to built better computers. The four new models will have better:

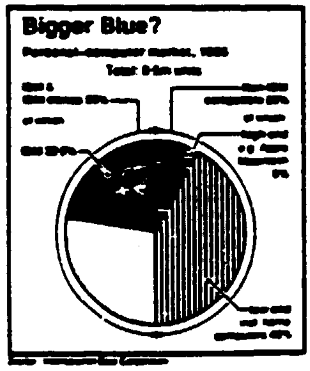
- Processing speed. The top-of-the-line machine, the $8,000 Model 80, uses Intel's new 32-bit microprocessor to crunch through data 3 1/2 times faster than IBM's present pace-setter, the PC AT. The beginner's Model 30 will be about twice as fast as the corresponding machine in the old product line, the PC XT. The new models' prices will be roughly comparable to those of today's IBM PCs.
- Graphics. Apple, a rival company, has long made a selling point of its fancy graphics. Now IBM's new machines do graphics every bit as well as Apple's latest Macintoshes.
- Software. Although the new machines will run the old software, a new "friendlier" operating system will give users many of the capabilities of a minicomputer - like running several programmes at once. But it will not be available until early 1988.

Another strand in IBM's strategy is to try to prevent rivals from copying those features as soon as its new computers hit the market. It has two ways of doing this which have the happy side-effect of boosting efficiency. One is to incorporate many of the new features into custom-designed chips. The other is to change the way in which the computers' components talk to each other.

But a gap remains in its strategy to protect itself against copycats: the easy-to-use interface it intends to incorporate in the new operating system. IBM plans to incorporate many of the features of this interface into new standards for software which will be used in its whole product range. But both interface and operating system were developed in co-operation with Microsoft. Microsoft is free to license its own, virtually identical version to anybody who wants to make a computer look like IBM's.

To win victory over the clones, IBM must rely on the final strand of its strategy: service. Instead of selling the new PCs as a commodity, it is backing them with the service and support for which it is legendary in the mainframe world. The Personal System/2 will be sold only through specially selected and trained dealers. It will also be equipped with software packages that can do everything to automate, say, a doctor's surgery.

IBM is tying the new machines more closely to the rest of its product line. And they are being equipped with a set of software tools that allows them to integrate easily into IBM databases and communications networks. IBM has over two thirds of the world mainframe market, so this tactic promises to give the new personal computers a big boost.



(The Economist, 4 April 1987)

European computer makers try to pull the plug on clones

The clone wars are getting too hot for some European computer makers. Angered by surging imports of cheap Far East knockoffs of IBM's Personal Computer, European manufacturers are quietly preparing to file an antidumping complaint with the European Commission against Korean and Taiwanese copycats.

Italy's Olivetti is trying to galvanise European manufacturers, such as France's Groupe Bull, plus US companies that manufacture in Europe, such as IBM, NCR, and Commodore International. They will fight the "no-name" clones, which sell for as little as half the price of the European-made models. The no-names have only about 6 per cent of Europe's market now, but their share is growing fast. If Olivetti can convince the EC that it has a case, insiders say that Zenith Electronics Corp., among others, may file dumping charges in the US. (Business Week, 23 March 1987)

IV. APPLICATIONS

Process data go digital

Here's a glimpse of the future, as foreseen by process control experts: In the next several years, analog transmitters - units that send process data via a 4-20-mA signal - will give way to digital devices, ones that use microprocessors to convert process measurements into a more accurate digital form before transmission to a process controller.

These digital transmitters, several have already become available in the last year or so, feature accuracies of better than 0.075 per cent over the calibrated span, compared with around 0.2 per cent for conventional analog units. With the digital versions, plant engineers are obtaining better temperature, pressure and flow data, thereby improving product quality and reducing process-control errors.

The new units also have a much greater operating range - for example, digital pressure-transmitters have a 1-to-400-in.-H_2O range, vs 25-150-in.-H_2O for their analog counterparts. An added benefit of the devices' greater range is that users will require fewer units to fill their needs, and this will reduce inventories. Further, since digital transmitters can both send and receive messages (as opposed to conventional analog units), plant engineers can re-calibrate, re-range and troubleshoot transmitters from a remote location such as a control room.

The first move to introduce microprocessors into transmitters came about three years ago, with the introduction of so-called "smart" transmitters by such companies as Honeywell, Inc. (Phoenix, Ariz.) and Bailey Controls Co. (Wickliffe, Ohio).

These units increase the accuracy of process measurements by converting analog-sensor data into a digital signal that is then corrected for errors introduced by ambient-temperature changes, static-pressure shifts and the nonlinearity of individual sensors. In addition, the microprocessors perform such other aspects of a transmitter's operation as calibration, ranging and diagnostics.

Despite these improvements, the smart transmitters are still basically 4-20-mA devices. For example, the corrected digital output is reconverted to an analog signal and transmitted to the process controller. This analog signal is then once again digitized for use in process calculations.

As a result, each analog-to-digital conversion - and vice versa - of the signal introduces errors in the data (even though smart transmitters are still about twice as accurate as conventional analog ones). "Typically, signal accuracy drops from 0.07 per cent to 0.1 per cent when a digital output is converted to analog form for transmission to the controller," says Edward Webster, manager of product planning and development for field instrumentation at Honeywell. He adds that transmission-line losses, and the subsequent reconversion of the analog signal to a digital one, cause overall signal errors to increase further, to about 0.15 per cent or more over the calibrated span.

Last September, Honeywell solved some of these problems by introducing a direct digital link between the firm's TDC 3000 process controllers and its ST 3000 transmitters (for flow, level and pressure uses). The link, called the ST/DC, doubles the overall accuracy of process measurements, and decreases the errors introduced by changes in ambient temperature by a factor of five, compared with conventional analog transmission.

The ST/DC enables an ST 3000 transmitter to send data directly in a digital form to the process controller. Also, each process measurement sent to the controller contains secondary information regarding the status of the transmitter when the data were collected, thus enabling the controller to continuously verify each measurement.

The digital link also helps process operators recalibrate or re-range a transmitter from remote locations. For example, if the process variable goes out of range, then the transmitter's operating limits can be re-ranged - expanded or contracted automatically to keep the variable within scale.

Honeywell says that this digital system can be retrofitted to existing ST 3000 transmitters and TDC 3000 controllers without changing any field wiring. In practice, the TDC 3000's analog-to-digital converter is replaced with an ST/DC. Each ST/DC can handle up to 16 inputs, eight of which can be connected to ST 3000 transmitters.

The ST 3000 transmitters also must be upgraded - by adding a new computer program to the units' electronic memory - to enable them to transmit data digitally to the TDC 3000 controller. The software is necessary because the ST 3000s in use today transmit pressure readings as an analog (4-20 mA) signal to the controller.

The ST 3000 transmitters cost almost twice as much as conventional analog units. Last September, however, Honeywell introduced a new member to its ST 3000 line called the Series 600, which the firm claims offers twice the performance of analog units at about the same price. The Series 600 devices permit re-ranging, self-diagnosis of transmitter problems, and digital readout of process variables.

Making its debut at the Instrument Soc. of America's ISA 86 show, held in Houston last October, was a new family of smart transmitters from Rosemount Inc. (Eden Prairie, Minn.), which includes devices for temperature (Model 3044), pressure (Model 3051), and flow (Model 8712). All these units are designed to communicate directly with the firm's System 3 and RMV9000 process controllers.

In contrast to Honeywell's totally digital system, Rosemount's transmits the measured process variable both as a digital and as a conventional analog (4-20 mA) signal. The transmitters send the former signal to the controller by superimposing it on the analog one. The digital portion - based on a standard technique known as Bell 202 that is used for such simultaneous transmissions - is said to not interfere with the transmitter's analog output.

Like Honeywell's ST/DC, Rosemount has a special input/output board that must be installed in the System 3 and RMV9000 process controllers to allow signal reception and communication with the transmitters. The board makes it possible for the controller to monitor the status of the transmitter or of a process variable, or to recalibrate and re-range the transmitters, directly from the control room. In addition, the Model 268 Remote Transmitter Interface, a handheld communications terminal, can be hooked directly to the transmitters - or from any wiring termination point in the line between the transmitter and controller - to access data being sent to the controllers.

Rosemount's temperature transmitter accepts multiple sensor inputs, and offers 0.05 per cent accuracy and 0.1 per cent stability. The pressure transmitter offers 0.1 per cent accuracy, superior stability and 27:1 rangeability. The magnetic flow-meter guarantees 0.5 per cent accuracy and 30:1 rangeability.

A different tack for digital communications has been taken by Bell Microsensors (Newbury Park, Calif.), a Barber-Colman Co. subsidiary that was recently acquired by Daniel Industries. Last April, the company brought out its Gold Series differential pressure transmitters, with an accuracy of 0.1 per cent over the calibrated span. And late last year, the firm enhanced this line with the Platinum Series, which has an accuracy of 0.05 per cent.

Bell's system consists of a digital network, based on Hewlett-Packard Inc.'s HPIL network, that is separate from the analog transmission line. The HPIL hooks up the Gold and Platinum Series transmitters directly to an "electronic screwdriver", a handheld communications terminal that is basically a Hewlett-Packard HP-41 calculator.

The HPIL link can send a transmitter's signal without amplification via a 4-wire line for a distance of 200 feet; however, by using repeaters to amplify the output, the signal can be sent several miles. Robert Bell, the firm's president, says that the HPIL link is a simpler and more inexpensive alternative to superimposing a digital signal on an analog one.

The HP-41 has two memory chips, one of which contains the software for setting up the transmitter and checking up on its operation; the other has software for sending and receiving messages over the HPIL data link. The calculator's data-entry keys enter numerical data or constants into the transmitter. The control buttons are used to access operating information from the transmitter, display its present condition, and reconfigure the transmitter's span, zero, filter value (for screening electronic noise), etc.

Introduced about 18 months ago, Bailey Controls' BC Series transmitters, used for pressure applications, were among the first units capable of sending digital messages to process controllers. A more recent introduction is the Type EQ, a high-performance temperature transmitter that accepts single/dual RTD-, thermocouple- or mV-inputs; the output is a 4-20-mA signal with a repeatability of 0.05 per cent of input span.

Bailey's transmitters can send messages - e.g., their identity and configuration, and whether they are operating properly - but not process information in a digital form. Messages are transmitted as digital pulses superimposed on the 4-20-mA analog output representing the process measurement. The data can be sent to the firm's System 90 process controller or its handheld terminal, the STT01, or to a personal computer (including the IBM-PC).

Reverse communication (from controller to transmitter) is done by slightly changing the line voltage. According to Bailey, the duration and magnitude of the messages (to and from) take up such a small percentage of the transmitter's total output that this does not significantly affect the unit's operation.

According to John Blagrave, senior product marketing manager, a new all-digital system similar to Honeywell's will be introduced by midyear. With this in mind, the firm has recently upgraded the electronics of the BC transmitters to enable them to send both process information and messages digitally. EQ units also will have digital capability.

The Sensor-Mate 4500, a temperature transmitter from Wood Instrument (Austin, Tex.), works on a principle similar to that of Bailey's message-sending units. In this case, a Hewlett-Packard HP-94 calculator is used as a handheld terminal. The HP-94 plugs directly into any termination point in the 2-wire line connecting the transmitter to the main process controller.

The calculator sends messages as a low-voltage signal on top of the transmitter's analog signal. During message transmission, the value of the analog output is distorted by about 4 per cent. However, says the firm, such distortions last for only about five seconds, since the HP-94 transfers data at a fairly fast rate of 2,400 baud (words/min.). (Chemical Engineering, 16 February 1987, pp. 22-24)

Welding times cut by 57 per cent thanks to robotic installation

A 57 per cent reduction in floor-to-floor welding times has been achieved by Lace Webb Spring Co. of Sandiacre, Derbyshire, following the installation of a ESAB robot welding system costing under £100,000.

The 250-man company, with a turnover of around £7 million, has a vehicle seat frame throughput of around 65,000/month average. Prior to the installation of the robot cell, all assembly and welding was performed manually on the mild steel components.

However, increasing work volumes prompted action to meet output needs and, in May 1984, a production method survey identified areas where advanced technology might offer benefits.

It was forecast that seat frame welding could be performed 25 per cent faster with a robot cell, and give a two-year payback.

The ESAB system incorporates a five-axis ASEA robot and associated MIG welding equipment, ESAB orbit 160R twin-station head and tailstock manipulator, fume extraction plant plus safety interlocked enclosures. Fixturing was subcontracted, since the system was to be tooled for a new job. The fixtures, one for each of the two head and tailstock positions, each hold two sets of components. And while one pair is welded another set is unloaded/loaded.

A total of 21 welds are needed for each frame, which comprises eight components, with four at two in. long and the remainder 1/2 in. or less in length. The floor-to-floor welding time for the robot system is 1.5 mins/frame compared with 3.5 minutes manually.

The system is operated daily on a single 10-hour shift, and quality levels are such that rework is necessary on only two per cent of output. (Machinery and Production Engineering, 21 January 1987)

Software goes to the rescue at sea

Software is helping Britain's coastguards to mount faster, more effective searches for people missing at sea. John Astbury, senior officer at Her Majesty's Coastguard (HMCG), claims that Britain now leads the world in the use of computer techniques.

Traditionally, an officer on watch has to calculate manually where survivors might be when the last known position of a wrecked ship or crashed aircraft comes through. Given information on wind direction and strength, currents and tides, and local conditions, he or she works out a search area. The area takes two to three hours to define and is usually massive.

It was logical to move from manual to computer techniques. The British effort differs from most others in that the program has been devised from a model of the traditional technique. Astbury wrote a program on his BBC microcomputer, which went through the same calculation processes. This revealed the anomalies and errors of assumption from which the traditional method suffers.

From this, Astbury devised a system to help officers on watch determine a search area within minutes. It includes a database of information on weather conditions and rescue resources. It allows the officer to base the search area on "what-if" questions, and to make the best use of everything available from the Nimrod early-radar system to inshore lifeboats and helicopters.

Astbury's initial work was the basis for a final software package developed for HMCG by Logica at a cost of £75,000. The six Maritime Rescue Co-ordination Centres around Britain's coast now use it daily.

The US Coastguard has developed its own technique. It also devised a program that automatically selects a search area, but it ignored the old manual concept. Astbury believes that the weakness of this approach is that officers may not understand the implications of each step they take.

In the British version, the onus is still on the operator to make decisions based on the information provided and with the help of the computer program. Because it is based on the manual method, the officer is less likely to make simple blunders or to accept without question what the computer tells him or her to do. Astbury believes that the operators' familiarity with the calculation methods is the key to avoiding simple mistakes that could endanger life. (This first appeared in New Scientist, London, 22 January 1987, p. 32, the weekly review of science and technology)

Computers lend an ear to AIDS victims

A British health authority is seeking money to develop a computer system to help counsel AIDS victims.

The Association of Health Visitors has recommended that each health district has an AIDS counsellor, says Dr. Roger Brittain, district medical officer, of the North Warwickshire Health Authority, but too few people with knowledge about the disease are available. Brittain has assembled a team of three computer scientists to develop expert systems, software that mimics the knowledge and decision-making skills of a human expert for use in the treatment of communicable diseases.

The computer experts, working at Warwick University and the George Eliot hospital, need at least £10,000 to carry on with their work. The team has already unveiled a prototype system for rabies, but is now concentrating its efforts on AIDS counselling. The Bureau of Hygiene and Tropical Diseases in London is supplying Brittain with the raw material for his project: articles in machine-readable form on AIDS. Currently, the bureau scans some 170 articles a month on AIDS.

The counselling system is important, says Brittain, because little is known about the disease, or its impact on the quality and stability of a victim's life. For example, people who catch AIDS may find their life insurance cancelled.

Brittain stresses that the task of developing a system that could advise doctors and others on the implications of the disease for individual patients is still in its early stages. But he is confident that such a system could help make better use of scarce expertise on AIDS and other illnesses.

The expert system Brittain wants to develop would have four elements covering clinical procedures (including AIDS counselling), diagnosis, health service management, and research. The software could be held centrally on a mainframe, or on a personal computer. (This first appeared in New Scientist, London, 1 January 1987, the weekly review of science and technology)

Computer-aided cows

A Canadian dairy farmer has developed a computerised milk-measuring device which gives a wide range of information for about one-twentieth of the price of current systems.

It measures milk flow from individual cows in either pounds or kilograms, gallons or ounces. By monitoring flow temperature, it also indicates how ready the cow is for breeding.

The computer, which is the size of a pocket book, hooks to the milking machine, close to the udder. It has enough memory to store information on a herd of 60 cows, for a week at a time. Steve Mangan, who spent three years developing the device, says that it could also be programmed to take samples of the milk that indicate the levels of calcium, protein and butterfat. In Ontario the price of milk is now based on the content of these solids.

The battery-operated computer costs C$500. Current systems are priced at around $10,000. Mangan is looking for someone to make and sell his invention worldwide. (This first appeared in New Scientist, London, 22 January 1987, the weekly review of science and technology)

Computer-aided cows

(New Scientist, 22 January 1987)

V. EXPERT SYSTEMS

Too much hype:

Over the past few years, significant expectations have been raised about the impact expert systems would have on the way we do our jobs. Among the claims were assertions that such programs would guarantee instant access to technical expertise, regardless of the availability of a human expert. Such programs were also expected to combine the knowledge of several experts into one readily accessible source. And best of all, they would provide a means of solving tough engineering problems without the expense of a human expert.

In reality, few engineers use expert systems today, and it seems unlikely that many will be using such software in the near future. In general, the initial claims from software vendors appear to have been overly optimistic.

A number of reasons are cited for the slow growth of expert systems. One is that like any new and different technology, the principles of expert systems are difficult to grasp. Also, programmers lack experience with the technique, and better AI development tools are needed.

Others, however, feel such explanations skirt the real issue. Many feel that both the needed technology and the knowledge to apply it are in place today. The problem is economically putting the two together. One obstacle is that expert systems that do truly useful work are complicated and require a considerable amount of development time and effort. Several companies have looked at expert systems for various applications and concluded the programs are uneconomical today.

Another problem concerns acquiring the knowledge needed to make the expert program work. Knowledge built into the program must come from a human expert. But human experts generally perform important tasks for their employers. Thus these individuals often cannot be spared to work on a computer program for a substantial period of time. And allowing the expert to only work part time on such a project makes its success all the more improbable. Other day-to-day deadlines tend to have priority.

Perhaps the biggest hurdle is an unwillingness on the part of engineers to divulge design tips. Most people, regardless of profession, are wary of the effect automation might have on their job. Engineers are no different.

To allay these fears, the realities of expert systems must be stressed. While the intent of these programs is to put expert knowledge into the hands of novices, the complexity of expert systems for engineering design dictates they be narrow in scope. As such, they will likely be useful only as design tools, not substitutes for designers, in the foreseeable future.

Guidelines

Expert systems are often not the best approach for many applications. David Prerau of the Computer Science Laboratory, GTE Laboratories Inc., has developed some useful guidelines that help determine good candidate applications for a successful expert system.

Some of the basic requirements are that the task involves expert knowledge, judgement, and experience. And also important is that conventional programming approaches are not satisfactory. If ordinary methods work, there is usually less technical risk. In addition recognized human experts should be able to solve the problem today. If an area is too new or changing too quickly, there may be no real experts. The completed program should also have a significant payoff that can be measured.

Tasks to be carried out by expert systems should involve symbolic reasoning, and require heuristics: rules of thumb, strategies, and so forth. Other programming methods should be considered for primarily numerical tasks. The problem should not require knowledge of a large number of areas. Otherwise, the knowledge required is probably beyond acceptable limits. Finally, the problem and desired solution should be very narrowly defined.

Prerau agrees that finding a source of expertise can be a significant problem. There must be an expert available willing and able to communicate knowledge. Strong managerial support is needed to enable those involved to commit sufficient time to the project. The expert's reputation should be such that the system will have credibility. And if multiple experts contribute to the knowledge base, one should be the primary expert with final authority.

Prerau also cautions that users should have reasonable expectations. They should understand that even a successful expert system will likely be limited in scope. And like a human, it may not produce correct results every time. The system should be introduced with a minimum of disturbance and not threaten current practice. This makes acceptance more likely. (Machine Design, 11 December 1986)

Expert systems in mechanical design

Expert systems are, in general terms, computer programs that apply human knowledge and decision-making expertise to a given problem. Recently, expert systems have been highly touted for a number of applications. Claims are that this kind of software can aid or replace humans in tasks such as process control, troubleshooting, and engineering design. But to date, expert systems have failed to live up to their billing.

Few expert systems are used today for design, because engineering design is a complex process, programming is time-consuming, and the expert knowledge needed for the job is not always readily available. Advances in hardware and software have eliminated many of the early impediments for using expert systems on design problems. But the development process promises to remain slow.

A look at two expert systems developed for mechanical design illustrates the difficulties involved in creating such programs. The dividends that can be expected over the long term must be weighed against the required effort.

Flange design

Expert systems are sometimes advertised as design tools of the future. Surprisingly, there are instances where these methods have been used for years in product design. A notable example, according to Dr. Lawrence J. Wolf, Dean of the College of Technology at the University of Houston, is a bolted joint design program developed at Nooter Corp. of St. Louis.

Since the ASME Pressure Vessel Code governs basic design, one would expect a flange to have a standard configuration - or at least sufficient design constraints so that experienced engineers would configure them similarly. However, flanged joints have eight geometric variables, a variety of styles, many material possibilities, and are to a considerable degree statically indeterminate. Even when using the same stress formulas, individual designers usually arrive at markedly different configurations.

These design variations cause several engineering problems. Production costs vary widely from one design to another. The cost of large body flanges is a major part of heat exchanger and some pressure vessel expense, sometimes running into the tens of thousands of dollars. Thus some jobs probably are overbid and lost because of these differences. And there is a better chance for leakage in larger vessels operating at higher pressures, even though the flange designs meet ASME codes. This results in delivery delays and costly rework.

As a possible solution, Nooter investigated automating the design process. The company first investigated linear programming techniques. But like most real engineering work, flange design is not an optimization process. Rather, it involved applying a number of rules and guesses, and making engineering judgements based on experience.

Code design formulas use 77 intermediate variables to determine flange stresses. Results from these calculations are compared to allowable stresses. If calculated stresses are too great or small, one or more geometric variables must change. Because of the many steps involved, it is not readily apparent how a change in particular variables affects the final stress levels.

Experience determines which variables to modify and the degree of change needed. Skilled designers generally obtain acceptable designs in two or three iterations, but a major body flange design could easily be a day's work.

Because of this complexity, program development proved to be demanding. Among the problems encountered were disagreements among designers about proper procedure, a lack of understanding about fundamentals, and some "gray" areas where engineering data simply were unavailable.

The company faced the problem that not all designers used the same design techniques, and some designers even disagreed with the methods used by their peers. While a fundamental part of program development consisted of interviewing designers to determine how they actually designed flanges, in the end the expert program reflected techniques used by some designers, but not by others. Getting group approval was impractical, and therefore deliberately avoided.

An unintended but added benefit of the expert system development process was a better understanding of the actual problem. The process of building the expert system helped spotlight instances of over-design and designs that were uneconomical.

A main reason for developing the program was to eliminate leakage, which had become a frequent problem in large flanges operating at high pressures. There are three ways in which a bolted joint can fail. First, bolts can yield and permanently stretch because of overloading. This lowers compression on the gasket. Second, flange material can be overstressed and yield, again reducing gasket compression. Finally, the gasket itself can flow plastically from overstress. The result in each case is a leaking joint.

Designers developed interesting techniques to stop leakage that occurs during hydrotest. The first instinct is to further tighten the bolts. Sometimes leakage stops, often it does not. Some designers routinely design in 10 to 20 per cent more bolt area than required to handle such "overbolting".

However, this practice leads to other problems. On some large diameter, loose-ring flanges, the large bolt load bends mating flanges, resulting in contact at their outer diameters. This prevents further loading of the gasket. Some designers routinely cut back flange faces so that such interference is unlikely. But this practice results in thicker blanks and higher costs. An expert system can eliminate such instances of overdesign, simply by adhering to Code practices.

In some cases design guidelines simply are not available. For example, the Code does not consider the third possible cause of leakage, gasket flow. There is no standard method of preventing gross over-stressing of gasket material.

Engineers generally agreed that there must be an upper bound on gasket stress to prevent flow when bolts are tightened. But no general design rules cover the situation. Rather than delay program development, it was arbitrarily decided to keep gasket loading under twice the minimum seating stress for any design condition. This practice offered little risk because the parameters could be adjusted when the program was tested.

Once the initial set of design techniques had been built into the expert system a testing phase began. Tests of the expert program compared flanges that the software designed to equivalent parts conceived by experienced humans. The testing process hammered out bugs and improved the overall system. It also generated interest in the program and built up confidence in the results. Some designers were initially skeptical of using a computer program for design. Others felt threatened by change. Once engineers saw that the program indeed produced good designs, fears were allayed and they soon forgot about differences in techniques.

The program that evolved designs a bolted joint according to Code. Given some basic inputs such as system pressure and a basic shell ID, the program selects other basic parameters. These parameters include flange thickness and OD, gasket width, thickness, and diameter, the number and size of bolts, and bolt circle diameter. The program then calculates stresses in the bolts, flange, and gasket, and checks for allowable bounds. One or more variables are then adjusted and the stresses are recalculated, until results are acceptable.

The expert system provides benefits that include better overall designs that eliminate leakage, a reduction in the time needed to configure a flange, and a reduction in design and production costs. Additional benefits came to light only as the system developed. These benefits mainly arose from a better understanding of fundamental elements in flange design, elimination of hidden overdesigns, and a standard configuration for the end product.

O-ring, gland design

NL Industries uses O-ring seals to protect electronic sensing equipment in down-hole drilling. The environment is severe, with pressures to 20,000 psi. Through in-house testing and development, the company has created designs suitable for these conditions.

However, much of this information resides with individual design engineers. These individuals generally use their own guidelines for selecting O-rings and designing glands. And many design techniques are not written down. One designer might be unaware of a material or technique someone else in the same company had used successfully.

Also, each designer is responsible for an entire mechanical design project, only a portion of which may involve O-ring and gland design. There is no one specializing in this area, because the task is not performed every day. Though most engineers are familiar with the process, they must often refer to a handbook or notes.

Expert systems provided a promising way to consolidate this information and streamline the design process. The hope was that such a program could reduce the time needed to select O-rings and design glands, and help produce the best possible design for every application. Both benefits could reduce costs substantially.

However, though the task was well defined, development proved to be tough. According to senior research technician Troy Lewis, the two biggest headaches were that a tremendous amount of development time was involved and that acquiring the necessary knowledge base was difficult.

Some of the information needed for the program was available from seal manufacturers' handbooks. However, a great deal more had to be gleaned from the experience of designers. It was difficult to obtain this knowledge. Few designers were willing to part with useful information. Another problem was acceptance. Initially, many designers were skeptical that a computer program could do design work.

It turned out that a basic demonstration system was a key factor in gaining acceptance for the approach. Once engineers saw that the program could be a tool and not a threat, the concept of an O-ring expert system was readily accepted and usage increased substantially. Designers quickly noted that the system saved time that would otherwise be devoted to looking through catalogs and notes, and to making calculations. The software also helped eliminate errors due to miscalculation, lack of experience, or just plain oversight.

As a result, comments and suggestions started flowing in. People offered better or alternative methods for solving particular application problems. The system also generated many requests for further expansion of software capabilities. Thus, a tremendous amount of heuristic knowledge surfaced that was initially unavailable. The feedback also provided insights about the direction for further program development. The downside, however, was that the additions increased programmer workload substantially.

Initial development focused on only static applications. This sub-set was preferable to dealing with all possible design criteria simultaneously, which would have been an unmanageable task. Since the program's introduction, many users have suggested that it be expanded to new applications outside the original bounds.

Developers at NL chose to base the program on an AI programming tool called OPS5, and found that it generally worked well. One problem was the inability of AI tools to handle numbers. Though they work well with words, calculations take a long time. One approach that can help alleviate such difficulties is to use subroutines in Fortran or similar languages for numerical sections of the expert system code.

The program itself leads the designer through a series of standard questions about the particular application. It prompts for information such as pressure and temperature bounds, and size limitations. The program generates a list, in order of preference, of all applicable seals by attributes such as diameter, cross-section, and material, and gives a vendor part number. Cost is a major factor in ranking the possible candidates. However, the designer and not the program actually selects the O-ring. The program then proceeds with gland design.

Program designers felt that forcing a selection on the designer would be counterproductive. Developers also strove to explain, throughout the program, why particular choices are made. Such explanations are especially important to users with an extensive background in the problem area. The offering of these justifications allows end results to be accepted at face value. (Machine Design, 11 December 1986, pp. 121-124)

Expert support systems (ESSs) by Russell Jones, a freelance writer.

For many years, hardware has evolved quicker than software, though the process may be about to be reversed. Single processor hardware is now at the pinnacle of its capabilities. While the next generation of viable multiprocessor computers, containing perhaps millions of individual processors, still seems to be some way from commercial implementation, much progress is being made in improving software capabilities.

Already, PC software is broadening the horizons of capability and usability, and the first fruits of research into artificial intelligence are reaching the market in the way of expert systems. Much exciting work is also being done in providing business managers with effective support as they undertake decision-making tasks. Expert systems and decision support systems are merging to create the software support needed for a new type of computer system. According to a recent article, * expert support systems (ESSs) are in fact a hybrid of the two.

Advertising copy-writers might say decision support systems can be anything from a spreadsheet for a BBC Micro to a huge suite of integrated modelling programs for IBM mainframes. An IDC report says they are the marriage between computers and management science. These definitions reflect the haziness of decision making. It is an esoteric discipline, with

* "Expert Systems: The Next Challenge For Manager". Sloan Management Review - Summer 1986. Available from 50 Memorial Drive, Cambridge, MA 02139, USA.

its practitioners keen to bewilder outsiders with their talk of "managerial skills" and "intuitive perception". One thing is for sure, however. The use of the word "support" is not simply pedantic. Very few computer systems can make "final" decisions.

Most non-AI-based decision support systems have in fact emerged from within the traditional data processing culture. Whilst they expect the power of computers in applying standard procedures (such as modelling) to certain highly structured data, they rely on people to decide which procedures should be invoked in any given situation.

Users are also responsible for placing an interpretation on any results produced.

Expert systems use AI programming techniques, such as production rules and frames, to encode some of the same kinds of goals, heuristics, and strategies that people intuitively use in solving problems. These techniques make it possible to design systems that don't just follow standard procedures, but instead use flexible problem-solving strategies to explore a number of possible alternatives.

Decision support systems were developed within the DP world because of the practical limitations of data processing for helping people solve complex problems in actual organizations. Expert system technology reflects a largely independent evolution that took place in computer science research laboratories. It grew because of the limits of traditional computer science techniques for solving the complex problems that people can solve. These two separate progressions can now be united to help solve a broad range of important practical problems.

One of the earliest, and most impressive, ESSs comes from Palladian Software, of Cambridge, Massachusetts. Financial Advisor is designed to help executives analyse a proposed investment in a new plant or product, in the acquisition of another company, and other financially complex tasks.

The software runs on Lisp machines. Texas Instruments' Explorer and Symbolics 3600 are optimized for AI work. Much of the data needed and used by Financial Advisor is stored within traditional computer systems on an IBM or DEC mainframe.

Palladian has built all the types of knowledge that an expert would use in analyzing the output from a DSS into the Financial Advisor.

Users enter information relating to the modelling process directly, by prompting the entry of that information intelligently. The software may first collect general information relating to an organization, such things as accounting policies or corporate structure. Then it requests details of any particular project an organization may want to undertake. These would include projected costs, revenues and cash flows. The user can ask the system straightforward business questions, such as the impact of competition on the project and on the project's preferable run.

Financial Advisor can answer intelligently because Palladian has built into it knowledge of management and accountancy science, the sort of knowledge a user would normally use in analyzing the output from traditional decision support systems.

Professor Madan Singh of Manchester University's science and technology institute is also developing expert support systems. He has set up a company, Control Sciences, to market some of the new ESSs that have emerged from his research.

Singh says business managers have a lot of knowledge that is difficult to put into a computer program.

"Managers need tools which allow them to organise their gut feelings in some coherent way. People are very good at looking at patterns, computers are very good at number crunching. Combining the two may be an attractive thing to do for higher managerial tasks."

Control Sciences has developed three retailing packages - Resource-opt, Mark-opt and Price-strat - for the IBM PC. Resource-opt is being used in new retail store design and in optimizing space allocation. It is also used by manufacturing companies with a limited sale staff who need to allocate the team between different market segments. Price-strat is designed to fix the right price for goods. Any available hard data about product pricing is enhanced by setting parameters using soft data, drawing upon the expertise of users. Mark-opt addresses the problems of competition between products and between retailers anxious to win more shelf space for their goods.

Palladian claims AI technology is highly applicable to the task of responding to questions that managers typically ask during their daily work. The message from that is clear. AI techniques such as goal seeking and games playing mirror accurately many of the techniques used intuitively by managers in reaching decisions. Products incorporating the use of these techniques are becoming well accepted and, to an extent, they threaten the existing market for decision support systems.

Products such as Financial Advisor represent just the start of the ESS market, a market that could be the biggest yet for AI-based software products. (Computing)

Expert systems: Present and future*

Two contrasting views of artificial intelligence

Expert systems technology is in its infancy, emerging from the new and expanding field of AI (artificial intelligence). There are two contrasting views of AI. One, the theoretical viewpoint, is concerned with understanding how computers can be developed to perceive and understand to the level of human ability (Figure 1). The other, the engineering viewpoint, is concerned with developing computers that can demonstrate human ability without requiring a theoretical foundation. Just as it was possible to construct bridges before the science of mechanics was well developed, so too is it possible to develop intelligent systems that can contribute to problem solving and decision making before a comprehensive theoretical foundation has been developed.

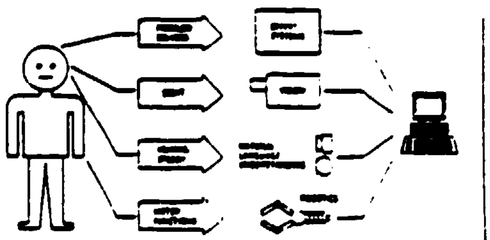


Figure 1: Artificial intelligence models human behavior

* Based on an article in Electrical Communication, Vol. 60, No. 2, 1986, published by and copyright by ITT Corporation, Great Eastern House, Edinburgh Way, Harlow, Essex, England.

As illustrated in Figure 1, the major AI areas mirror human abilities: locomotion and manipulatory skills in robotics; communication skills in natural language and speech; the ability to distinguish and recognize images in vision; and problem solving skills in expert systems.

Techniques to develop computer models

Orthogonal to these viewpoints are the AI techniques used to develop computer models. These can be classified into several areas. First is knowledge representation which covers the formalisms used to describe both declarative and procedural knowledge. Declarative knowledge is what we know (facts, theories, hypotheses), while procedural knowledge describes how we use that knowledge (strategies and tactics). Second is knowledge processing, that is, the mechanisms that search through the knowledge and make reasoned deductions to reach a conclusion. Third are learning techniques that produce new knowledge by observing how effective the existing knowledge is in interacting with the world. Fourth are the planning strategies for organizing problem solving. And fifth is the user interface which determines how the system interacts with the users.

Expert systems cover the area of human ability concerned with problem solving and applying expertise. They are computer systems that use knowledge and inference or reasoning procedures to solve problems that are normally handled by experts. Thus an expert system is designed to capture the knowledge of experts in a particular application area (known as a domain), and make that knowledge available to less experienced personnel.

Components of an expert system

There are three main components in an expert system: user interface, inference engine, and knowledge base (Figure 2).

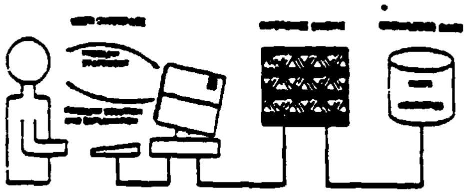


Figure 2: Main expert system components: user interface, inference engine, and knowledge base.

User interface

The user interface allows the user to interact with the system to present the problem and see the conclusions. A key feature is that the expert system can justify its conclusions in the same way as a human expert, and can say why particular options were taken up or ignored.

A major consideration for the designer of user interface concerns how the initiative is to be shared between system and user. When the system takes the initiative, it directs the dialog and asks questions of the user; unless requested, the user cannot present information to the system. Consider, for example, a diagnostic expert system that takes the initiative; the system selects a hypothesis and asks questions of the user until that hypothesis is confirmed or fails. This works well for inexperienced users who may not have alternative views but can be frustrating for experienced users who might have an alternative hypothesis or additional information, and who might feel that their views are not being considered.

When the initiative is shared, the user is able to volunteer information without a specific system request, and to share in decision making. Returning to the diagnostic example, if the initiative is shared, the system invites the user to select a hypothesis from those that are available. Further, at each decision point the user is invited to comment on the current hypothesis to suggest an alternative course of action.

As might be expected, the design of an expert system in which the initiative is shared is more complex than one in which the system takes the initiative. Even more complex would be a system in which the user takes the initiative completely. In this case, the difficulty is in constraining the interaction to cope with a wide range of possible user inputs, which might be in natural language with all its inherent ambiguity and thus beyond the present capability of the technology.

Inference engine

The inference engine, or reasoning mechanism, is similar to the control structure in a conventional program; it operates deductively and selects the relevant knowledge to reach a conclusion. Thus the system can answer users' queries even when the answer is not explicitly stored in the knowledge base. The aim is to imitate human reasoning so that the user can understand the steps taken by the system. One of the designer's main tasks is to choose an appropriate inference technique.

Various inference techniques exist, each of which models a different reasoning procedure. For example, the backward chaining or goal directed technique models the thinking used by a diagnostics expert in starting with a hypothetical fault and reasoning backwards to identify possible causes of that fault. In contrast, the forward chaining or data driven technique models the reasoning used by a configuration expert in starting from a list of requirements to determine the detailed bill of materials necessary to satisfy those requirements. Both forms typically use an inference net to model the reasoning process.

Characterizing inference techniques in this way provides a broad generalization of their use. In practice, however, both techniques may be required; one part of the problem might be suited to a forward chaining strategy, while another is best suited to a backward chaining approach. The challenge is to provide these techniques in a way in which the knowledge engineer can experiment with different options to arrive at an optimal strategy.

Another important aspect of inferencing is the ability to deal with problems where the data is uncertain. This might be necessary, for example, during diagnosis if the data or evidence for the cause of a fault is unreliable. The user will typically express this as a degree of certainty or probability for the occurrence of the evidence. Techniques for reasoning with uncertainty will be a component part of the inference engine.

Knowledge base

The knowledge base is perhaps the most important component as it contains the experts' knowledge and expertise. For this reason expert systems are often known as knowledge based systems. A major advantage is that the knowledge base is seperate from the control part and the inference engine, enabling knowledge to be added or changed without worrying about control or going through the lengthy development process required for conventional programs.

The designer of the knowledge base must choose a suitable representation technique to describe the experts' knowledge. Important factors are the expressive power of the representation (the ease with which the experts' knowledge can be described and read) and the computational efficiency (the run-time performance overhead in processing the representation used). At one extreme, a highly expressive representation might use free-form natural language to describe the knowledge, while at the other extreme a srepresentation based on a programming language might be used to ensure rapid execution. In general the chosen technique is a compromise that is understandable to the experts, so that they are encouraged to maintain the knowledge base and validate its performance, yet provides an acceptable speed of execution.

Underpinning this choice are the principal knowledge representation techniques used in expert systems applications: rules, semantic networks, frames, and objects.

"Rules of thumb"

Rules are the most common form of representation. Each rule consists of one or more conditions which, if satisfied, give rise to one or more actions (Figure 3). Knowledge bases using rules have the advantage of being easy to change since, in principle, each rule is a declarative statement of knowledge which is isolated from the other rules. Furthermore, rules seem to match the way in which experts formulate their knowledge ina kind of "cause and effect" way. Typically experts develop a store of heuristics, or "rules of thumb" which can readily be described using a rule-based representation. However, when there are more than a few hundred rules the ease with which they can be changed causes a problem because it becomes difficult to determine how a change will affect the overall problem solving behaviour. One way of minimizing this problem is to seperate the knowledge base into groups of rules where each group addresses a different aspect of the problem.

EXAMPLE RULES - TOY CASE	
IF THE ANIMAL HAS HAIR OR IF THE ANIMAL GIVES MILK THEN THE ANIMAL IS A MAMMAL	IF THE ANIMAL HAS FEATHERS OR IF THE ANIMAL FLIES AND THE ANIMAL LAYS EGGS THEN THE ANIMAL IS A BIRD

EXAMPLE RULES - REAL WORLD
IF THE TRAFFIC PER LINE IS NORMAL AND THE TYPE OF LINE CIRCUIT IS BLC THEN THERE IS ONE SPARE LINE PER 40 LINES AND THE NUMBER OF LINES PER ABU EQUALS 10 AND THE NUMBER OF LINES PER PBA EQUALS 1

Figure 3: Knowledge representation using rules. This is the most common form of representation in today's expert systems.

A variation on the rule-based representation is one using the predicate calculus form of logic. In this variant the rules adopt the mathematical rigor vested in logic and use logical deduction in the inference technique. The value of this representation depends on whether the application is suited to inference using logical deduction.

Semantic networks

Semantic networks or associative networks represent knowledge in the form of a network of relationships. The network consists of a series of nodes interconnected by arcs, that is, by lines connecting the nodes (Figure 4). Nodes represent the elements of the knowledge while arcs determine the relationship between nodes. This might be an inheritance relationship in which one node inherits the properties of the other node, or a descriptive relationship in which one node describes the properties of the other. The problem with such networks is the difficulty of updating them to reflect new knowledge or changed relationships.

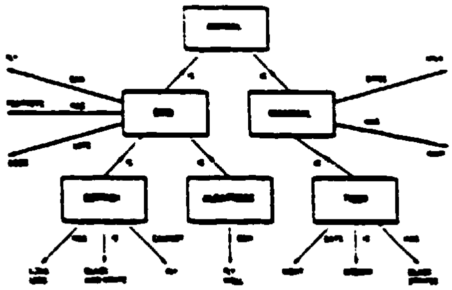


Figure 4: Knowledge representation using semantic networks. Knowledge is represented by the nodes, while interconnecting arcs (i.e. the lines) determine the relationship between nodes.

Frames

Frames are an increasingly common form of representation, combining the ideas of semantic networks and rules. A frame is a template consisting of a number of slots and, optionally, the values that the slots can take. These values can be in the form of rules where a deductive process is necessary to derive the value of the slot. Frames have the advantage of explicitly representing data relationships in hierarchical form so descendent frames in the hierarchy can inherit values from superior frames.

Objects

Objects use a similar representation to frames and incorporate the notions of slots, values, and inheritance. The key difference is that communication with objects is in the form of messages which results in objects being used as agents to perform tasks requested by other objects via these messages. Thus an object can represent a group of rules with messages being used to schedule execution of the rules.

Development of an expert system is really the development of appropriate representations for the experts' knowledge. Tools for building expert systems generally offer a choice of knowledge representation techniques so that the knowledge engineer can select one that is appropriate to the application.

Benefits of expert systems

The most obvious benefit is that expert systems capture human intelligence and judgement for use in areas where resources are scarce and therefore at a premium. This is particularly important in high technology companies with a large demand for expertise.

As with conventional technology, a strong case can be made for using expert systems technology if it can be supported by some measure of the benefits. However, this is not an easy task since there are no established methods for estimating the impact of a developed system on an organization. Some work has been done within ITT on formalizing and applying such measures. Benefits may include a cost reduction through reducing the number of skilled personnel needed, a reduction in the time taken to solve a problem, or the wider availability of specialist expertise in a particular area.

Other potential benefits are the ability of the technology to manage more complex systems and the provision of computer support in areas where conventional computer technology has not been of assistance. An example of complexity management is to be found in VLSI (Very Large Scale Integration) design where there is a need to develop digital circuits with more than 100,000 gates. Automated computer support is used to configure System 12 digital telephone exchanges (manufactured by ITT Corp.) where differing administration requirements and frequent changes make it difficult to develop a satisfactory conventional computer solution. A key feature of the expert system developed by ITT to support the configuration of exchanges is that the rules governing the process can easily be changed.

New products and services

Expert systems technology offers the opportunity for developing new products and services, including tools for building expert systems (estimated to be worth $220 million by 1990), and systems for such tasks as providing consumer advice.

Experience within ITT has shown that expert systems have a major impact on productivity and achieve cost savings in areas where traditional programming has been unable to make inroads. Applications include fault diagnosis at printed board and system level, the configuration of telephone exchanges and the population of the related data tables, and real-time decision making. ITT's strategy for expert systems has focused on their immediate use within the corporation while ensuring adequate research and development to provide the techniques that will be needed for future applications. New techniques will emerge from investigations into architectures for diagnostic systems and VLSI systems, and into how multiple inference mechanisms can be integrated into a set of knowledge engineering tools. The corporation has not only benefited from implementation of a number of expert systems, but has also gained considerable experience in the technology and established a strong technology base. Present experience indicates that the range of applications will increase in the future, bringing further benefits.

Development of an expert system

Development of an expert system takes place in a number of stages. This process, which is known as knowledge engineering, covers two aspects. One is knowledge acquisition, that is, capturing the experts' knowledge and storing it in the knowledge base in a usable form. The other is knowledge processing, which is the application of that knowledge to solving a problem.

Knowledge acquisition

Knowledge acquisition is a major limitation on the widespread use of expert systems since it is a skilled and time consuming task. Two principal techniques are used to acquire an expert's knowledge: handcrafting and induction.

Handcrafting, which defines the rules directly, is based on interviews between the knowledge engineer and the experts to identify the domain knowledge. The output is a set of rules (or an alternative representation) that encompasses the experts' knowledge.

Induction uses computer-based tools that induce rules from examples supplied by domain experts. The output is a set of rules that can be reviewed and amended. Alternatively the examples could be amended and the induction repeated.

The choice of technique is determined by how knowledge is represented in the application area. Handcrafting is more appropriate when knowledge is represented as a set of rulebooks, or as a set of engineering and manufacturing standards. However, induction is more appropriate when knowledge is represented as a set of examples of the skills practised by engineers in the domain.

If knowledge exists in one of these forms, knowledge acquisition has a good foundation. However, if knowledge does not exist in either form, it will take considerably longer to develop an application.

Knowledge processing

A number of technologies are available for building expert systems, including general and special-purpose languages, applications shells, and toolkits. Languages such as LISP and its dialects fall into the first category. Their drawback is that the knowledge engineer has to develop the required expert systems mechanisms as none are provided by the language. This is a skilled and lengthy activity.

Special-purpose languages include OPS5, OPS83, and Prolog, all of which incorporate techniques that are specific to expert systems. The OPS family has been used in industry generally to build expert systems for particular applications. As long as these techniques are appropriate to the application there are few problems. However, if the application requires different techniques or greater expressive power for knowledge representation, then the language will have to be significantly enhanced.

Applications shells, such as EX-TRAN, Sage, and Emycin, provide a higher level view of the techniques available for building an expert system and hence further simplify the knowledge engineer's task.

Expert systems toolkits include Knowledge- craft, ART, and ESSAI. These toolsets incorporate components that are used in most expert systems, such as knowledge acquisition tools, and various knowledge representation and inference mechanisms. They provide a common set of components in the form of building blocks which can be used to acquire and process knowledge in a wide range of applications.

The trend is towards greater generality and flexibility by offering the knowledge engineer a variety of techniques that enable applications to be developed within a common framework. This approach reduces the specialist knowledge needed to build expert systems, enabling knowledge engineers to concentrate on applying the techniques rather than on developing them.

Resources needed for development

The resources required depend on the complexity of the domain and the goals set for the expert system, as well as on the chosen technology. A project team will consist of domain experts (although they need not be full-time), knowledge engineers, and technology support. The knowledge engineers form the link between the experts and the expert system; they are akin to systems engineers, their task being to acquire knowledge relevant to the domain and populate the knowledge base. Technology support is needed to provide advice and guidance on using the technology, and to enhance it should this prove necessary.

Evaluation of performance

Once an expert system has been developed it must be evaluated to validate its performance against known and previously solved problems. Evaluation should involve domain experts who can critique the performance of the system, pointing out omissions in the knowledge base and suggesting improvements to the user interface. This stage provides a review point for further development.

Expert systems develop incrementally, that is, the knowledge base grows as more knowledge becomes available. Throughout this process of enhancement, the expert system is both usable and useful.

Future expert systems

If it is to be possible to build expert systems that can solve the whole range of problems in a domain, then such systems need to integrate and be able to reason with a wide variety of knowledge about the problem area. Fault diagnosis is an example. Most present diagnostic expert systems use empirical knowledge bases, that is, knowledge based on experience. This has the advantage of computational efficiency and is often the only solution in situations where causal knowledge (knowledge of the effect based on an underlying model of the problem) is unavailable, such as in medical diagnosis. Empirically based expert systems are satisfactory where experience covers the full range of problems encountered, but are inadequate for novel problems. In this case the typical reaction of the system is to give up and call for the expert. Empirical knowledge bases are also limited if a detailed explanation is required of the problem-solving method, since it can only be given in terms of empirical associations rather than in terms of the underlying cause.

Experts use empirical knowledge for problem solving because it is both cognitively easier and faster than using causal knowledge (knowledge of cause and effect) which reasons from first principles. However, when experts are faced with novel problems they do not give up, but use their knowledge of structure, behaviour, and cause to arrive at a solution. Hence future expert systems will combine both forms of behaviour.

The issues raised for research and development in expert systems are fundamental and include the following.

Techniques to represent knowledge

An expert system needs to deal with multiple models of the problem area: knowledge of the structure or topology of the area such as the physical connectivity of components in a VLSI circuit, or the units in a computer system; knowledge of function and behaviour, such as the electrical characteristics of the components in a circuit and their behaviour under simulation; knowledge of the design and the constraints observed by the designer, such as the reasons behind using a particular connectivity; knowledge of the physical laws operating and governing behaviour, such as Ohm's Law; knowledge of the interpretation of behaviour which may involve knowledge of problem-solving skills such as troubleshooting and fault finding; and knowledge of previous cases, that is, empirical knowledge.

These models are further complicated by the need to represent time and the ways in which behaviour might vary over time.

There is a need to develop techniques to represent these models; there may also be a need to extend the representations that are available. In addition it will be necessary to consider the problems associated with large knowledge bases and distributed knowledge bases.

Techniques to process knowledge

As future expert systems will use both empirical and causal reasoning, there is a need for techniques that can switch between these modes using the different models of knowledge available and in response to the user's input. There may be multiple sources of data or evidence which may interact with the different models to provide partial solutions which together can contribute to an overall solution.

The inference mechanisms, search techniques, and methods for dealing with uncertain evidence depend on the problem and cannot be expected to be homogeneous for the knowledge base as a whole. Techniques need to be developed that reflect this mix of inference mechanisms, which might include mechanisms that can be invoked by the knowledge engineer or by the system as part of the problem-solving process.

User shares initiative

An expert system needs to provide ways in which the initiative for problem solving can be shared with the user rather than being dictated by the system as in most present expert systems. This includes enabling the user to present input unsolicited and to share in the decision-making process. Input could take place at critical points in the process, enabling the user to suggest the optimal path to be followed when the system is faced with a choice of paths.

The expert system must provide explanations to the user in terms of the underlying physical cause. Any explanations should take account of the user's level of knowledge of the domain, which can be learned by the system through the user interface.

Validation and maintenance of knowledge

Present knowledge bases are still modest, ranging from 200 to around 4,000 rules, but with an expected growth of up to many thousands of rules. Development of knowledge bases is a skilled task, while knowledge engineering is in its infancy. Consequently, rules may be generated that give rise to inconsistency or incompleteness in the knowledge base, resulting in errors, or at least a less than optimal solution, in any conclusion reached by the operational system. Inconsistencies are difficult to detect by a manual review with limited tools support, and in general it is not possible to establish completeness.

Any validation process should therefore consider both the consistency and completeness of the knowledge base. Consistency covers rules that conflict (i.e. rules with mutually exclusive decision parts that can be satisfied at the same time) and rules that are redundant (i.e. with decision parts that have the same effect). A further complication is that inconsistency may be related to the control strategy; thus rules which are consistent under a breadth-first search scheme might be inconsistent when a depth-first scheme is used. Completeness ensures that rules exist to provide a solution for all possible situations.

It may prove possible to develop techniques that support the automatic reorganisation and refinement of the knowledge base over time and that can learn from experience in operation.

Learning and knowledge acquisition

Techniques need to be developed that reduce the time taken for knowledge acquisition. Empirical models could possibly be derived automatically, perhaps by some inductive process, from the causal models of the problem area. This still leaves the problem of knowledge acquisition for causal models. Research into the process of learning may lead to suitable techniques being developed.

The search for new architectures

So far the article has only considered the challenges facing the software designers. In parallel there is an equal, if not greater, challenge facing hardware designers in the search for new architectures that can exploit the growing availability of knowledge systems. Present generation computers use Von Neumann style processing based on the sequential execution of program instructions. This style, of course, is reflected in the nature of conventional programming. What is needed is processing based on the parallel execution of knowledge, each piece of which is independent yet may affect the solution of the problem.

Systems are becoming increasingly complex as technology makes it possible to provide more and better fetures for business and industry. This complexity can be viewed in terms of the growth in the sizes of programs that have been developed and of the density of transistors on a chip. The next generation systems, already under development, will offer even greater capabilities and, for the first time, a means of managing this complexity using intelligent systems based on artificial intelligence. Intelligent systems will emerge from this combination of hardware and software and the various enabling technologies.

Truly intelligent systems

Expert systems technology has already advanced to the point at which it offers innovative and cost-effective solutions to a wide range of industrial problems. Over the next decade, further improvements in methodologies, new hardware architectures, and more powerful software will result in expert systems being introduced into almost all areas where expertise is routinely applied.

Truly intelligent systems, that is, systems that enable us to interact with them at the same level as human interaction, will provide a gateway to knowledge much as formal education has done up to the present day. The key difference is that intelligent systems will be constantly available sources of knowledge with the ability to adapt and filter the flow of knowledge so as to meet the needs of individuals throughout their lives. (Reprinted with permission from Computers and People, January-February 1987, pp. 12-18)

VI. COMPUTER EDUCATION

Computer literacy also in African schools

Several African countries are developing programmes for making the population computer literate. The most recent breakthroughs are being made in Egypt and Kenya, although other countries are alert to the problem. Proof of this lies in the actions undertaken in Burkina Faso, Morocco and Senegal for developing informatics in schools with the support of the Intergovernmental Bureau for Informatics (IBI).

Each Government is becoming increasingly more aware that computer literacy is a vital need for the future development of the country. Almost every day foreign foundations are starting up experimental informatics programmes, notwithstanding the innumerable problems that have to be overcome such as: lack of infrastructures, reluctance on the part of the teaching staff, local inadequacy of technical support and, last but not least, cultural adaptation to technological models thought up in a Western environment.

In Egypt last year the Education Ministry promoted courses for teachers in microcomputer-use. Recently the Starabe computer education project set up an informatics study centre for students equipped with about 40 Apple and Sinclair computers. This project was launched also thanks to a US$150,000 funding from the West German Government. Moreover, an association of Egyptian teachers practising abroad supplied 50 Sinclair computers to the Ministry which then saw to their installation in 25 schools throughout the country.

In addition the Aga Khan Academy of Nairobi, based in Geneva, included informatics education in its curriculum. It is also studying a plan to introduce microcomputer courses in schools in other developing countries.

According to a UNESCO study, at least 18 private schools in Kenya have introduced computer use in the school curriculum. In Senegal microcomputer use is seen as a means of upgrading school education and, backed by the IBI regional centre, its dissemination is being promoted. The use of Logo appropriately translated into the traditional Senegalese language makes it possible to improve the teaching of mathematical and linguistic concepts. Under an IBI-sponsored programme, 48 Olivetti m24 pcs have been installed in 11 high schools in Burkina Faso. Also in Morocco an important experiment for introducing informatics into primary and secondary schools has been started up. (Bulletin IBIPRESS, 124, 12 April 1987)

VII. FACTORY AUTOMATION

Manufacturing Automation Protocol (MAP)

Manufacturing industry is now, for the first time ever, dependent for its well-being on a technology which is entirely information-oriented. Computer-based systems and the information which drives them now determine the difference between success and failure.

The extent of computerization is already self-evident. In a recent design study covering the mechanical engineering/machining sector, ESPRIT (European Strategic Planning for Research in Information Technology) identified five application areas for computers:

- Design;
- Production engineering;
- Production planning;
- Manufacture; and
- Storage and transportation.

Paper is already tottering on its last legs as an industrial medium of communication. Information is rapidly becoming electronic: versatile, instantly accessible and communicable. IBM, for example, has 90 per cent of its engineering drawings already in digital form and is able to introduce design changes into the US, the UK and Japan within 24 hours of deciding on them.

For most companies, however, there are still problems blocking the way. Not the least of these is the impracticability of slotting electronic information into the sort of communications system which has grown up around paper.

Since information is such a decisive factor, it follows that the efficiency with which it is generated, updated, and above all communicated, must also be decisive.

Efficiency is impossible without an effective information flow between functions, and current data-flow paths in manufacturing firms are extremely tortuous and divisive.

At present, fragmentation between the key company operations is a serious problem. Direct links between commercial and shopfloor activities are usually minimal or conspicuous by their absence, and the manufacturing operation has complicated matters by inadvertently erecting barriers between computer-based production systems and programmable shopfloor equipment.

Computer-aided production usually means proprietary systems. These tend to be developed in isolation, with little or no compatibility between systems developed by different suppliers. Shopfloor equipment suffers from the same incompatibility. Computer-controlled machine tools, linked together to perform a specific production task (say, as part of a flexible manufacturing system), usually form 'islands of automation' - cells which stay stubbornly self-contained, incapable of communicating with other cells.

In contrast, the aim of computer integrated manufacturing (CIM) is to mesh together every department and every activity within departments. Externally, sub-contractors, suppliers, and where possible customers, will be sucked into the integration by means of compatible information flows.

It was because no existing system had the sort of universality required for integration that General Motors began to work towards a universally accepted communications system to which any make of programmable device could be easily standardized.

By the end of the 1970s GM found itself with 20,000 programmable controllers, 2,000 robots, and over 40,000 intelligent devices in use in its manufacturing operation. Only 12 per cent of all this was capable of communicating beyond the limits of its own 'island of automation'. The company therefore gathered together representatives from its own divisions and from its suppliers, and set up a task force to develop an independent computer network protocol capable of creating and sustaining a true multi-vendor environment on the shopfloor - the Manufacturing Automation Protocol (MAP).

Progress since then has been rapid. GM has introduced MAP into all new or refurbished plant, and is now planning to extend the system to all its manufacturing facilities.

The foundation for MAP was laid as far back as 1978, when the International Standards Organisation issued its seven-layer Reference Model for Open Systems Interconnection (OSI): the start of a massive initiative to provide standards for all aspects of data communications. Consequently MAP, which is based on the OSI model, not only provides a communications system for the factory as we now foresee it; it also ensures compatibility with the more distant future.

The OSI architecture is layered - organized as a hierarchy of independent, but supportive, functional levels. This splitting allows each function to be made 'transparent' (i.e., utterly unaware and independent of the existence of the others), and so enables any layer to be modified (e.g., updated) without disturbing the others.

Each node (for example, a computer, a terminal, a shopfloor device) on the network is equipped with layers, and each layer plays its part in data transfer by adhering to the rules of its own protocol, communicating, of course, only with its alter ego (its so-called 'peer') in the node sending or receiving the data.

The only direct link between nodes is the actual network cable, which each node accesses at Layer One; but within the nodes there are interfaces between the layers which allow them to accept, process and pass on data during a transfer.

So the data transfer is routed from Layer Seven (the user level) down to Layer One at the transmitting node; thence along the network to Layer One at the receiving node; and finally from Layer One up to Layer Seven (the user). Corresponding layers communicate with each other by the same route.

At the transmitting node, the message initiated at Layer Seven is passed down from layer to layer, each layer adding control information if needed, and behaving in accordance with control information from its peer in the receiving node. At Layer One, the message goes on to the cable.

At the receiving node the procedure is reversed. On its upward path, each of the items of control information stops at its appropriate layer, and the message itself is passed on up to Layer Seven.

Functionally, the seven layers are usually divided into two groups: lower (Layers One to Four) and higher (Layers Five to Seven). The lower layers' job is to get the data from system to system without errors, losses or distortion. The sophisticated work - interpreting the data stream and presenting it to the user in an intelligible and usable form - is done by the upper layers once the data reaches its destination.

A communications network built to the complete seven-layer MAP specification is usually called a full MAP system. It has come under criticism on two points:

- The relatively high cost of the broadband technology specified for the network at Layer One is regarded as prohibitive for some applications;

- The seven-layer route makes data transfer too slow for operations which are time-critical.

The first criticism has led to the development of Carrierband MAP - a version with a simpler and cheaper technology at Level One, but otherwise unchanged from full MAP. Since carrierband is a one-channel technology, and broadband is multi-channelled, the substitution is not without its sacrifices.

Two MAP modifications have been developed to cope with time-critical data transfer. One is MAP enhanced performance architecture (MAP/EPA) the other MiniMAP. A MAP/EPA node is a dual-architecture device, incorporating a full MAP version on one side, and a so-called 'collapsed architecture' version (consisting solely of Layers One, Two and Seven) on the other. The node can therefore switch to either of two communication paths. The seven-layer side allows it to communicate as usual with other full MAP nodes, and the collapsed-architecture side gives very rapid access to like nodes, provided they are on the same network segment.

MiniMAP has only the three-layer architecture as on the collapsed-architecture side of a MAP/EPA node. It therefore allows rapid data transfer, but, being incapable of open-system communication, is not an OSI-compatible device, and as such cannot access devices with a seven-layer architecture. It can, of course, communicate with like nodes on the same network segment, including the collapsed-architecture side of a MAP/EPA node. It could therefore use a MAP/EPA node to gain access to other MiniMAP nodes on a full MAP network, though it might need the help of a router to do this.

All this raises the question of where to use full MAP and where its variants. At present:

- Full MAP provides a factory-wide communications spine in the manufacturing and process-control industries;

- Carrierband MAP provides a cell-level communications system in manufacturing industry; and

- MiniMAP and MAP/EPA co-exist on the same network, predominantly for time-critical operations in the process industries.

Technical and Office Protocol (TOP) does for the office and design environments what MAP does for the manufacturing sector. Like MAP it is based on the OSI seven-layer architecture, and for most of the layers it uses the same specifications as MAP. The main difference is in Layer One - the physical medium. MAP uses a broadband token-passing bus system. TOP employs a baseband 'contention' system - CSMA/CD (Carrier Sense Multiple Access/Collision Detect).

A joint MAP/TOP Steering Committee is ensuring that the two protocols develop hand in hand and to mutual advantage.

So what sort of factory environment is MAP designed to fit into?

The automated factory of the near future can be modelled as three tiers: the cell, the area, and the factory. For service in this environment, an integrated communications network will have to meet four basic requirements at each of the three levels. It will have to:

- Be able to cope with multi-vendor users (i.e., be capable of servicing different makes of equipment);

- Be fast enough to enable control to be exerted in real time - anything from moving a robot arm to rescheduling the factory;

- Have the capacity to handle all the information needed to fulfil the functions demanded of it; and

- Be reasonably priced.

At the base of the hierarchy is the cell, which consists of a group of programmable devices operating together to perform a well-defined function under the supervision of a cell-control computer. It could, for example, consist of one or more metal-cutting machines supported by robots, automatic feeds, wash baths, etc.; or a metal-bending machine with support equipment; or a unit in a flexible manufacturing system.

The cell controller oversees the work and organizes any adjustments needed as a result of internal malfunctions (e.g., a robot inaccuracy) or external influences (e.g. an instruction, or the non-arrival of work material). Data flow within the cell will, of course, differ in degree or kind from that at area or factory level.

Data flow can be defined in terms of speed, message size, system sophistication and (taking the OSI seven-layer architecture as a criterion) functionality. On this basis the cell's requirements are: high speed, to allow the cell controller to react to, and correct, potentially critical conditions; a message size limited to small information or control messages; and comprehensive functionality, so as to allow application software to communicate.

The area is a number of cells with related functions in the mechanical or electrical engineering fields (say, metal-cutting, assembly, inspection). It is equipped to produce semi-manufactured goods or sub-assemblies. The equivalent in the process-engineering sector would be a grouping of sequential and related stages in the process system.

The area controller manages the whole operation. Its data-flow requirements are high speed, for effective control; a larger message size than at cell level; multiple communications, with data links supplemented by voice, video, security and monitoring facilities; and comprehensive functionality catering for communications between programmable devices.

The factory controller co-ordinates the work of the areas. Linked to design, stock control and the factory's commercial activities, it implements any factory-wide changes demanded by, say, design modifications or new orders. Its data-flow requirements are high speed for maximum response; a large message size, typical of that needed for design or analysis; possible links to co-operating sites, or specialist facilities, on the corporate network; and very comprehensive functionality to cater for the wide variety of tasks.

Applying MAP to these different hierarchical levels means selecting a variety of solutions.

For intra-cell communications there are three questions to ask:

- How much is it going to cost to interface devices (computers, machine tools, robots, etc.) to the network?

- Does the cell have any time-critical functions?

- Do you need any form of intra-cell communication other than for data interchange?

At cell level, a data network capable of interlinking the devices operating in the cell is usually all that is needed; voice and video links will normally be organized at area level. But which of the MAP options do you use?

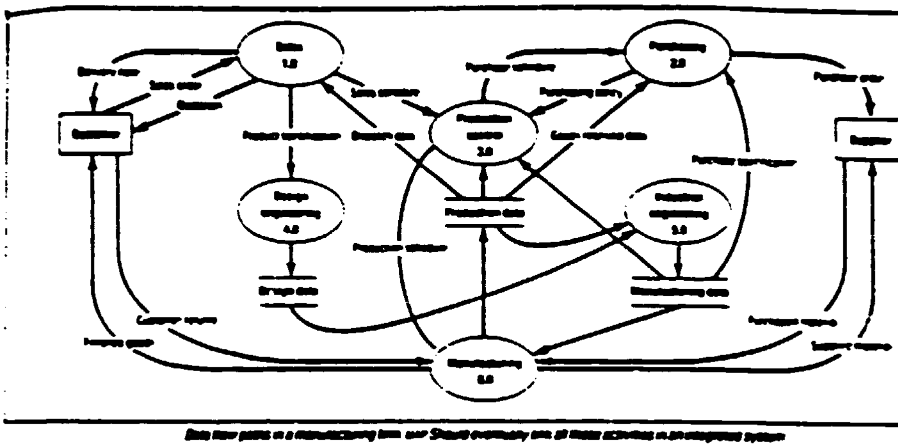
Carrierband MAP has the same functionality as full MAP, and is cheaper; so using the full broadband specification is pointless unless you need the extra communication channels which go with it. If there is a time-critical requirement, the best option is to use a MiniMAP system if the devices do not need to communicate outside their local network, and a MAP/EPA system if they do.

If a proprietary network for intra-cell communications is already in place, a gateway will be needed to link it to the area-level full MAP system. But prepare for difficulties in getting instructions through the gateway if the proprietary system doesn't have the same functionality as MAP.

At area level things are simpler. Full MAP is the only viable option. The cells, and any other distinct functional units such as autostores and automated guided vehicle systems, will be linked to the network by the appropriate interfaces. The area controller may itself act as the interface to factory level.

At factory level, a bridge or a router will link TOP to MAP. For access to other sites in the company organization as well, a gateway to a wide-area network can be used.

The above model is not the only model for a factory-wide communications system. But it has one thing in common with all the others: it serves to emphasize the contrast between what actually exists in most factories today, and what must exist as a preliminary to CIM. Obviously, with this sort of contrast, most firms are not going to convert to MAP in one fell swoop; most firms will 'migrate' towards integration.



(Source: Engineering, March 1987)

A full range of MAP-compatible products will not spring from the equipment suppliers overnight, so companies have the opportunity to get ready for when they do emerge. Start with the links: the physical network and the interfaces.

For example, when a new plant is built, or an old one refurbished, broadband co-axial cable should be installed. This will provide the basic infrastructure for MAP without affecting existing communications services - multi-point links and proprietary networks, for example.

And, since integration of MAP and non-MAP systems is sure to loom large in the uptake of MAP technology, the gateways and attachments available for connecting non-MAP systems and devices to MAP networks should be used wherever possible.

Gateways will, without doubt, be with us for a long time to come - if only as interfaces to systems co-existing with MAP; for example, non-MAP sub-nets offering specialist services, very low-cost devices for which MAP interfaces may never be cost-effective; or wide-area networks and PBX systems. A crucial question to ask therefore is whether it is better to place devices directly onto the MAP network via a MAP interface (but with the likelihood of having to write software to link into particular application programs), or to use gateways and the much simpler attachments which they permit.

The time will come when otherwise-saleable items of manufacturing equipment will not find a market unless equipped with a suitable MAP interface. The lack of a home-based test centre with facilities for developing and testing MAP-compatible products could therefore handicap UK firms in domestic and world markets.

To help fill this gap, the Department of Trade and Industry is supporting work on a range of test facilities which, when in full operation, will offer the following services:

- Formal conformance testing;
- Inter-operability testing;
- Consultancy;
- Information;
- Environments in which new users can 'cut their teeth';
- Software development;
- Acceptance testing;
- Line/network monitor supply;
- A product-development test bed;
- Training.

The Networking Centre at Hemel Hempstead is already working on a two-stage development programme which will lead to the establishment of a full seven-layer conformance-testing service. Information on other aspects is available from the ComCentre, PERA, Melton Mowbray.

(This article is based on Through MAP to CIM, a comprehensive and readable guide to MAP, written and prepared by Eric Morgan, at the Department of Trade and Industry. Copies of the booklet are available from ComCentre, PERA, Melton Mowbray, Leicestershire LE13 OPB). (Engineering, March 1987)

Total factory automation engineering

Chiyoda Chemical Engineering & Construction has introduced technology for factory automation and robot simulators from ASI (Simulation, Inc.) of the US. The Japanese company has actively participated in food plants and factory automation engineering operations. Furthermore, the company has completed a factory automation technology centre provided with a pilot plant at its Kawasaki works. ASI, with its base in Utah, has been engaged in simulation services, factory automation consulting and software development. The American company has rich experience in more than 500 cases involving main automobile factories and electric machinery assembly factories in the US.

The factory automation simulators from ASI which were introduced by Chiyoda have functions lacking in the conventional simulators. For instance, they can simulate automatic warehouses, unmanned carriers, conveyers, and other material-handling machinery and equipment, robots and machine tools, by modelling using a simple simulation language. In addition, the results can be seen on the graphic computer three-dimensionally. The factory automation simulator, which can simulate large-scale complex production processes, can accurately respond to systems whose operation scale varies according to time. Meanwhile the robot simulator can design and simulate visually dynamic machinery elements such as robots and automatic machines, and can be used in a form incorporated into the factory automation simulation. By introducing these simulators, it will be possible to simulate various operation conditions before the construction of a new plant, and to diagnose existing plants.

Chiyoda Chemical Engineering & Construction has completed a factory automation technology centre at its Kawasaki works in order to better respond to users' needs. This centre consists of (1) a machining centre with NC lathes, (2) an automatic assembly line composed of various robots and a conveyer line, (3) measurement experiment facilities composed of machinery measurement and electronic measurement facilities, and (4) a 32-bit minicomputer, a 16-bit personal computer, a programmable controller, and a LAN connecting them.

The factory automation technology centre, where various experiments on factory automation are possible, is so designed that experiment is possible as a system by connecting these machines and equipment. Tests on the connection of various machines and equipment produced by different manufacturers will become an important role of the experiment facilities. Chiyoda will use this factory automation technology centre for prior inspection of users' plans, and also trial manufacture and tests aiming at total factory automation in the assembly/processing industry, the food industry and goods distribution. (Chemical and Engineering News, December 1986)

The automation of manufacturing in Europe

The European industry has also put out the first prototype of what is destined to become the standard of the future automatic manufacturing along the lines of the American MAP.

The practical application of the new protocol has shown that it is capable of integrating the computers SPS-7 of Bull, Tarsan 35 of Nixdorf, M60 of Olivetti, and M70 of Siemens. All of them are linked up to a robotized system for loading and unloading goods which, using a local communications network, interact with an automated system for their transport.

Thirteen European industries participated in the research project on the communication network for manufacturing applications (CNMA) which was started up about two years ago as part of the Esprit programme - some of them in the role of manufacturers and others of potential users of the CNMA, for example: Aeritalia, Bull, Elf, Nixdorf, Olivetti, Siemens, etc.

The first five levels of the MAP were used for setting up the new European CNMA protocol. The MAP (Manufacturing Automation Protocol) was launched a few years ago by the research centre of General Motors. The insertion of MAP in the OSI communications protocol, the adhesion of hundreds of firms, both producers of informatics equipment - DEC, HP, IBM, Motorola, etc., and users: Boeing, Kodak, Lockheed, etc., has resulted in the MAP becoming in fact a standard for manufacturing automation.

The first industrial level applications of the European protocol will come about very shortly in the production of British Aerospace's aeronautical equipment. A further experiment will be started up also in Aeritalia and in other industrial centres.

The main aim of the CNMA project is that of becoming part in the near future of the American standard when this is fully defined. In the face of this challenge, the Europeans are working towards developing the last phases of the protocol so as not to arrive at tomorrow's technology unprepared and behind the others.

There is in fact the growing danger that the European firms, bogged down by legislative provisions and rules which are not homogeneous, may find themselves tomorrow out of the international market. It should also be considered that in the production automation sector there is an annual growth rate of 10-15 per cent in real terms. This is an occasion therefore that cannot be missed. (Bulletin IBIPRESS No. 126, 3 May 1987)

Flexibility in car manufacture

The range of automotive applications for jointed robots of three or more axes capability continues to grow. So does the versatility of the robots. That much was obvious from a visit to one of Europe's leading robot manufacturers, KUKA.

This German company of 2,000 people builds transfer lines, assembly has and welding systems and industrial robots. Its Augsburg plant lies between Munich and Stuttgart, in the heart of Germany's automobile country. So it's no surprise that automotive assembly has influenced the way KUKA has developed.

In return, KUKA's commitment to robotics development, like that of other major robot builders, has done much to enhance flexibility in car manufacture - particularly in the weld assembly of body components ... Today's automated transfer assembly lines must be capable of random or small batch production of more than one version of car or component, each with several variants.

Nor is it only automobile makers that benefit from the robot's programmability and flexibility. Many other industries stand to gain from robots which are flexible enough to perform a variety of jobs, and advanced enough to work unwatched in variable environments. They gain, too, from the robot builder's ability to manufacture in quantities that make their products cost-effective for smaller users. KUKA, in fact, builds between 800 and 1,000 robots/year with payloads from eight to 100 kg.

The automobile maker is the most demanding of automation users. And with robots he needs unattended reliability combined with a flexibility that permits a rapid product change-over. The large number of robots used on welding lines contributes greatly to the levels of flexibility, but their use in such numbers also demands that each robot has a high level of operational reliability.

An equally important reliability aspect concerns having robots technically capable of doing the job. There are several identifiable directions of development in automobile assembly. Chief are the complex tracking tasks such as welding safety critical or filler seams and the application of sealant and adhesives; and the performing of two or more sometimes dissimilar tasks through changing end effectors (grippers, tools or hands) and power supplies.

For continuous operations such as shielded arc welding or the laying of adhesives, the inevitable component-to-component variations in seam and edge positions, as a result of preceding operations or open tolerance work-piece location or even temperature changes, makes it impractical to use off-line or teach methods of programming robot movements. Reliable methods of on-line seam tracking are, therefore, essential for automation.

KUKA has put much effort into developing laser sensors attached to the robot close to the welding torch or dispenser. One type, for seam start location and tracking, uses a weaving laser beam which scans 25 mm across the area of seam, deflected left and right through 20° by a motor-driven mirror. Distances are measured by triangulation with the aid of a microprocessor.

With scanning at 10 sweeps/sec., a maximum of 256 picture elements are used to locate the exact centre of the seam. The robot continues to be guided by the sensor as it welds or dispenses. The sensor communicates any deviation to the robot controller via a computer. Lateral and height errors, as well as joint volume, can be detected and used to correct robot motion and weld deposition rates.

Automating continuous shielded arc welding also depends on a constant feed of wire to the weld area, not always easy when soft or tubular wire is used or where the wire is kinked or its quality and hardness is likely to vary. KUKA's answer is to apply the push-pull principle, with the wire being pushed and pulled through at the same time. This gives arc- and spatter-free welds and consistent positional accuracy of the seam ... (Machinery and production engineering, pp. 43-45, 4 March 1987)

Development of an advanced manufacturing cell

The following article which was written by the Head of the Department of Engineering Technology, Dublin, Ireland describes a system integrating some of the most advanced manufacturing and materials handling systems into a flexible handling cell. The article is addressed to Irish industry but may be of interest to others, too.

CAD: Computer Aided Design
CAM: Computer Aided Manufacture
CNC: Computer Numerical Control
AGV: Automatically Guided Vehicle
FMS: Flexible Manufacturing System
QC: Quality Control

The cell in the production unit is a fully integrated CAD/CAM system which was developed with partial funding from Airmotive Ireland Ltd. The multi-user CAD system is capable of producing working drawings and conducting design analysis via a finite element software suite. It is also capable of solid modelling analysis and it can generate the necessary CNC data for conducting machining operations without manual intervention. Briefly, the flexible cell is comprised of a CNC milling machine and lathe (both of which may be operated directly from the CAD system), a Puma robot, which services both machines, several assembly robots and an automated materials handling system. The automated materials handling system is in essence an AGV, loaded and unloaded by various robots. This maximizes cell production and flexibility. As a result of this and other high-tech developments the college now provides students with unequalled 'hands-on' experience of state-of-the-art technologies.

Apart from the cell's teaching role demonstration of these developments to industry should stimulate interest and investment in this type of technology. It is envisaged that the complete system be accessible to anyone interested in CAM, CAD or both combined. By encouraging company involvement the College should gain valuable industrial feedback which will be of great benefit in formulating course structures and student projects. In the final analysis our success in achieving this will be gauged by the demand from industry for students with this type of expertise. Company involvement is central to having this expertise capitalized in Ireland. At the heart of the advanced manufacturing laboratory containing the flexible manufacturing system (FMS) is the materials handling system. The primary materials handling system consists of a single wire guided vehicle. The automatically guided vehicle (AGV) transports pallets of component parts and tools to the machining cell, and it shuttles pallets of machined parts to the automatic assembly or QC area. The AGV also moves completed assemblies to the QC area.

The secondary handling system is composed of a number of industrial robots. At the machining cell a Puma 762 6-axis robot loads unmachined parts onto a Deckel FP2 NC CNC milling machine. These parts are secured by a custom-built automatic clamping device. Machined parts are removed by the Puma and passed to the automatic assembly area, or periodically they go to the automatic QC zone for inspection via the AGV. At the automatic assembly area a series of gravity feeders, bowl feeders and a power screwdriver work in tandem with a Scara configuration assembly robot to produce a variety of product assemblies. Automatic test and QC is carried out by a computer controlled 3-axis measuring machine. Parts are loaded and unloaded by a single Tequipment laboratory robot.

The FMS is controlled and supervised by a single Compaq 386 32-bit computer while the Puma 762 AGV and Deckel are programmed via direct numerical control. The FMS is capable of producing a large number of component parts and a variety of full or sub-assemblies. The control of the materials handling system allows for part control and routing as well as AGV re-routing in the case of product change or emergency. Parts to be produced within the FMS are designed on the FMS CAD/CAM system with NC part programs being developed via customized post-processor software and downloaded automatically to the CNS machine. The second phase of development will see the purchase of an automatic machinery centre and the development of an electro-discharge machining facility. These will be integrated into the existing FMS and handling system.

A number of student projects have been undertaken and these examples stress the practical nature of their work.

Digital image shape detection

This project consisted of an investigation into, and the application of, pattern recognition and image analysis techniques to the field of industrial automation. Using semiconductor technology, a solid state camera was designed and constructed employing a scanned linear array of photodiodes. This camera formed the 'eyes' of a modular vision system consisting of the camera, control electronics, and a PET micro-computer for control and signal processing. The system allowed for accurate dimensional analysis of components, together with the ability to graphically display the components on screen. Digital image sensing is being further developed as part of a final year project.

Solution to pallet entry/exit problem

This project was carried out in conjunction with Hyster Automated Handling Limited. It investigated the problems associated with automatic pallet trucks when making entries into, or exits from, empty or lightly loaded pallets. In particular, load wheels on pallet trucks sometimes have difficulty mounting the bottom pallet boards, especially if the pallet is empty. Possible solutions to the problem were investigated. One solution was selected and a demonstration model was built. Modifications were made during model assembly which eventually led to a new solution to the pallet entry problem. This involved counter-balancing the forks of the pallet truck and retracting the load wheels. In this way the pallet's load wheels were lifted over the bottom pallet boards and so could not push or pull the pallet around the floor.

A general-purpose robotic system

This project consisted of the design and construction of a low-cost industrial robot system. The system consisted of three main elements.

(a) The actual mechanical robot;

(b) The electronic hardware;

(c) The computer and associated software.

The robot was powered by a hydro-pneumatic circuit, in which low-pressure hydraulic oil passes through pneumatic components. The electronic hardware consisted of a decoder which allowed data to be inputted and outputted from the computer, and a feedback mechanism to control the arm. The robot was controlled from an Amstrad Micro-Computer. The software consisted of:

1. An adaptive basic program, which was used for inputting and outputting data as well as calculating joint angles and so on.

2. A machine code program which controlled the arm while it was moving.

Tests were carried out on the built system indicating repeatability errors of less than 1 mm and performance compared favourably with many commercial robots.

Computerized stability testing Hyster high lift turret trucks

The truck is a narrow aisle high-density storage vehicle guided by either rail or wire. The dominant characteristics are high stacking (12.0 m), narrow base width (1.4 m) and 180° rotation of load to service both sides of the racks. The performance of the machine is thus limited by its inherent stability. All stability options of the chosen truck were modelled on a computer (IBM PC) and the truck was put through a series of tests for the relevant country of destination. The accuracy of the program was backed up by extensive truck stability tests formated by such bodies as FEM in Europe and ANSI, ITA in the US.

Automated guided vehicles

Automated guided vehicles available to industry are limited in scope because they either follow signals emitted by a buried guide wire or a fluorescent line painted on the surface of the floor. The project investigated the possibility of building a prototype AGV which can travel under the guidance of an inboard computer programmed to guide the vehicle on predetermined paths. It directed the vehicle to move a set distance before changing direction as required. To do this it was necessary to measure the distance travelled by the vehicle and to provide feedback to the computer for purposes of control. A Commodore 64 computer was used for control and stepper motors provided motion where distance travelled could be controlled accurately by pulsing. Feedback was provided by means of optical encoders on the undriven wheels. To steer the vehicle, two stepper motors were used as it is possible to drive them independently and at different speeds. (Technology Ireland, March 1987)

VIII. COUNTRY REPORTS

Australia

Survey of software sales

Software sales for 1985-1986 were $600 million and are growing an average of 50 per cent/year above the growth rate of 1983-1984, according to survey respondents in a study of the industry conducted by the Ministry for Industry, Technology and Commerce. The industry employs about 16,500 people. Product exports in 1985-1986 accounted for 10 per cent of sales and the market is expected to increase significantly in 1986-1987. Some 78 per cent of the respondents reported developing, in Australia, software or hardware for multiple sales, licence or lease. Development expenditure in 1985-1986 was $67 million and this is expected to rise 28 per cent to $85.5 million in 1986-1987. However, limited knowledge of overseas markets and lack of financing are hindering export growth. Other problems in the industry include lack of external financing for expansion and availability of skilled workers. (British Business, 16 January 1987, p. 16)

Chip design costs cut

Chip design costs have been slashed by 40 per cent by an Australian chip design company, International Chip Design (ISD). The company is set to offer its cut-price services in the United States and Europe under the direction of a newly appointed high-powered management team.

ISD has recently appointed a new managing director Laird Varzaly, from California-based Advanced International. The company's biggest scoop so far is the appointment of Steve Wozniak, the co-founder of Apple, to its board last month.

Varzaly says his company is able to design at a fraction of the cost of other companies. "We have virtually no overheads and the Australian dollar is so low that it is ridiculous."

ISD will be holding a series of technical presentations at Middlesex Polytechnic starting on 18 May to introduce itself to the UK market. (Electronics Weekly, 18 March 1987)

Brazil

Brazil expects pressure against its draft law on software

Every software product, in order for it to be marketed in Brazil, will have to be registered in a separate book of the special informatics secretary who then classifies it in the appropriate category, depending on whether it is of foreign, national or joint production. The draft law will not establish differences as regards these subdivisions, in the protection of copyright; however it stipulates that in order for a program to be registered, it must be proven that no other operationally equivalent program is produced in the country by a national company.

The registration of programs will authorize foreign companies to distribute only those versions which can be processed on equipment marketed in the country. The contracts for marketing programs between Brazilian and foreign companies will have to be approved by the competent authorities, and the national company which imports the material will also be required to make investments in the field of research and development of new products. The special informatics secretary will be able to authorize the importation of a single copy for the exclusive use of its end user.

Brazil, whose market protection policy for computer equipment is encountering strong opposition from the United States, expects that its draft law, which moreover seeks to foster production in this field, will be criticized both nationally and abroad. The Secretary General of the Ministry of Science and Technology, Mr. L. Continho, anticipating this criticism, said that the draft law will not isolate the country from the latest international advances and it will not create a technological delay, nor will it impede the importation of programs for equipment which is not covered by market protection. The draft law guarantees the production of software and is based on the principles of copyright law for artistic, literary and scientific works, to the extent that Mr. Continho said that respecting the copyright law does not mean surrendering the Brazilian market to multinational companies. (Bulletin IBIPRESS No. 124, 29 March 1987)

China

Singing telephones

The Peoples Republic of China now has its own patent law. Firms in the West can file for monopoly rights, which were never previously available. The law also allows Chinese inventors to apply for patent protection in the West, if they can afford the heavy fees.

The Beijing Ever Bright Industrial Company is one of the first to do this, filing a European patent application (203 394) for an electronic telephone. Instead of producing ringing tones when someone calls, the phone plays what the Chinese describe "sweet melodic music calling signals". These stop when the telephone is answered. But should someone not answer, the music will continue for 15 seconds after the ringing pulses have stopped. This gives users the dubious pleasure of knowing they have just missed a call.

In the telephone, incoming electronic pulses are stored in a capacitor. The stored signal is then used to trigger a music synthesis chip. The chip can, if wished, synthesize speech instead of music, announcing that a call is waiting.

Although the idea may be new in China, the strict examiners at the European Patent Office in Munich may be hard to convince that it is novel. (This first appeared in New Scientist, London, 26 February 1987, the weekly review of science and technology.)

Joint ventures offer a chance in China

IT companies have their opportunity to get a toehold in the Chinese market through setting up equity joint ventures. The first systematic study* published since China legalized manufacturing equity joint ventures in 1979 says 94 per cent of joint venture companies are meeting their business targets.

The study of 70 companies was done by management consultant A.T. Kearney in collaboration with ITRI, a consulting arm of the Chinese Government.

Philip Banks, vice-president of international operations at A.T. Kearney, says equity joint ventures are now the most important single type of foreign investment for companies aiming at the Chinese market.

"In 1984 investments by joint ventures exceeded the total of the previous five years and in 1985 they more than doubled again."

Of the companies that have set up joint ventures in China, 87 per cent give long-term market strategy as their prime motivation. But, says Banks, "there's no way joint ventures will get unbridled access to the Chinese market".

The Chinese partners, most of which are State owned, have different objectives. They are interested in acquiring high technology and earning foreign exchange.

Despite this difference Banks says the Chinese Government is taking steps to attract more foreign investment. (Computer Weekly, 9 April 1987)

France

French software

French software and services houses are often accused of never having developed a world-rated software package and of missing out on microcomputers and export opportunities. Yet they seem to have by-passed the economic crisis currently plaguing the computer manufacturers. And they've attained number one status in Europe, and second place worldwide after the US.

Software and services are growing rapidly in France. Some houses annually achieve 20 per cent growth, and shares in them are in demand on the Paris stock exchange.

Several factors explain this success. Software development's emphasis on abstract ideas such as logic and aspects of maths is far closer to the Gallic mentality than routine hardware manufacture. French engineers value the intellectual freedom. Setting up a software and services house requires modest capital investment. Once a company gets going, the wages bill represents about 80 per cent of turnover (compared to 20 per cent in manufacturing). The French economy encourages services like banking and insurance, which are major users of IT. The Government's decision to keep world-renowned computer manufacturer, Bull, in French hands has played a decisive role in encouraging the development of home-grown talent. When the main French software and services houses were created in the 1960s, there were few computer specialists available. This gave rise to a new animal, the computer advisor.

It was similar in the UK, but in the US, things were different. Major users there invested enough to start the ball rolling, and assigned top personnel to systems development.

Sèma-Métra, France's fourth largest software and services house, doubled its turnover in three years, to 1.4 billion francs in 1986. Net profits have doubled in two years, to 36 million francs. The company's activities are not limited to IT, which accounts for 82 per cent of turnover. The rest is made up of marketing and advisory services. Before being quoted for the first time on the unlisted securities market in 1985, Sèma-Métra staged a remarkable entry into the industrial computing field by acquiring, for 250 million francs, 97 per cent of Cerci, up to then a subsidiary of heavy industry giant Jeumont-Schneider. Sèma-Métra has just announced the formation of a joint subsidiary with the Credit Agricole agricultural credit bank to develop and distribute software, initially to the bank's 84 autonomous regional offices.

But the company is perhaps best known to outsiders for its value added network (VAN) consortium, with IBM France and the Parisbas Bank, which has still to win wholehearted approval from the DGT State telecommunications utility. This 600 million francs project needs 200 to 300 people to complete its development. High-end information processing are to be offered, although voice and dynamic image processings are excluded: they will remain the DGT's responsibility. The project is currently suspended, awaiting approval from the recently created Communications and Civil Liberties Commission (CNCL). Exports are not a strong point at Sèma-Métra (only 20 per cent of turnover). Sèma-Métra sees software packages as a European, rather than a specifically French, bugbear. Recently, however, it introduced an accountancy package in the US, and initial results are promising.

After losing more than 100 million francs in 1983 and nearly 200 million francs in 1984 Cisi, a state-owned subsidiary of the French Atomic Energy Commission (CEA) underwent radical reorganization.

German and US subsidiaries and Cisi-Wharton were sold off. Network engineering and CAD/CAM have been developed with the result that France's second longest software house showed a profit in 1985. Its customers are large corporate users, with small companies coming into the picture for technical applications like CAD.

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* Manufacturing Equity Joint Ventures in China, published by A.T. Kearney, Stockley House, 130 Wilton Road, London SW1V 1LQ. £500.

The company is strong in videotex, artificial intelligence and software engineering. It won a contract to provide the online database when the French inland revenue wanted a videotex service to help taxpayers fill in their forms. Cisi aims to maintain the capacity for major one-off jobs like this, while at the same time providing services for regular customers. It also intends to make sure artificial intelligence is application oriented, rather than to develop basic generic systems. Software engineering is Cisi's bread and butter. It is participating in seven related European Esprit projects, involving considerable investment. (Computer Weekly, 2 April 1987)

Greece

Computer market rises

The market for computers, software and peripherals in Greece jumped by 90 per cent in 1986. The highest growth was in the microcomputer sector where an increase of 92 per cent was recorded.

According to statistics released by Strategic International Limited of Athens the sales of minis rose significantly, by 32 per cent, while the market for mainframes remained stable. (Electronics Weekly, 25 March 1987)

India

US approves Cray super for India

The US Government has approved the export of a scaled-down Cray Research XMP-1 uniprocessor supercomputer to India after Cray earlier beat Control Data (CDC) for the order. But the US Office of Export Administration rejected Cray's original order with the Indian Meteorological Centre in New Delhi for a four-processor XMP supercomputer configuration. The Government said the danger of such a powerful supercomputer being diverted for non-meteorological purposes was too great.

Cray won the Indian order after CDC asked the US Government last year for a policy decision so that a supercomputer might be approved for India, the first such powerful computer allowed to be exported to a third world nation. CDC had counted on the large sale to India to help inject revenues into the financially-ailing firm. But after getting the precedent-making decision, CDC was then knocked out of the sale by Cray Research, which proposed the same four-processor XMP configuration used for meteorological operations in the European Community. Sources said the total order would be likely to exceed $25 million. US export control authorities had already agreed that a supercomputer the size of a XMP-1 uniprocessor or a CDC Cyber 205 could be shipped to India under proper safeguards. But US officials balked at the much more powerful four-processor configuration ordered by the Indian centre. It was not clear if the Indian Meteorological Centre would accept the US restriction of a single Cray processor. NEC of Japan has been pressing the Indian operation to buy an NEC SX-2 dual processor. Sources believed Japan might interpret export restrictions more liberally to approve any SX-2 shipment.

NEC has already received a letter of intent from the Indian Scientific Centre at Banklador for an SX-2 supercomputer. NEC beat Cray and CDC for the order. Industry observers will be watching closely to see if the US Government tries to block the SX-2 shipment to the scientific centre. If NEC succeeds in selling dual processor SX-2 supercomputers to the emerging third world market, Cray is expected to press hard to get the US Government to lift its restrictions on exports of multiprocessor configurations to such countries. (Electronics Weekly, 25 March 1987)

Japan

Real-time operating system - TRON

The Japanese have already closed ranks in a US$60 million project to research a computer architecture that would allow them not only to loosen the stranglehold of US software and microprocessor suppliers, but also to establish new industry standards.

The goal of the project, known as TRON, after the Japanese acronym for "real-time operating-system nucleus", is to develop operating sytems - the programs which control computer systems - and microprocessors - the central processing units on individual chips - that could be used to build highly-compatible, superfast machines.

Unveiled in 1983, the project gained little support until American software and microprocessor suppliers began to adopt more aggressive tactics. The microprocessor-market leaders, the US companies Motorola and Intel, for example, have refused to license their latest designs for 32-bit microprocessors to Fujitsu and Hitachi.

This, combined with criticisms of the ability of US-designed microprocessors to handle the Japanese language adequately, has prompted the Japanese industry to show more interest in TRON. Last summer, the project received the backing of eight electronics companies, and dozens of others have added their support since then.

Fujitsu and Hitachi have announced a joint plan to market a 32-bit TRON microprocessor by the end of this year. Two other companies, Matsushita and Mitsubishi, are also working on TRON chips. Toshiba is developing a TRON personal computer, Hitachi is already selling TRON software for robots and machine tools, and NEC has introduced an industrial version of a TRON operating system for use on NEC microprocessors. Finally, a TRON research team has developed operating systems which can communicate with each other.

None the less, the Japanese will have a tough time beating out the competition. The Unix operating system developed by ATT for workstations and the MS-DOS operating system developed by Microsoft for personal computers and used on IBM and IBM-compatible hardware have become the de facto industry standards. Furthermore, the 32-bit TRON chip will be introduced more than a year after the Intel 80386 and the Motorola 68020. (Bulletin IBIPRESS No. 124, 12 April 1987)

Robot production in Japan

Robot production in Japan declined by seven per cent last year. This was the first drop in the seven years that the country has been manufacturing robots on a large scale.

According to the Japan Industrial Robot Association (JIRA), production was worth 280 billion yen - about £1.2 billion - in 1986, down from the 370 billion yen (£1.6 billion) level that the Association had forecast for the year. It was a sharp drop from the 30 per cent growth levels which had been experienced in previous years.

The Association blames the decline on a rush by manufacturers to cut capital investment - in the wake of the sharp appreciation of the yen - and a move to US-based production by Japanese industrial firms, notably the car manufacturers. The robot market has also been affected by investment cutbacks in the semiconductor and consumer electronics industries.

Early evidence that the market was beginning to go into a depression was provided last autumn when Dainichi-Kiko, one of Japan's leading robot manufacturers, filed for bankruptcy. But despite the current downturn, JIRA is still optimistic about 1987 and predicts that production will rise to approximately 380 billion yen (£1.62 billion) by the end of the year. (Computing, 29 January 1987)

Japan cuts down on chips

The Japanese Trade Ministry last week took the unusual step of telling indigenous chip-making firms to cut production by up to 33 per cent in order to keep prices up, and let competitors in.

The intention was to hold together an agreement with the US, signed in September 1986, and forestall lawsuits and high tariffs against Japanese companies.

But to many furious members of the US semiconductor industry, and angry US senators, the Japan Trade Ministry's instructions will have sounded hollow. A lot of damage has already been done in the US industry by low-priced Japanese chips. Nearly 15,000 jobs have been cut by US chip firms in the past two years.

But while the conflict itself is interesting, it masks the important question for PC users. Will it put up the prices of the PCs?

That depends on how cheaply semiconductor firms around the world produce the chips in use, particularly the 256 Kbit RAM chip. It depends also on how quickly (and cheaply) they move on to making the next generation of memory component, the one Mbit RAM chip.

US firms that cannot make a profit on the present generation of chips will have difficulty investing in the equipment for the next. If Japanese firms push US ones out of the market, they will be able to set their own prices in the one Mbit era.

There is also the possibility that US firms will lack the capital for further innovation and development.

Last September the Japanese Government reluctantly signed a wide-ranging agreement with the US to monitor chip prices at all stages of production and sale, and ensure that Japanese firms did not dump products in the US or other countries at artificially low prices.

The US also demanded that its own analysts should determine a "fair market value" for the chips.

The alternative was US tariffs on a variety of Japanese products - not just chips. The semiconductor world market is so large and so valuable, at nearly $36 billion this year according to market research firm Dataquest, that it is "strategically important" for industrial countries.

The agreement covers metal-oxide semiconductor (MOS) and emitter-coupled logic (ECL) ram chips, eight-bit and 16-bit microprocessors, eight-bit microcontrollers, gate arrays and standard cells using application-specific integrated circuits (ASICS), and logic arrays using ECL.

The two Governments were exuberant about the agreement which was intended to help US firms get into the Japanese market, worth about 40 per cent of world sales. (The US makes up a little over 32 per cent of world sales, according to Dataquest.)

But nine months after the US and Japan signed this agreement dumping has not stopped and market access has not improved. People in the US are angry.

The US Senate takes a similar view. In a vote last week, a call for action on the subject was passed 93-0. For Japan damaging tariffs look dangerously likely.

Thus the call for the cut in production. But the Japanese Government knows it will never make companies there accept foreigners. Outside firms face trade cul-de-sacs in all industries, not just semi-conductors.

So the Government there is looking for other solutions, as are some far-seeing chip-makers. The least painful to the Japanese mind is joint ownership and production.

In the past couple of years, 26 Japanese chip firms have tried to set up links with 34 US firms, with mixed success. The latest was Fujitsu's attempt to buy part of Fairchild Semiconductor which fell through following political pressure in the US.

Another option open to Japanese firms is to set up manufacturing bases overseas as, indeed, US firms have also done. Europe is a favourite venue.

NEC has a new plant in Livingston which beats up its foundries soon to produce a range of chips including RAM, DRAM and ROM components. Matsushita, one of the huge Japanese consumer electronics conglomerates, is looking at a similar option.

The US-Japan agreement does not cover Japanese firms producing abroad, making foreign manufacture a convenient loophole for them.

But for the Japanese chip firms, the message from the US is that you can run, but you can't hide. Stronger action is very likely. (Computer Weekly, 2 April 1987)

Mexico

MexCom '87 (Computer and Communications Trade Show) heralded the start of what could be the most important year to date for high technology in Mexico. For while the technological discrepancy between Mexico and its northern neighbor is overwhelming, this year the country is taking the first steps to narrow that gap. Among them are sweeping changes in trade restrictions as well as the allocation of billions of pesos to modernize the country's telephone and data communications networks.

Mexico traditionally has had a closed, protectionist economy, but this is changing. The government decided in late 1986 to join the international trade organization GATT, the General Agreement on Tariffs and Trade. This move potentially opens the door for a wider and more state-of-the-art selection of computers and electronic products.

Affording new technology has always been a problem in Mexico. The country has faced economic hardship since the oil glut in 1981 and is struggling under the weight of poverty and illiteracy. Computerization in a country with plenty of excess labour clearly has not been a number one priority; MexCom show organizers say the Mexican market for computers and peripherals could reach only $559 million this year.

But there are signs of hope across the board. Mexico hopes to finalize this month a $12 billion loan, jointly supplied by the World Bank and commercial lending institutions. According to a US Embassy official, the Mexican Government has not received such money in any magnitude in almost two years.

While most of the incoming funds will be spent on housing and projects such as building roads, a chunk -

some say upwards of $5 billion - will be allocated to expand telephone services in the country.

That's particularly heartening to satellite equipment suppliers. Last year, in preparation for televising the World Cup soccer games, which it hosted, the Mexican Government purchased two Hughes satellites dubbed Morelos.

"The satellites are up there but are only being partially used," says Patricia Farias Barlow, president of Fapezal Comunicación, Mexico City, a cosponsor of MexCom. Providing telephone services to outlying areas via satellite is an obvious way to go. Barlow says that the satellite equipment the Mexican Government will be in the market to buy includes transmitters and receivers.

An interesting outgrowth of Morelos is that with so much excess capacity, more is being made available for data transmission. The Mexican Government reportedly is beginning to make pricing concessions to facilitate this type of usage. Additionally, Barlow says that a push is under way to sell Morelos space segments to companies in the southern US.

Under the new way of doing business, Mexico is in the process of abandoning its tough import permit requirements on all except approximately 900 of 7,000 items. Computers are no longer on the list. Under the previous arrangement, some felt that import permits were hard to come by.

Another change is in the manner import duties are assessed. Mexico used to charge duties up to 100 per cent of the value of the imported goods. Now, the top rate is in the 45 per cent range. Additionally, Mexico has abandoned its practice of allowing customs officials to assign the worth of the product in question. By the end of 1988, the country will move to the GATT system, whereby there is one commonly agreed-upon international value for products. ...

The economy is the number one worry for Mexican businessmen. Although the economic incentives give hope, the US Embassy official claims that, until the peso strengthens, it is doubtful that there will be an onslaught of outside computer vendors on the country. Instead, the official says, those companies already established in Mexico will battle it out among themselves. Major US companies already in Mexico are IBM, Unisys, Hewlett-Packard, NCR, and Apple. ... (Reprinted with permission of DATAMATION ® magazine ©, 15 March 1987, pp. 26-32, copyright by Technical Publishing Company, A. Dunn and Bradstreet Company — all rights reserved)

Korea

Korean semiconductor makers cutting into Japanese and European markets

Reports from Japan indicate that Korean semiconductor manufacturers are making gradual inroads into other markets - specifically in Japan and the Federal Republic of Germany. Two Korean firms, Samsung Semiconductor and Telecommunications and Goldstar Semiconductor, have reportedly sent sample ICs to potential Japanese customers and have met with moderate success.

The Tokyo office of Samsung, Korea's biggest semiconductor producer, was originally set up in 1983 as a base from which to procure semiconductor manufacturing equipment and materials in Japan. In 1985, the firm began marketing strategic products - 256K DRAMs, 16K and 64K EEPROMs, and 64K SRAMs - on the Japanese and West German markets. Despite their limited success, a Samsung company spokesperson voiced criticism of Japan's closed market policies: "Now, a year and a half later, our sales in the Federal Republic of Germany are triple those in Japan," he said. "In other countries, if we can provide the quality, the price and the delivery schedule, we can sell. But in Japan, even if we fulfil these conditions, it's no good. Their mood of exclusivity is an impenetrable wall. They won't let us in."

Goldstar Semiconductor, Korea's largest manufacturer of home appliances, believes that it can profit by selling in areas where there is no great competiton with Japanese manufacturers. For example, many Korean manufacturers produce discrete components, but Goldstar has put its efforts into TTLs, for which the volumes are the same as discrete semiconductors, but unit prices are higher. According to Goldstar, "In TTLs, there is competition with TI, Signetics and others, but our quality is higher and our prices are a little lower. In memories, also, Samsung has concentrated on the 256K DRAM, but we are handlig 64K SRAMs, which is not a competitive product."

Both firms are currently distributing samples in Japan, but it is yet unclear how much of the Japanese market they can absorb. Still, several Korean electronics companies posted 100 per cent growth rates in 1986. (Reprinted with permission from Semiconductor International Magazine, March 1987. Copyright 1987 by Cahners Publishing Co., Des Plaines, Ill., USA)

Switzerland

Swiss complete compiler for RT

The Swiss Federal Institute for Technology has completed a joint project with IBM to produce a compiler for the Modula-2 programming language. It will run on the IBM 6150, more commonly referred to as the PC/RT (for reduced instruction set, or Risc architecture).

The compiler can handle 20,000 lines of source code a minute on a 6150 with the recently announced advanced processor card fitted. Although IBM has not yet decided whether to offer the compiler as a product it has, an official says, "made a decision to consider offering it". Endorsement by IBM would be a useful boost for the language, which was written by Professor Nicklaus Wirth, the man who gave the world Pascal. (Computer Weekly, 9 April 1987)

United Kingdom

Labour unveils its plans for training

Training is too valuable to be left to the whim of individual employers, according to Labour leader Neil Kinnock. The Labour Party has proposed a crash programme to provide 360,000 training places in two years, designed to double manufacturing training levels. Launching his party's 'New Skills for Britain' policy, Kinnock said companies would have to contribute towards improving the nation's skills.

The exact form of funding has yet to be finalized. Consultations are planned with employers, trade unionists, and other interested parties, according to Labour's employment spokesman John Prescott. The Party is eagerly awaiting a Manpower Services Commission study on the funding of Britain's training.

Labour's industry spokesman John Smith spoke of a levy of one per cent on company turnover, and John Prescott's office agreed this would be the 'ball-park' figure needed to bring Britain into line with her competitors. Prescott also spoke of the need to raise the quantity and quality of training.

A Confederation of British Industry (CBI) spokesman said it would be studying the scheme in depth but was in principle against statutory provisions. "The voluntary method seems to be the best way forward," he said. (Electronics Weekly, 25 March 1987)

Scots told to make it just in time

Scottish electronics companies must change their manufacturing techniques if Scotland is not to lose its hard-won reputation as the focus of the UK electronics industry.

At last week's opening of the sixth Scottish computer show George Mathewson, chief executive of the Scottish Development Agency (SDA), launched a campaign to persuade companies of the benefits of the just-in-time manufacturing philosophy. Just-in-time means that a manufacturer can order components from the supplier at very short notice, using a computer, rather than keeping parts in a storehouse.

Everybody from the smallest indigenous supplier to the biggest Scottish-based multinational is under pressure to adopt the Japanese pioneered technique, which has already been enthusiastically taken up by several companies, most notably Hewlett-Packard.

Mathewson said the concept could reduce inventory, get rid of poor components and drastically cut manufacturing costs.

This year's show was smaller than the last, although it managed to haul in half a dozen of the bigger names like ICL, British Telecom and Digital Equipment.

Scotland has been chosen as the site of the world's second computer museum. The first opened in the US, Boston, last year. (Computer Weekly, 9 April 1987)

Leo's birthday reunion

The UK's commercial computing industry is 40 years old this year, and the anniversary was celebrated by people who worked on Leo computers.

Development of the Leo 1 started in 1947 at J. Lyons. This unlikely diversification of business for the UK catering group happened when it decided to automate its administration but found no suitable machine in the US.

The first Leo (Lyons Electronic Office) went live running payroll in 1954. It was the first machine in the world to be used for commercial computing.

ICL was supporting the machines until the end of the 1970s, when the last machine was taken out. Lyons formed Leo Computers, which became part of English Electric and then ICL. (Computer Weekly, 2 April 1987)

USSR

Soviet systems

Over many years, the Soviet Union has allocated substantial resources to the development of supercomputers. The most established installed machine in this class is the workhorse BESM-6, the design of which dates back to the 1950s. At less than 7 MIPS, the BESM is not astoundingly fast, but is good enough to support the Soviet space program. The flagship supercomputer is the Elbrus. It is considerably more sophisticated than the BESM, with multiprocessor configurations combining as many as 10 CPUS, and is rated at well over 100 MIPS.

In the 1960s, the Sovet Union decided that it could not afford to diversify its resources in the development and production of mainframe systems. Soviet technologists were impressed with the design and quality of the System/360s they had bought from IBM. They were equally impressed with Big Blue's increasing domination of the Western market and decided that compatibility would yield benefits in international trade in both hardware and software.

Eastern bloc versions of the IBM 360 - and subsequently the 370 - have never been copies. The technology gap in LSI chip manufacture dictated that Soviet versions be reengineered equivalents compatible at the instruction set and I/O bur levels. This is the same approach adopted by Western pcmers.

Sovier mainframes are often described in the West as the Ryad series. The Soviets themselves designate them as ES models, from the Russian for "unified system". The larger ES models are made in the Soviet Union, but the nine or so smaller models are manufactured in Hungary, Czechoslovakia, Poland, Bulgaria, and East Germany. The power of the bigger computers ranges up from the old IBM 370/168 and includes multiprocessor configurations. The fastest of the medium range are said to be equivalent to the IBM 370/148 models.

A similar strategy of compatibility with a key Western product has also been taken - in this case with a 16-bit Digital Equipment Corp. PDP-11. These were designated SM after the Russian for "minicomputer system". The popular SM1420 (known as the SM5 in export markets) runs at 1 MIPS with up to 4MB of main memory, ranking it in performance alongside DEC's PDP-11/23.

The Eastern bloc is also gearing itself up for the manufacture of what it calls megaminis. These 32-bit processors (called E82 or SM52) are thought to be compatible with the DEC VAX but engineered with lower-density chips. Bulgaria, Czechoslovakia, and the Soviet Union are all participating in the development of these machines, and limited production of models in the DEC VAX 11/750 and 11/780 range is now under way.

The relative success of the SM range clearly influenced the Soviet Union's decision to base its first volume microcomputer on a chip set implementation of the PDP-11 instruction set (analogous to the LSI-11 range). The advantage of this approach lay not only in the familiarity of the technology, but also in the fact that a real-time operating system was available. This was important for a country that puts such emphasis on process control and instrumentation systems.

This class of product is available as the SM1300 and SM1800 ranges as well as 12 models of the Elektronika-60. Commitment to the LSI-11 instruction set will continue in the tv-based micro-developed by the Institute of Informatics Problems and the Intersectorial Scientific and Technological Complex for Personal Computers, but it is understood that some compatibility has been sacrified.

The Agat micro, similar to an Apple IIe, was short-lived, with the ISTC for Personal Computers recently killing the project to release production capacity for more modern products.

The gap between the low-priced tv/micro and the expensive Elektronika-60 is likely to be filled with an IBM PC look-alike. Limited manufacture of various models using a chip equivalent of the Intel 8086 has already begun in Leningrad, Moscow, and Minsk. It is thought that the existing production capacity will be sufficient for only about 20 per cent of the target of 1.1 million personal computers set by the current Five-Year Plan to 1990. This capacity will be increased, but the Soviet Union will import PC clones to make up any shortfall. (Reprinted with permission of DATAMATION ® magazine © 15 March 1987, p. 50, copyright by Technical Publishing Company, A. Dunn and Bradstreet Company, all rights reserved)

IX. STANDARDIZATION

Explaining OSI

OSI, or Open Systems Interconnection, is a conceptual framework for development of standards to enable different types and makes of information processing equipment to work together. The OSI basic reference model is an international standard - ISO 7498 - of the International Organization for Standardization (ISO). The model consists of seven layers:

- The physical layer deals with the electrical, mechanical, and procedural means of transmitting data. It includes such variables as voltage levels and the number of pins required;

- The data-link layer is concerned with procedures and protocols for operating the communication lines. It offers a means of detecting and correcting message errors;

- The network layer determines how data are transferred between computers and is primarily concerned with routing within and between individual networks;

- The transport layer defines the rules for information exchange and manages end-to-end delivery of information within and between networks, including error recovery and flow control. This layer separates the upper three layers from the telecommunications details dealt with by the lower four layers, allowing communications facilities to change without requiring changes in upper-layer procedures;

- The session layer deals with the establishment, management, and disconnection of communications between processes in the communicating devices;

- The presentation layer performs format conversions that allow otherwise incompatible devices to communicate;

- The application layer provides the actual service sought by the end user. It covers such functions as password authentication, user directories, and file transfer.

Now being developed are many of the future international standards that will be required for each layer of the basic OSI model. In this development of standards, ISO has had the co-operation and support of the European Computer Manufacturers' Association (ECMA) and the International Telegraph and Telephone Consultative Committee (CCITT). For example, ISO 8073, Open Systems Interconnection - Connection oriented transport protocol, published in 1986, was based on ECMA standard ECMA-72 and is closely related to CCITT recommendation X.224.

OSI is important because of the diversity and enormous proliferation of information-processing equipment. Compatibility of such equipment is fundamental to efficient information processing and communication - whether across a room or across the globe. (Information sources: ISO Bulletin, August 1985 and Datamation, 15 October 1985, reprinted in ACCIS Newsletter, 4 March 1987)

A UNIX opportunity

Most big computers cannot follow programs written for other manufacturers' machines. This is because computer makers have been reluctant to standardise their operating systems - the master programs which manage the computer's internal workings and make the bits attached to it (screens, keyboards, etc.) function properly. Manufacturers like the way these little monopolies help keep customers locked into their own products. Customers are fed up with all the incompatible bits and pieces on the market. Their dissatisfaction at last shows signs of persuading computer companies to change their ways.

The problem scarcely applies to personal computers which are dedicated to a single user. The majority use an operating system known as DOS which is produced by an American software firm called Microsoft. DOS is used by IBM on its personal computer, and by about 250 other personal-computer manufacturers making "clones" of the IBM PC. There are about 10 million personal computers in the world now using DOS, and they are increasing by about 30 per cent a year.

Bigger computers, which tie together dozens of users, need a different type of operating system. IBM uses several systems, which means that some of its computers are incompatible with others. Digital Equipment uses an operating system called VMS on its minicomputers.

Both IBM and Digital Equipment, as well as other manufacturers, also offer versions of an alternative operating system called UNIX, developed by AT&T specifically to work on different computers. Although UNIX is popular with scientists and engineers, it accounts for only 5 per cent of operating systems used on minicomputers and their bigger mainframe brothers. One snag is the different dialects of UNIX.

A group of 11 computer companies is hoping to iron out these differences. The group, called XOPEN, includes AT&T, Digital Equipment, Olivetti, Philips, Siemens and Unisys. The aim is to have a UNIX program written on one XOPEN computer run unfettered on any other XOPEN machine. In Luxembourg, the group recently demonstrated for the first time how this will be done. An international centre near London's Heathrow Airport, packed with computers from each manufacturer, will be opened soon so that programmers can develop software for the new standard.

In America, another effort at standardizing operating systems is gathering speed. In January, more than 50 computer companies (including IBM and the XOPEN group) agreed to support a standard called Posix. A first working draft of this laid down a set of "links" between the UNIX operating system and applications programs. Standardizing the link, rather than the system, will allow computer companies to keep their different dialects of UNIX and share programs without changing the way machines work.

Some people think this presents UNIX with an opportunity to become a significant operating system in the future. If it seizes it, UNIX might help European computer makers to get a bigger share of their fragmented home markets. At least two Japanese computer makers are taking a chance on UNIX. A new 32-bit microprocessor being jointly developed by Hitachi and Fujitsu will use the system. (The Economist, 14 March 1987)

Unix: Barking up the wrong tree?

If Unix is ever to start making strides toward establishing itself as a viable alternative mainframe MIS operating system to IBM's MVS/XA, it seems there would be no time like the present.

For one thing, although IBM's commitment to mainframe Unix has been lukewarm at best, two of its major mainframe competitors have had plenty of reasons to look for OS alternatives. Legal and technical problems have made it difficult for Fujitsu and Hitachi to maintain operating system compatibility with MVS/XA and have forced both vendors not only to attempt to negotiate large cash settlements with IBM, but also to rewrite large parts of their own operating systems and rethink whether and how to remain in the IBM-compatible computer business.

At the same time, mainframe vendors Amdahl Corp. and National Advanced Systems in the US and Siemens in Europe, while staying clear of legal difficulties with IBM, have been looking for a competitive advantage over IBM, something other than just a lower price tag to lure mainframe users. To that, add steadily increasing IBM system software prices, and you would think mainframe users as well as vendors would be in the market for an alternative.

But mainframe vendors and the vast majority of their MIS users are far from ready to stray from the MVS fold, and if or when they do, they aren't at all sure that Unix is the logical alternative. Although IBM, Amdahl, Fujitsu, Hitachi, and Unisys in the non-IBM-compatible world all have versions of Unix running on their mainframes, most vendors continue to market mainframe Unix primarily to technical and government users, markets they see as incremental to their primary commercial MIS customer bases. Although vendors see some commercial applications orginally written for Unix-based minicomputer hardware migrating to mainframes with Unix, none are currently willing to invest the time and money it would take to develop the transaction-oriented facilities Unix would need as a mainstream DP operating system. Nor are they ready to start pitching mainframe Unix to a customer set already heavily invested in MVS application software.

AT&T alone continues to insist that not only will Unix continue to grow as the standard operating system in the technical workstation and midrange system market but that it will also emerge as the key commercial MIS operating system. "It won't happen overnight, but in five to seven years, Unix will be the dominant operating system for mainframes," says Larry Crume, president of AT&T's Unix Pacific operation, who is trying to sell Japanese vendors and users, among others, on Unix.

So far, both Fujitsu and Hitachi have started marketing mainframe Unix. Fujitsu is selling a version of Amdahl's UTS implementation, and Hitachi offers a version of Unix System V that runs on top of its VMS virtual OS. Neither Fujitsu nor Hitachi, however, sees Unix as a way around the challenges posed by staying close to IBM compatibility. Fujitsu, which is currently in arbitration with IBM over charges it copied parts of MVS/XA, believes that "the Unix OS cannot replace other operating systems," says systems engineering department manager Yasuyuki Yamana. "In some fields Unix is particularly good, [but] if Unix is modified to cover every application, it will lose its strengths." He adds that mainframe Unix is weak in transaction processing but strong in scientific applications and software development.

Fujitsu, which started selling a guest version of UTS in April 1985, says it has shipped 50 Unix systems. Although the company won't say how many of those are running on mainframes, observers believe it is only a small percentage of the total. Most of Fujitsu's Unix base reportedly runs on minicomputers. In fact, Fujitsu orginally started marketing Unix to counteract DEC, not to compete with IBM. "Previously, when our customers wanted Unix, they had to buy DEC machines," says Yamana.

Hitachi introduced its version of Unix, developed by Interactive Systems, Santa Monica, Calif., only in November, and isn't scheduled to start shipping it until next month. Hitachi projects 300 sales of its HI-UX/M over the next four years, but few if any of these licenses will go into MIS applications. Fujitsu is already shipping a native mode version of UTS, and Hitachi plans to refine its offering "sometime in the future," a spokesman says. Both mainframe vendors see the upgrades merely offering better performance for engineering and scientific users, however, not transforming Unix into a viable dp operating system.

The most successful Unix backer to date among the mainframe vendors is Sunnyvale, Calif.-based Amdahl, which analysis estimate has between 300 and 350 of about 450 mainframe Unix installations worldwide. Its UTS product has enabled Amdahl to establish itself as a vendor of systems software in addition to mainframe hardware, but even Amdah' is not ready to promote Unix as an alternative MIS operating system.

The exception is AT&T itself, historically a large Amdahl mainframe customer and a user of UTS for MIS as well as engineering and technical applications. According to Andrew Schroter, manager for systems programming at AT&T's interactive network optimization unit, the native mode version of UTS is supporting database-oriented transaction applications as well as network software development and capacity planning activities. Many of those applications were written to run on 3B20 or VAX hardware. They were shifted to an Amdahl 5860 running UTS when more power was required.

"That's the way Unix will infiltrate MIS," says Schroter. "Applications will be written for minicomputers, especially those that support relational databases like Informix. Then they will migrate to mainframes." Schroter acknowledges that that won't happen in a wholesale fashion until new Unix facilities supporting transaction processing and error recovery are improved. "But efforts are now under way to provide those facilities," says Schroter. "It won't be long before everything MVS can do, Unix can do."

It's unclear, however, who will invest in developing those facilities to make Unix fit into the MIS world. The major developers of systems software management tools, such as Uccel and Boole & Babbage, so far have continued to put most of their eggs into the MVS basket, leaving only smaller entrepreneurial concerns such as Aim Technology, San José, to develop Unix tools. Observers say IBM, with its current guest-based IX/370 offering, seems content to play a follower's role rather than one of leadership, and the other mainframe vendors have decided to place new Unix facilities development low on their list of investment priorities. Some are even questioning whether to offer Unix on their mainframe hardware at all.

"If we do anything on the large machine it will only be to host Unix as an additional OS, and if we decide to run Unix as a native OS it will only be on our small mainframes," says Klaus Gewald, head of operating systems development at the data systems and communications division of Siemens, which resells Fujitsu mainframes as well as its own hardware. "There are a number of reasons for this. The practical reasons are that we have allocated a lot of people and money to developing Unix on the micros and minis, and we can't do everything at once. The competitive reason is that we have our own operating system for mainframes, the BS 2000, and if we offered Unix as an alternative we would be competing with ourselves."

Even Amdahl is hesitant to invest in developing MIS-oriented facilities for Unix. "We've got plenty to do in the next few years selling into the engineering and scientific markets and developing products to improve connectivity between UTS and SNA," says O'Connell.

Mainframe vendors aren't the only ones hesitating to invest in mainframe Unix for MIS applications; even some users with Unix applications running on smaller hardware hesitate to make the jump to a mainframe Unix OS. One such user is New York stock brokerage Dean Witter, which, like many such firms, has some programmed trading applications written for 68000 Unix-based hardware marketed by Quotron. Dean Witter is looking to migrate those applications onto larger systems, says MIS vice president George Ross, but it won't necessarily be a Unix mainframe system. "I wouldn't rule it out, but we're looking very hard at the Stratus system in that environment. They've come on very strong in the last six months."

Working against a Dean Witter commitment to mainframe Unix is IBM's less than aggressive support for the operating system. "We're part of Sears, and Sears is pretty much an IBM shop," says Ross. "Once we see IBM deliver native mode mainframe Unix, there might be more willingness to get involved here."

Resitant users point to a continuing gap between AT&T's Unix V.3 standard and current ANSI efforts to come up with an official industry standard as another reason to stay away from current mainframe implementations of Unix.

Even if mainframe vendors and most users continue to turn away from mainframe Unix in MIS environments, there should be a healthy niche market for mainframe Unix implementations, analysts say. San José-based Dataquest says the 450 current mainframe Unix installations should grow to about 900 by 1990, not including implementations for supercomputers. That growth rate far exceeds the one predicted by most analysts for MVS mainframe installations.

Meanwhile, some long-time Unix-market watchers are urging AT&T to stop trying to transform its operating system into an MVS challenger and instead focus more on promoting higher-level standards such as OSI that can accommodate several operating systems and different hardware on the same network. (Reprinted with permission of DATAMATION[r] magazine[c], 15 February 1987, pp. 26-28, copyright by Technical Publishing Company, A. Dunn and Bradstreet Company, all rights reserved)

<u>An international standard for messaging</u>

The need for collaboration between hardware producing companies in the field of electronic messaging was seen at the last exhibition of Hanover where 14 European, American and Japanese companies participated in a demonstration on the need for adopting an international standard, entitled X400.

Electronic messaging must be universal, that is to say, it must allow the exchange of data between informatics systems of different companies. This need for universality demands the use of an international standard. This standard exists and is called X400. It has two protocols (p1 and p2) which govern the link-up of private hosts. The adoption of this standard by the major informatics firms has shown that the X400 standard has gone beyond the prototype stage to become a commercial reality.

The X400 standard defines in detail the way the informatics systems and the electronic messaging is connected. The International Standardization Organisation (ISO) some years ago designed and developed a series of rules defining the dialogue mode between several systems, known as Open System Interconnection (OSI). The OSI is divided into seven levels, the highest of which concerns the applications or the standards regarding transmissions. The XARPP defines therefore the specific rules for such applications, namely the transmission of a message which can comprise the text, the images and the graphics.

The firms participating in this demonstration were: British Telecom and International Computers of the UK, Bull of France, Data General, Digital Equipment, Hewlett Packard and Xerox of the United States, Nixdorf, Siemens and the Bundespost of Federal Republic of Germany, NTT of Japan, Olivetti of Italy, Philips of the Netherlands and the Sydney Development Corporation of Canada. Less than 24 hours before the meeting in Hanover IBM expressed its intention to join the X400 club, launching a new software which conforms to the X400 standard.

Through this demonstration it was possible to underline that not only were the basic principles there for a universal messaging system, but, moreover, that the manufacturers were aware today of the need to produce the necessary equipment so that this exchange may take place. (<u>Bulletin IBIPRESS</u>, 29 March 1987)

X. RECENT PUBLICATIONS

<u>Forthcoming UNIDO publications</u>

The following publications are in the process of being printed and will be available upon request in due course:

Study on organizations and modalities of software production
Prepared by H. J. Schneider.

Computers in the meat processing industry: a case study of application and implementation experience in a developing country
Prepared by A.A. Pardo

Expert systems: prospects for developing countries
Prepared by A.K. Jain

Terms of reference for the establishment of silicon foundries/design centres
Prepared by O. Manck

Technology Trends Series No. 3: Global trends in microelectronics components and computers
Prepared by K. Guy and E. Arnold

Technology Trends Series No. 4: The international telecommunications industry: the impact of microelectronics technology and the implications for developing countries.

<u>Proceedings of BCS conference on expert systems</u>

Research and development in expert systems III, the proceedings of the sixth annual technical conference of the BCS specialist group on expert systems are now available in the BCS Workshop Series. Edited by Max Bramer, Head of the School of Computing and Information Technology at Thames Polytechnic, the volume contains contributions from leading figures in the expert systems field.

The price of the publication is £22.50 (25 per cent discount available for BCS members) and copies may be obtained from Sally Seed at Cambridge University Press, Edinburgh Building, Shaftesbury Road, Cambridge CB2. (<u>Computing</u>, 19 February 1987)

XI. MISCELLANEOUS

<u>DEC study finds Silicon Valley in poor health</u>

Production workers in semiconductor companies suffer high levels of miscarriages, headaches, nausea and dizziness, according to a US study.

Several of Silicon Valley's largest semiconductor manufacturers are issuing warnings to their employees based on the findings of the study. It is the first time a comprehensive examination of the health problems of workers in semiconductor manufacture has been made.

The study was paid for by DEC and carried out by the University of Massachusetts on 770 people at DEC's factory in Hudson, Massachusetts over a five-year period. There are over 26,000 semiconductor production workers employed in Northern California where the electronics industry is one of the largest local employers.

Women production workers were found to be twice as likely to suffer a miscarriage and there were much higher reports of 'general malaise' compared with other groups of workers.

Semiconductor production involves working with highly poisonous gases and organic solvents. Three months ago a federal report recommended that Silicon Valley's semiconductor production workers be studied to determine what kind of health problems occur when handling toxic materials.

The Semiconductor Industry Association has commissioned a study to determine long-term health problems among workers. The results are expected early in 1987. (Computing, 18 December 1986, p. 5)

Women suffer new technology hazards

Women are 'bored, tired and hurt' because of changes in their working lives brought about by new technology.

According to speakers at a London conference held last week on women and computers in the office, manufacturers are improving standards, but the law on health hazards from working with VDUs still needs to be considerably tightened up.

Veronica Baynes, technology officer of civil service union CPSA, commented: "Manufacturers are adapting to consumer pressure in making equipment less stressful to use, but there does need to be more awareness of the problem."

The CPSA is backing a call by the VDU workers' rights campaign group to add safety checks on VDUs to the 1974 Health and Safety Act.

Speakers at the conference outlined existing health hazards from VDUs including eye strain, stress and tenosynovitis - swelling of arm muscles as a result of keying in data for long periods of time.

There was also a call for further research into the link between working on VDUs and high frequencies of miscarriages.

Practice in the UK on whether pregnant women work with VDUs is currently left to individual companies.

One cause of stress in using new technology is inadequate training, said Bayne. "All too often, dealers are not particularly keen on after-sales service and just throw in half a day's training," she said. Complicated manuals can also cause frustration. (Computing, 9 April 1987)

Building your own computers can save you a bundle

Sometimes it pays to take matters into your own hands. When seven Phoenix (Ariz.) community colleges set out to buy more than 600 IBM XT and AT personal computers last semester, they decided that International Business Machine Corp.'s price tags were too steep. But the schools' administrators didn't buy cheaper IBM clones: they figured they could save even more money by buying components and building the machines themselves.

Save they did. Larry K. Christiansen, dean of administrative services for Glendale Community College, puts the figure at close to $1 million. While the schools hired the local company that supplied the components to assemble most of the machines, teachers and students pitched in, too. "Not only did the college save money," says Christiansen, "but some of our faculty and students got hands-on knowledge of the inner workings of a computer." (Business Week, 23 March 1987)

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