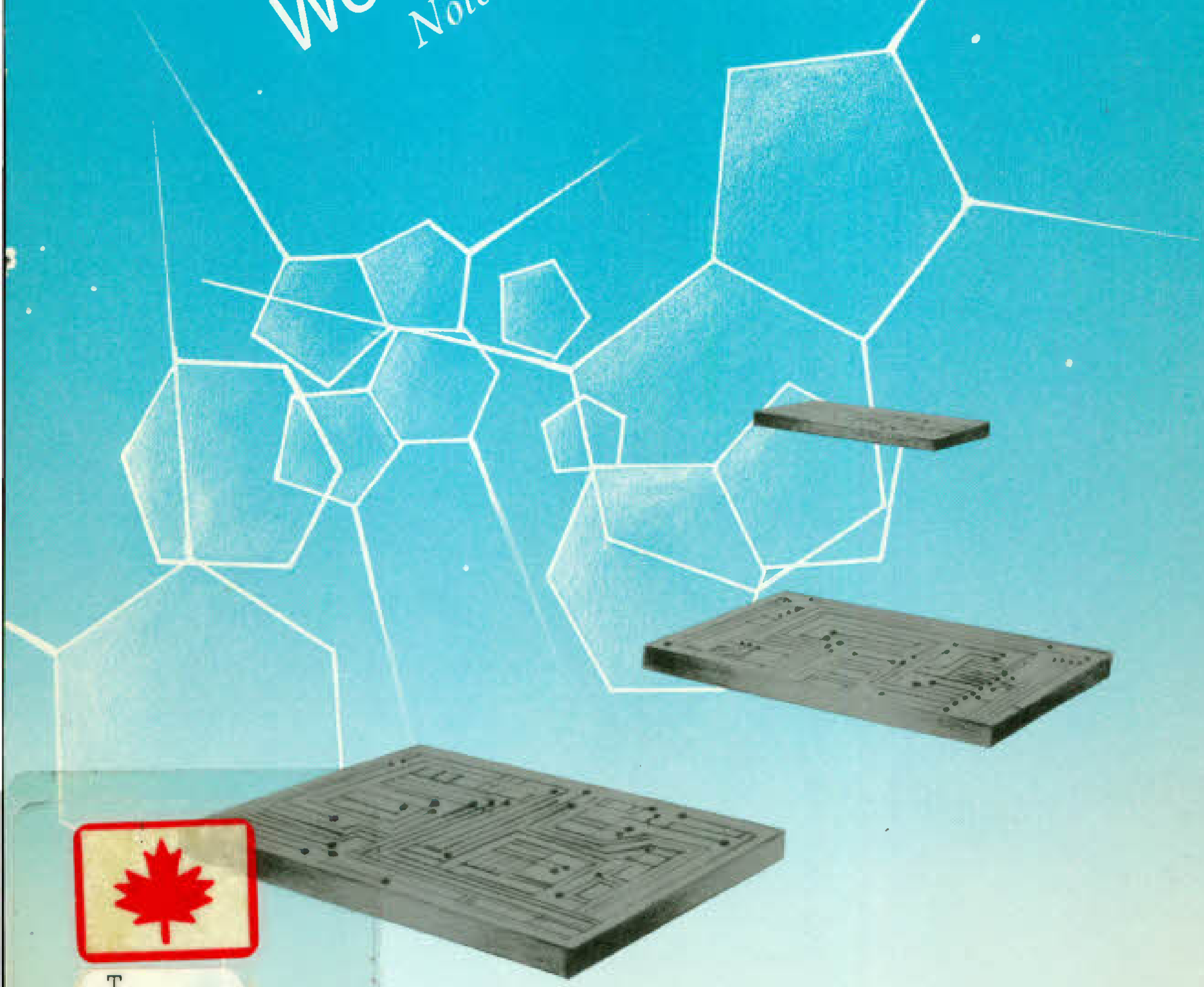
Workable Futures:

Notes on Emerging Technologies



prepared for the
Economic Council of Canada
by Words Associated
and Keith Newton

Available in Canada through

Authorized Bookstore Agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

Catalogue No. EC22-132/1986E — Canada: $ 5.95
ISBN 0-660-12131-X — Other Countries: $ 7.15

Price subject to change without notice

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Notes on Emerging Technologies

by Words Associated and Keith Newton

The findings of this Study are the personal responsibility of the authors and, as such, have not been endorsed by Members of the Economic Council of Canada.

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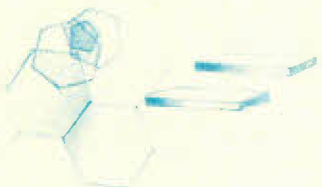

Thanks are also due to:
Economic Council: Kathryn McMullen, for preparing background notes on emerging technologies; Gordon Betcherman, for suggesting a guidebook for a broader audience; Judith Maxwell, the Council's Chairman, for enthusiastically supporting what is rather a departure from the Council's usual publication format.
Outside experts: Arthur Cordell and Jim Rollefson, for reviewing the entire text, and Louis Giroux, Alain Letendre and Bill Smith for reviewing particular sections.

Photos:
Chrysler Canada Ltd., pp. 19, 22
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Ontario Centre for Advanced Manufacturing, p. 14
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Typesetting: DavidBerman Typographics

Preface

In 1984 the Economic Council of Canada approved a research program on Labour Market Impacts of Technological Change. This book on new technologies is an outgrowth of that larger project.

Technological change affects us all in many ways. New products and processes may expand our horizons, liberate us from arduous labour and create enormous wealth. They may also bring new anxieties about our ability to adapt in a world of accelerating change and uncertainties about jobs and incomes. It's important, therefore, that we try to understand some of the opportunities that the new technologies may bring, and the challenges they represent. That is a principal objective of the Council's broad technological change program. It confronts a range of issues about jobs and people: What are the employment effects of technological change? What happens to the skill content of the jobs affected? How has technological change affected the labour market in the past? What are the prospects for the future? Who wins and who loses? What policies are needed to help us reap the gains while minimizing the pain?

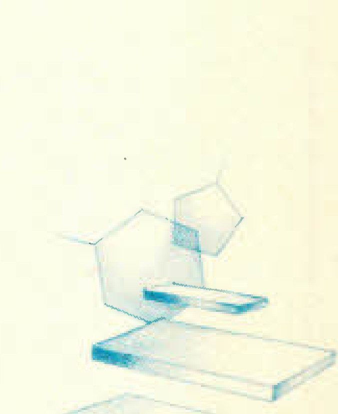
In addressing such questions we found ourselves on unfamiliar ground. The technical wizardry of robots and lasers, of satellites and cloning, is daunting for the non-specialist. We felt the need for a simple, readable guide to some of the major new technologies–a need we believe we share with many other Canadians. We were fortunate, therefore, in involving Ruth Tabacnik and her company Words Associated, whose technical background, creativity and writing flair gave substance to the idea. The resulting book aims to heighten awareness of several advanced technologies.

It is important to realize, however, that technological change is not just glamour and gadgetry. Many of the most powerful innovations are not embodied in machines or equipment. Rather, they are often subtle but potent changes in procedures, approach, method, organization and management that are no less revolutionary in their consequences. The last chapter of the book emphasizes this broader view of technological change and contains a brief description of some "soft" technologies and innovative practices.

A number of technical terms relating to the various technologies are contained in a glossary.

K.N.

Emerging Technologies



Microelectronics:
Big Changes in Smaller Packages

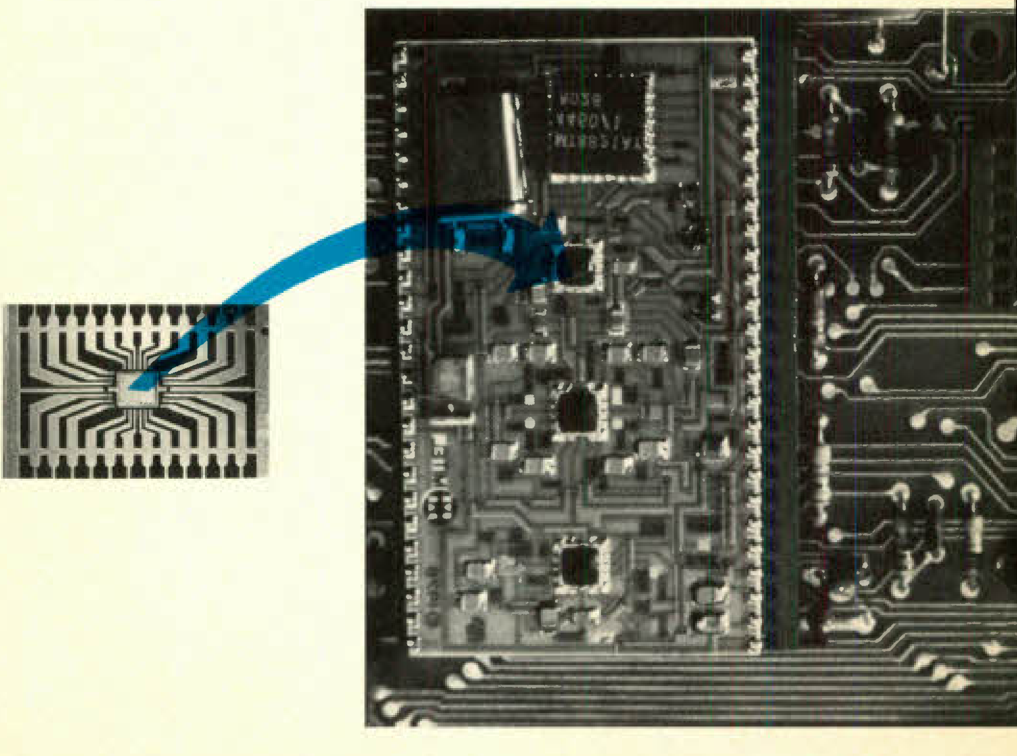
They started small and today have shrunk to almost nothing: microscopic slivers of silicon; hair-fine filaments of wire. They control electrical signals: switch; amplify; and make them do a new kind of work—work some claim is approaching the complexity of thought itself. While earlier generations of machinery were devised to augment the power of human muscles, the newest machinery augments the power of the human mind and senses.

Microelectronics arrived in the 1950s with the development of the transistor, first used to replace vacuum tubes, one for one. Soon after, the integrated circuit (IC) was invented, placing hundreds of transistors and other electronic functions on one small piece of silicon. Large-scale integration followed, with many thousands of electronic transistors—enough for a complete computer—etched into each tiny chip. Today manufacturers around the world are scrambling to perfect very large-scale integrated circuits, squeezing up to one million functions onto each chip.

- The number of circuit components per chip has approximately doubled every year since 1959.

With each reduction in size, microelectronic semiconductors become more powerful, less expensive and more reliable. In the process, they are shaping a revolution that will touch every institution in society. The horizons of this revolution are exhilarating and vast. Its only certainty: change itself...

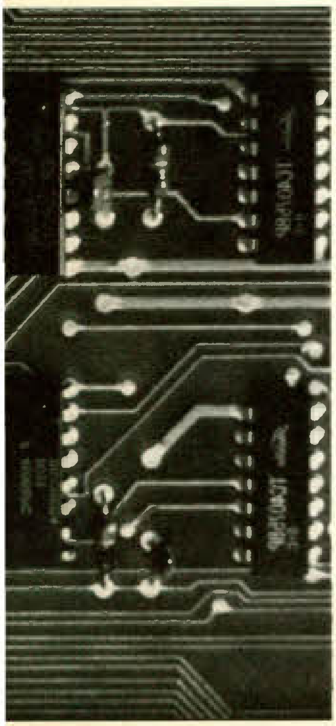
At the heart of the new electronics is the now famous marriage of the computer and the microchip. From the million dollar monsters of the 1950s—rooms filled with hot vacuum tubes, wires and hordes of technicians—computers have been tamed and trained. The cost of performing a given operation on a computer has declined over a millionfold in 30 years. The rooms full of tubes can now be packed in a briefcase.



With this radical change in the form of computers has come a profound change in ideas about what they are good for—their function. Three decades ago the scientists and engineers using computers to probe complex mathematical equations would have found the idea that their machines could be handy for typing letters ludicrous. Yet word processing has become the most common application for millions of desktop computers now in use around the world. The point is that today's casual employment of computing power was once not just impractical—it was beyond the wildest predictions of the computer's original developers.

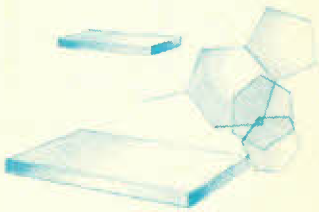
Despite the presence of established industry giants, it was two American university students (Apple founders Steve Jobs and Steve Wozniak) who made the desktop microcomputer popular. And even these two mavericks had no clear idea what people would want to do with their new product. That remained for the developers of software like Wordstar, Visicalc and Lotus—the brand names that led to fortunes built on microcomputer applications.

- Thirty years ago it took several thousand operators to handle one million long-distance calls. Today only a dozen or so are required.



Microelectronics has shown a seemingly limitless capacity to merge with other technologies. In the communications industry, for example, microchip technology quickly replaced earlier electronic hardware. As it did, it changed the nature of communications itself. Telecommunications technology became a hybrid of telephone technology and the computer. Computerized automatic switchboards merged with computer-controlled transmission, satellite technology and automated billing. Data transmission became a major new business for phone companies.

Today the hybrid trend continues with the introduction of digital voice transmission and optic fibre communications lines. Computers are even being used to get more work from each transmission line, by weaving one conversation through other conversations.



Post-Industrial Society, Information Society or Leisure Society?

- In the manufacture of sewing machines, one microprocessor has replaced 350 mechanical parts.

- The auto industry in the United Kingdom produces 17 cars per person-year. Japan's highly automated factories turn out 70 cars per person-year.

The trend of the new electronics to change not simply the products of industry but the way these products are made, delivered and consumed raises doubts about society's present attitudes to work and the worker.

Computer controls in the factory have ushered in a new era of automation. New combinations of robotics technologies and other production advances are replacing assembly line production with semi-automated and fully automated flexible manufacturing installations. In these new factories, output per worker is vastly increased.

Microelectronics may affect the future of demand in the resource industries in a more subtle way—by making possible a far more efficient use of resources than in the past. Scientists, engineers and designers are using computer-aided design (CAD) to achieve astonishing refinements in product design. Manufacturing and materials costs can be examined as never before. The old design rule that less is more is taking on a new holistic meaning as designers create computer models of both future products and production facilities simultaneously.

The collective result of these changes is nowhere more evident than in the automotive industry. Automobiles are shedding thousands of pounds, achieving improved performance with much less material. New materials are competing with established materials in an effort to reduce costs further. Computer-designed sub-assemblies reduce manufacturing time while robots take over more and more assembly work. General Motors, for example, plans to have 14 000 robots in service by 1990.

The Automatic Office

If the microelectronic revolution has created an unprecedented ability to disseminate, gather and store information, it has also created an intense demand for information. About half of Canada's workforce is now engaged in information-related work. The new automated office technologies are transforming industries that service this demand.

In the automated office, microelectronics is replacing the older paper-based systems of writing, storing and retrieving information. Word processors have already replaced typewriters in many offices. Ideas stored electronically can be retrieved anywhere automatically. Documents can be updated and edited as required or used to form the basis of vast information data bases. Electronic mail, memos, teleconferencing and other functions bring the entire flow of corporate activities within range of any desk equipped with an appropriate terminal. In this environment, routine tasks, such as ordering, billing, payrolling and keeping track of stock, are being automated.

The Automatic Manager

Microelectronics now has the capacity to affect every type of work. The new expert systems software, for example, is placing a growing range of professional skills within reach of computer owners. In the near future other developments in artificial intelligence could bring automation to types of work now considered immune.

Microelectronics may be the ultimate labour-saving technology. For the first time in history we have the capacity to eliminate much, and perhaps most, labour from the production equation. The coming changes will require massive readjustments in social values. And social issues raised by the highly fluid nature of work will be a considerable challenge for legislators in the electronic age.

Exciting opportunities will open up as new industries find their niche in society. There will be a dramatic shift in patterns of work... and leisure. The recreation industries can be expected to grow as leisure time increases. New industries will create new kinds of work as other industries decline. The educational process will continue throughout our lives as we adjust to the new employment opportunities.

The Office in a Suitcase

In theory, much of the work in the new electronic office can be done anywhere that a computer can be plugged into a phone line. A few years ago it was widely expected that this would result in the adoption of an "electronic cottage" lifestyle, with office workers doing their work from home-based terminals. Such is the social nature of much office work that the electronic cottage idea has not yet caught on in force. However, executives are now exporting data-entry work to keyboard operators in Third World countries. Computerized data is then relayed by phone back to the clients' computers. This trend is raising new concerns for social planners.

Artificial Intelligence:
To Be or Not To Be?

- *"It's not just the second computer revolution. It's the important one."* Edward A. Feigenbaum and Pamela McCorduck, The Fifth Generation–Artificial Intelligence and Japan's Computer Challenge to the World.

- *"These people have inherited a lemon."* Hubert Dreyfus, artificial intelligence critic.

So artificial intelligence is variously described as:
"The property of a machine capable of reason, by which it can learn functions normally associated with human intelligence,"
or:
"...concerned with understanding the principles of intelligence and building working models of human intelligent behaviour,"
or:
"A technical language with which to discipline the imagination."

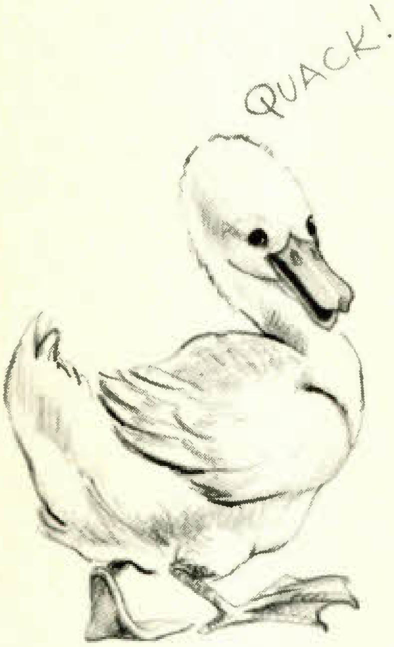
They're known as the artificial intelligentsia. Their ranks include computer science experts, engineers, mathematicians, linguists, psychologists and neurophysicists. Together they're bound by a common vision: that of creating machines capable of behaving in ways that humans recognize as intelligent.

Definitions have proved elusive. If notions of human intelligence vary according to culture and circumstances (Albert Einstein was thrown out of high school as a "hopeless" student), ideas about machine intelligence are as diverse as the experts working in the field. Like beauty, artificial intelligence (AI) is a subtle commodity that varies with the beholder.

At one extreme, AI enthusiasts imagine a day when thinking computer "minds" develop powers of "thought" surpassing mankind's. In opposition, AI's critics believe artificial intelligence research is a contradiction in terms, a billion-dollar graveyard for the mechanistic model of intelligence. Between these camps, a growing number of researchers work with varying degrees of conviction or indifference as to the accuracy of the "intelligence" label.

What is certain is that the intellectual challenge of putting thought processes into machines has drawn top-notch theoretical talent to AI research. These researchers see the work mainly as a testing ground for ideas about human perception and cognition, believing the ultimate gain may be a better understanding of the human organism. For another, much larger group of researchers, AI simply represents the logical evolution of computer technology from calculating machine to a tool that can learn, perceive, solve problems and reason.

Take Two Aspirins and Run Me Again in the Morning



Artificial intelligence emerged in the mid-1950s when researchers discovered that some "higher" mental powers were actually rather easy to represent on a computer using "if–then" rules. The formula sounds deceptively simple: "***If*** *it looks like a duck, and it walks like a duck, and it quacks like a duck,* ***then*** *it probably is a duck.*" Yet this type of inference procedure is the foundation of today's "expert system," a new way to apply knowledge that is fast becoming AI's first commercial triumph.

Expert systems software has been remarkably effective at duplicating expert decision-making in highly specific areas of knowledge. Thus expert systems have been created to diagnose disease, to prospect for minerals and oil, to trouble-shoot mechanical systems, to interpret experiments and to configure computer systems.

It has been shown that many types of expert systems work extremely well, bringing together the knowledge of the human experts who contribute to the software. A favourite example: one doctor, equipped with a portable computer and the appropriate expert systems, could bring together the distilled knowledge of the world's top medical specialists anywhere in the world. A point of caution—expert systems organize and deliver knowledge effectively. They cannot be said to "think" or "know," but simply to work.

Speak, Memory

- The most important new computer language is... English.

Developing computer systems with the ability to understand natural language is a central project of contemporary AI research. The problems are formidable: language involves much more than words—it is nuance, context, shared knowledge about the world, human goals, values and beliefs. The teams of linguists, psychologists, computer scientists and artificial intelligence researchers working on computer natural languages began with the idea that language and thought could be expressed in terms of formal logic. Today it's clear that this is wishful thinking. Once the social context comes into play, there are no boundaries for the meaning of words.

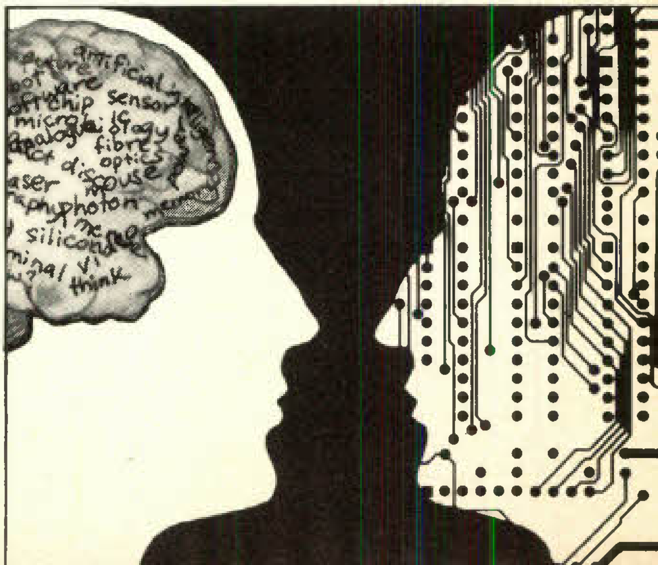
Yet elegant partial solutions to the problem have been found and applied with some success. In Canada researchers have developed automated translation systems. Automated dialing machines able to understand the difference between a "yes" answer and a "no" are reported to be doing a brisk business. In the United States, computer giant IBM has announced an experimental system capable of accepting verbal input with a vocabulary of up to 5000 words.

See Jane

One of the most interesting aspects of AI research concerns machine vision. Over half of the human brain is occupied with vision. In computer terms, experts have estimated that an equivalent of 10 billion calculations would be made on an image before it reaches the optic nerve *en route* to the brain—a daunting prospect.

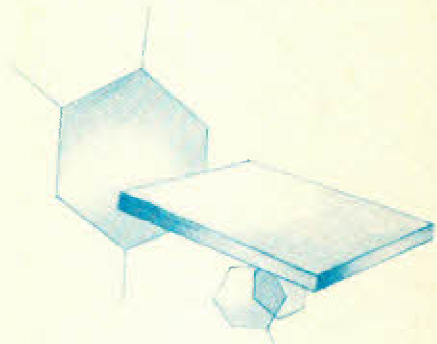
However, the human brain still needs to make sense of the two-dimensional impressions of the world received by each eye and to do this it seems to use "tricks" that can be mimicked in computer vision: stereo vision, shading, colour, surface texture, changes of the image with motion.

Success in finding equations to cover these properties has already produced computer vision systems able to distinguish between one part and another. The technology is finding its way into applications in factories around the world, bringing a new dimension of flexibility to previously blind industrial robots. One Canadian firm, for example, has produced a vision system to control robots working on auto parts assembly. Tomorrow, seeing robots will be the norm.



A Battle of the Budgets

A recent American bestseller on the subject of AI warned of the coming of Japanese "Fifth Generation" computers. The book explored Japan's computer project aimed at developing dynamic super-computers able to mimic some aspects of the human thought process. The book talks at length about the coming era of "knowledge processing," noting that the world's mushrooming knowledge base requires more advanced computers if it is to be fully used. The Japanese are reported to see knowledge processing as the industry of the future. Much of Japan's initiative in this direction is state-funded.



American efforts in artificial intelligence are also mostly state-funded, but, in contrast with Japan, they centre around military applications.The success of the "Star Wars" concept, for example, is heavily dependent on AI success.

Canada's strengths in AI are concentrated in three specific areas: computer vision, natural language processing (including fields such as automated translation) and logic programming. Unlike the United States, Canadian AI work is generally conducted in a civilian, academic environment. More than a dozen universities across the country have AI work underway.

In the private sector, large companies such as Bell-Northern Research of Ottawa and Spar Aerospace of Toronto, as well as a number of smaller firms, are forging ahead to develop practical products. The potential for AI products is, of course, what's drawing entrepreneurs into the field.

- US sales of AI products are expected to reach $2.9 billion by 1990, according to Arizona-based DM Data Inc.

A high-stakes research battle is shaping up which some believe will determine the location of economic power in the next century. One certainty: in some form or another, AI is going to revolutionize the future. One big unknown: how?

Expert Systems:
Knowledge to Go

- Computer: *"Question 11. Has patient 219 had symptoms of persistent headache or other abnormal neurological symptoms (dizziness, lethargy etc.)?"*
User: *"YES."*

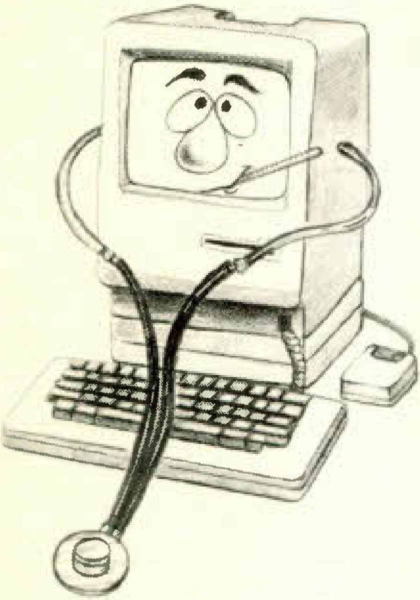
Edward Feigenbaum, one of Mycin's developers and a pioneer in the field, defines expert systems as: "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution."

The computer is running *Mycin*, the classic "expert system" program developed at Stanford University in the mid-1970s to diagnose blood infections. The program asks the user a series of directed questions about the patient: symptoms, lab test results and medical history. Answers lead to a qualified diagnosis (in this case, meningitis) usually about as accurate as a human specialist's. After diagnosis, Mycin considers patient weight, allergy history and other factors to recommend appropriate medication.

Expert systems are the fastest-breaking commercial product in the fast-lane field of computer artificial intelligence. Many successful programs demonstrate that expert systems provide valuable support to human experts in some kinds of problem-solving work. Enthusiasts predict a brave new future for expert systems as the software becomes more widely available and starts to enter the personal computer market. Some foresee libraries of canned consultants in every business and home—more than a match for problems from auto repair to heart surgery. Insiders caution that present knowledge-processing techniques are still saddled with very severe limitations. Mycin knows a lot about blood diseases. But it has no idea what a "patient" is.

Expert systems organize knowledge acquired from experts and apply it to assist in problem-solving. The inference procedure component of the program—the logic allowing the computer to arrive at decisions—is quite distinct from the knowledge base or specific expertise. Inference procedures follow a variety of formulas. Mycin, for example, is a "rule based" system using a "situation—action" or "if—then" line of reasoning to arrive at solutions. A sample rule:

*"**If** (i) the infection is meningitis and (ii) the organisms were not detected by culture colouration and (iii) the type of infection could be viral and (iv) the patient is severely burned, **then** it is probable that **Pseudomonas aerugninosa** is one of the organisms responsible for the infection."*



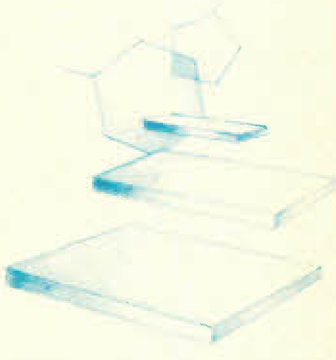
The Mycin expert system uses a total of 475 rules to interpret its knowledge base. At most, present expert systems can handle a few thousand rules before the program becomes intolerably slow. In contrast, a chess master is estimated to require 50 000 rules in his or her area of expertise.

Surprisingly, though the limited number of rules endows expert systems with plenty of muscle to handle apparently complex professional tasks, simple, common-sense human chores are still largely off-limits to the technology. So *Internist-1* is a diagnostic program for internal medicine; so *Prospector*, an expert system for petroleum geologists; so *DENDRAL*, capable of generating plausible structures for organic molecules on the basis of mass spectrometry. But try to get a driverless vehicle to a randomly selected destination with an expert system program and you've got big, big problems. The concept of time has also proved maddeningly elusive.

Fad Gadgets?

While for truck driving, expert systems may be out for the moment, they are "in" in a widening array of professional endeavours. Salespeople are using them to design computer systems; geologists are finding oil and minerals; engineers are trouble-shooting problems with complicated equipment; biologists and chemists are interpreting experiments; manufacturers are staying on top of production schedules in the factory... the list lengthens daily.

Whether or not computerized experts qualify as intelligent (they probably don't), they're getting a lot of work done these days. People like them. And the attractions and advantages of the expert system technique are fueling research that may someday move the technology out of the *idiot savant* stage and into a more fluid, human-like style of reasoning.



Here Today, Here Tomorrow

Already automated experts have advantages over the flesh and blood variety. They never get tired or bored—they'll never leave the firm—they're never absent-minded—they can be improved and they begin working with the knowledge base of the best experts in the field. Above all, they can handle problems too complex for a single human expert. To say nothing of their hourly pay rates...

Expert systems may also be useful to prompt human action or control machines in panic situations or where trained human intelligence is in chronically short supply. Thus experimental expert systems are being developed for nuclear reactors, to take control of equipment in case of serious mishap.

The US Defense Advanced Research Projects Agency plans a five-year expenditure of over $600 million for expert and other system development under the Strategic Computing and Survivability Program. One key objective of the research?—an expert system control for a driverless battlefield vehicle.

The Canadian Department of National Defence is attempting to apply expert systems to the interpretation of acoustic signals.

Northern Expertise

Interest in expert systems is relatively new in Canada. Almost unheard of as recently as the early 1980s, expert systems have been the subject of a deluge of conferences, seminars, courses and demonstrations since 1984.

The federal government is now developing expert systems for injection molding of plastics, for applications in robot welding, for the diagnosis of cardiac defects, and for the development of design strategies in engineering, architecture and industrial design, among other things.

About a dozen Canadian universities are active in expert systems research with applications in medicine, forestry, weather forecasting, teaching and programming.

The Canadian expert system industry, as in other countries, has only recently been created. The tremendous costs of getting a large-scale expert system up to scratch have so far been prohibitive for most firms. Only about 20 companies are currently producing systems, including custom expert packages—custom software in general being a Canadian forte. But the situation is changing with more affordable expert systems entering the market.

Experts on the Half Shell

An expert system without a knowledge data base is known as a "shell." A simple shell might include the user interface, the inference system and software tools for inputting specific expert knowledge. Expert shell software is now being introduced into the huge microcomputer market, a development expected to spur wild new growth in the technology. Many new users will be developing expert system models of their decision-making procedures. Small "do it yourself" software developers are expected to contribute creative vigour to the expert system concept, finding unexpected applications and inventing new solutions to expert system shortcomings.

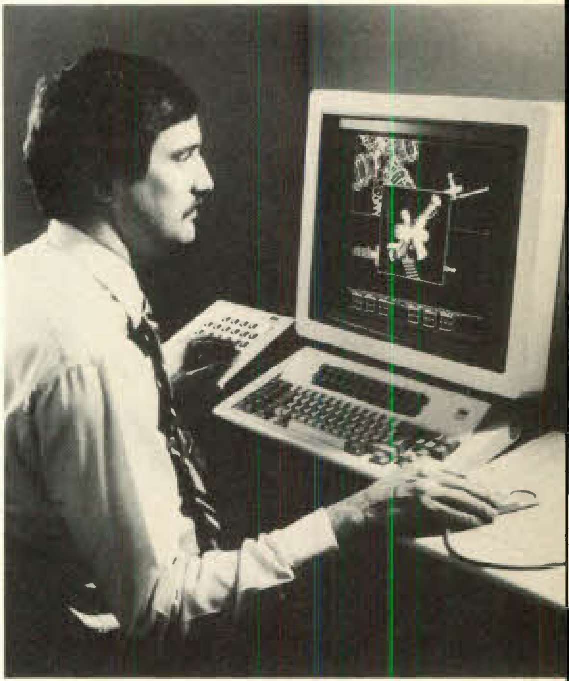
The Chicken in the Oven Can't Fly and Other Breakthroughs

Representing knowledge in machine terms is both a science and something of an art. To manipulate objects in the real world in anything but a rigid pattern, machines need to be programmed with concepts that humans take for granted. Software designers anticipate new and better equipment that will allow expert systems to handle 10 000 rules. Such a system could be programmed to share some aspects of human common-sense—the millions of assumptions and judgements that support human thought. Naive physics tells us, for example, that unsupported objects fall. In the same vein, we take for granted that the chicken in the oven will not fly.

Artificial intelligence dreamers imagine a day when sophisticated silicon experts will take over intellectual activities now thought to be beyond the scope of computers. Coping with the consequences of such a shift is a serious challenge for today's protein-based experts.

CAD/CAM:
Computer-Aided Design and Manufacturing Finally Come of Age

- *"The personal computer is really changing the marketplace: you can get a system today for $30,000 to $50,000 that would have cost $300,000 to $500,000 or more just a few years ago."* Jack Scrimgeour, founding member of the Canadian CAD/CAM Council.



From Drafting Table to Computerized Workstation

Computer-aided design (CAD) and computer-aided manufacturing (CAM) rode into public awareness some years ago on a wave of enthusiastic predictions. The CAD idea of merging the engineer's drafting table with the power of the computer to generate sophisticated graphic interpretations of new design ideas caught the imagination of engineers and the public both. The CAD workstation did for drawings what word processors did for words.

Technically oriented insiders were quick to perceive the possibilities of using the computer to work out engineering factors such as stress-strain analysis as the design takes shape. The technology was heralded as the most significant advance in the design process in the history of engineering. The idea of using the computer-stored design as a source of code to instruct automated machinery (CAM) offered more grist for the imagination, effectively turning the designer's computerized terminal into a 3-D industrial copier.

CAD/Scam

Unfortunately, reality proved less simple. Early CAD/CAM hardware and software were complex and expensive while compatibility with industrial machine tools, mainframe computers and other electronic equipment was far from guaranteed.

Though the potential benefits from CAD/CAM technology were perceived as authentic enough, the high entry price tag and fear of obsolescence scared off most smaller firms, and some larger buyers became disillusioned when the technology turned out not to be the hoped-for panacea. To some extent, the failure of the companies to define exactly what they wanted to accomplish with CAD/CAM was the root of the problem. They discussed "how" before they discussed "what and why."

Calculated Inspirations for Smaller Firms

One survey put the number of firms with CAD/CAM facilities installed in 1985 as low as 500 out of a potential 43 000 Canadian manufacturing companies. Now, with the advent of lower-cost microcomputer-based systems, one of the most serious barriers to the widespread introduction of the technology is disappearing. A renaissance of interest in the technology is expected to bring the revolution to Canada's smaller manufacturers—where experts feel the greatest benefits can be realized.

- *"This year, CAD/CAM will advance into manufacturing more than it has in the previous 20 years."* Manufacturing Engineering, February 1986.

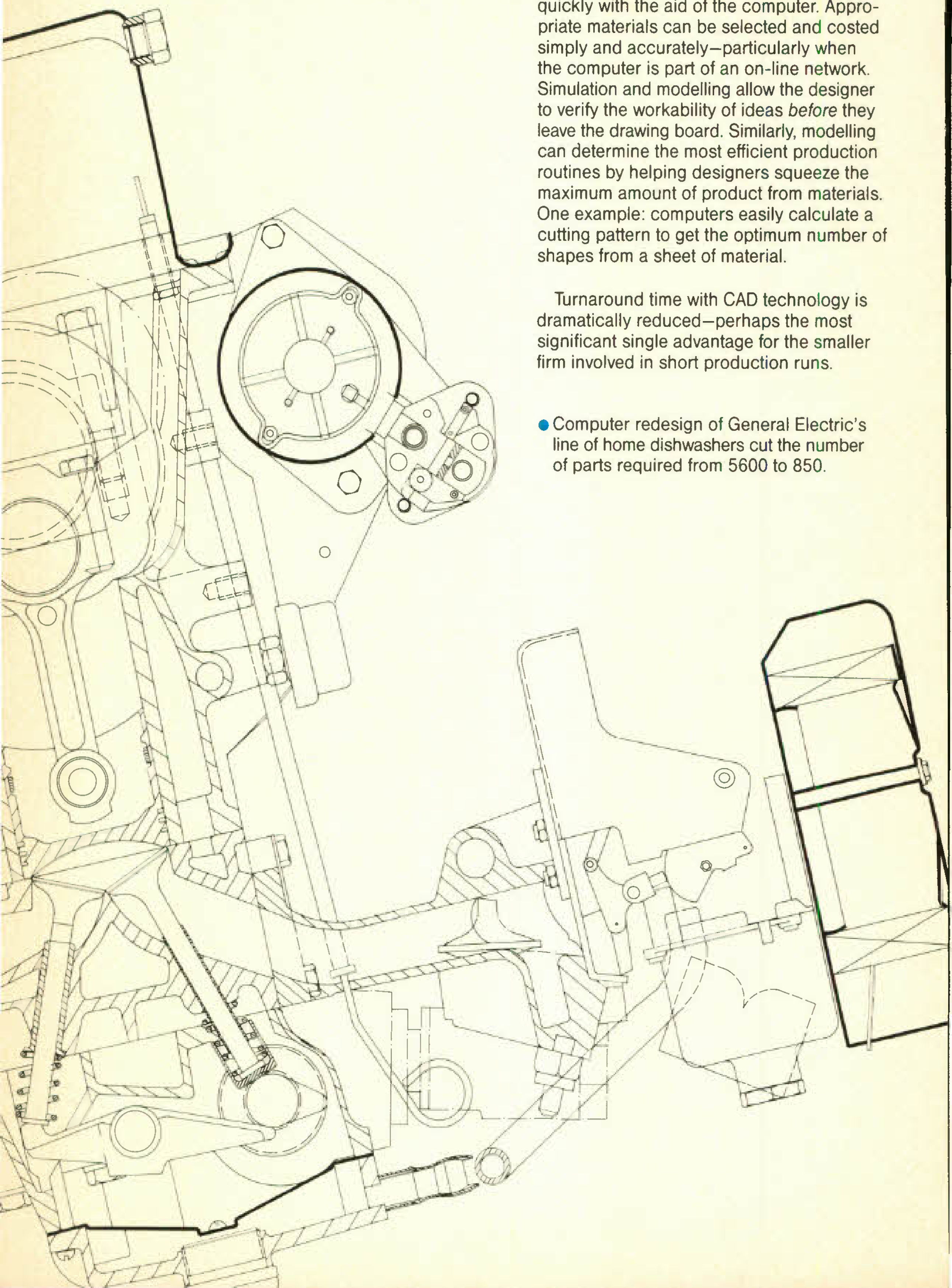
There is no arguing with the added clout the computer-aided design process offers designers and engineers. Standard shapes, parts, sizes, fittings and a whole library of common design elements can be stored in the computer and instantly incorporated into designs. Designs can easily be converted into convincing three-dimensional drawings. Various parts of a design can be rotated, exploded, edited and recombined. Relationships between different elements and the whole can be explored.

Radical departures from traditional design solutions are examined in detail without risking much time with painstaking manual drawing. Computerized animation gives the designer a dynamic view of the workpiece and its components interacting with other elements of the design.

The engineering leverage of CAD adds to the designer's creative potential. Basic engineering considerations are established quickly with the aid of the computer. Appropriate materials can be selected and costed simply and accurately—particularly when the computer is part of an on-line network. Simulation and modelling allow the designer to verify the workability of ideas *before* they leave the drawing board. Similarly, modelling can determine the most efficient production routines by helping designers squeeze the maximum amount of product from materials. One example: computers easily calculate a cutting pattern to get the optimum number of shapes from a sheet of material.

Turnaround time with CAD technology is dramatically reduced—perhaps the most significant single advantage for the smaller firm involved in short production runs.

- Computer redesign of General Electric's line of home dishwashers cut the number of parts required from 5600 to 850.

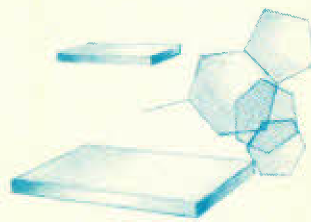


Computer-aided manufacturing is the other half of the CAD/CAM equation: information from the CAD-generated design is used to control automated machinery on the factory floor. The list of processes that can be controlled by computer is expanding continually. Some examples: machine tools, lathes, milling and boring machines, pattern and fabric cutting, welding, brazing, soldering, casting, flame cutting, painting and automated assembly.

To date, intensive CAD/CAM automation has been the preserve of large corporations. Now, thanks to what is being called a "revolt" by some of the largest purchasers of industrial computer equipment, computer manufacturers have agreed to develop a universal set of standards for computer and machine communications. More widespread adoption of the Manufacturing Automation Protocol (MAP) developed by General Motors of Detroit means that, for some applications, integrated computers and industrial machinery will become virtually off-the-shelf items. Costs for CAM equipment can be expected to drop sharply.

Full-blown adoption of integrated CAD/CAM procedures will never make sense for many small manufacturers. But lower-cost CAD/CAM equipment will find its way to smaller manufacturers interested in determining which applications of the new technology work for their business. CAD/CAM technology offers much greater flexibility than special-purpose machines because it is reprogrammable, making it suitable for small- and medium-volume production where frequent changes may be necessary.

CAD/CAM technology brings the smaller firm the mobility and forecasting ability to compete successfully with larger rivals. Surprisingly, while CAD/CAM generally reduces employment at large enterprises, it tends to increase employment at smaller firms.



Living Examples

- Increasingly, doctors and dentists are using CAD/CAM programs to design and manufacture body implants such as hip bones and teeth. Since these programs usually work the first time, they reduce pain and save time too.

- Bata Industries of Batawa, Ontario, has developed a $150,000 CAD system for designing shoe uppers and has sold it to manufacturers in the United States, Japan, West Germany and Canada. The company is also developing CAM systems for making different-sized shoe lasts, molds for shoe soles, and fixtures for holding shoe parts together as they are stitched.

- In Western Canada, MacMillan Bloedel has integrated CAD/CAM into its sawmill process. Data from sensors on the size and shape of logs is combined with information on orders for planks and studs and a computer program then determines what to cut from each log. This reduces waste considerably.

Robots:
From Fiction to Factory

Robots have occupied a secure place in the imagination of the twentieth century since Czech writer Karel Capek invented the term for his 1920 play, *R.U.R.* (Rossum's Universal Robots). Fortunately the new industrial machinery of the same name has little in common with the army of man-like machines Capek sent rampaging through twentieth-century science fiction.

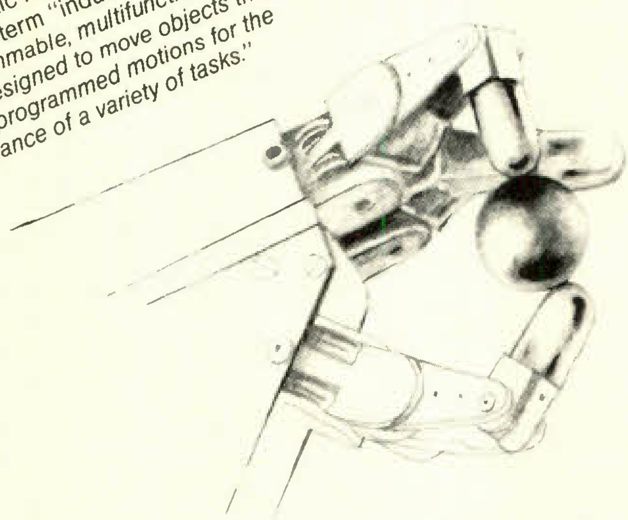
Today's industrial robots result from the marriage of earlier mechanical, electric and hydraulic technologies with microchip-based computer technology. Industrial robots have no specific shape or anatomy. They're as varied in shape as the tasks they're designed to perform.

The common variety of industrial robot takes the form of a flexible, computer-controlled hydraulic or electro-mechanical arm attached to a pivoting base. But there are no hard and fast rules.

A combination of computer control and flexible manipulation of objects means that robots can take on different tasks than earlier generations of industrial machinery. And being reprogrammable, robots are not limited to performing any specific work routine.

Robots can be used to transport and manipulate objects being manufactured from one process to the next. Or they can be fitted with tools to perform work on objects being manufactured.

The Robotic Industries Association defines the term "industrial robot" as a "reprogrammable, multifunctional manipulator designed to move objects through variable programmed motions for the performance of a variety of tasks."



- Some 112 of the 125 robots installed at Chrysler Canada's state-of-the-art Windsor, Ontario, mini-van plant are used to weld together the vehicles' basic structure.

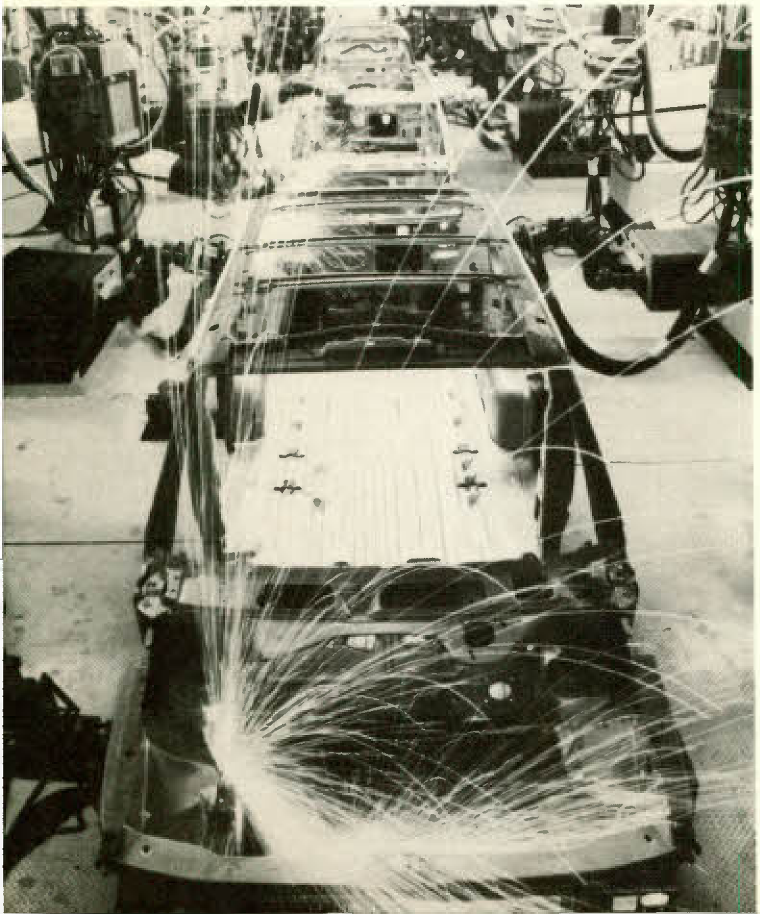
Seventy percent of Canada's robot population of approximately 1300 earn their keep in the automotive industry—down from 90 percent in 1977. The majority of these are used for spot welding, painting and metal working. Parts and materials handling and tasks such as loading and unloading machines are other major applications.

Over the past three years, the growth of robot installations in non-automotive manufacturing industries in Canada—particularly electronics—has exceeded that in autos. The potential benefits of robots are particularly great in the one-third to one-half of manufacturing industries that use batch production methods.

Robots Only Need Apply

Present-day robots are often blind, obediently repeating the motion sequences stored in their programs. Sometimes motion routines are established by a human "teacher" guiding the arm through an initial sequence which is then endlessly repeated by the device. But even these basic robotic devices can perform a surprising variety of industrial tasks.

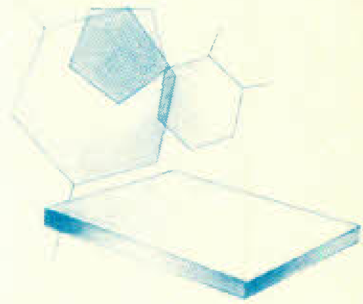
In many respects, robots are better suited to the modern factory environment than human beings. They thrive on repetition, never suffering from boredom, absent-mindedness or fatigue. They can be built to withstand hostile environments and processes: levels of heat, noise, fumes and dust that would cause a lot of wear and tear on human workers. Their unvarying performance is matched by a precision few humans can equal. They can be operated without breaks, 24 hours a day, 365 days a year, if required.



These qualities have so far meant that robots have been substituted for human workers largely in the most dangerous or unpleasant industrial jobs. Widespread use of robots has been prevented both by high capital costs and by the relatively limited sophistication of the first generation of machines. Estimates suggest that first-generation robots could be used to perform a maximum of 3 percent of all industrial work. The next generation of robots, now being introduced, is considerably more sophisticated. These machines will compete for a larger slice of industrial work, invading areas such as assembly and various other skilled and semi-skilled work.

- A machine vision system under development by Diffracto Ltd. of Windsor, Ontario, can relay continuous information on the location of machine parts, allowing robots to select any part as needed.

The major factors propelling the advance of robot technology are the plummeting cost of computer intelligence and new developments in the fields of machine vision and software development. Vision systems like Diffracto's let robots perform more complex and varied tasks. New controlling software enables limited "decision-making" by the robot, without direct human intervention.



Science Fiction to Labour F-r-i-c-tion?

One indication of the increased power of second-generation robots can be found in estimates of labour displacement. A West German study estimates a loss of 5 to 10 jobs for each second-generation robot installed, versus 2.5 jobs lost to each first-generation device.

Robotics also offers opportunities. A Canadian company, Clay-Mill Technical Systems of Windsor, Ontario, is developing a sophisticated vision-guided robotic automotive assembly system to be used for assembling trunk lids, doors and front fenders on cars. The company has already received a $10 million order from General Motors, in addition to $5 million in orders from other firms.

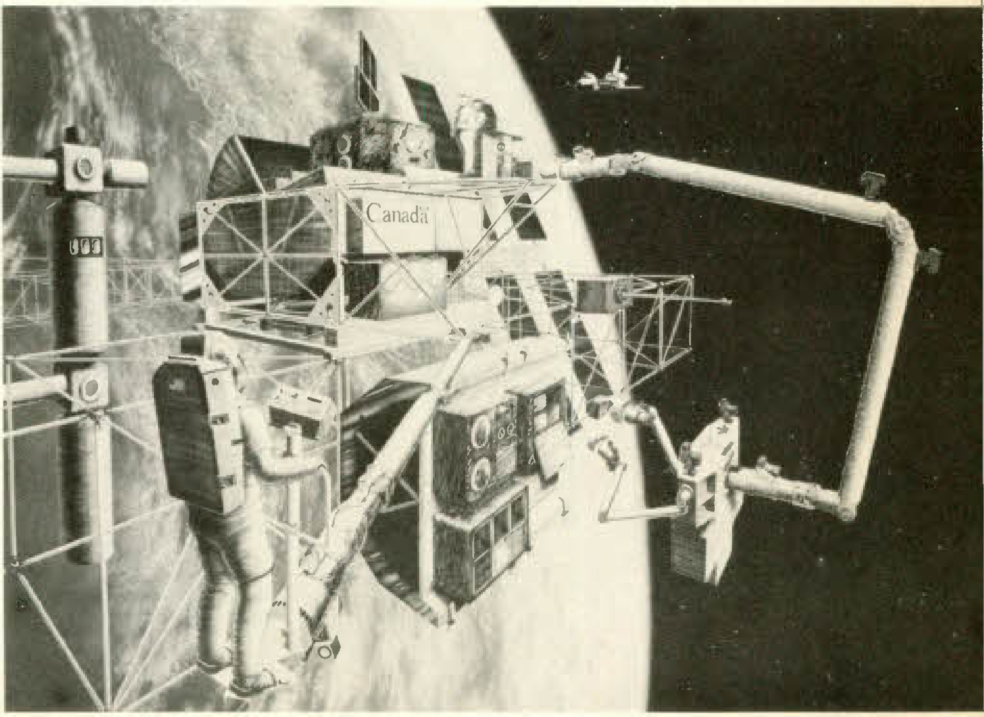
It is projected that, by 1995, 60 percent of all robots will incorporate robotic vision and other sensory devices. In these fields, Canada is already in the forefront. The highly acclaimed robotic Canadarm, for example, is Canada's unique contribution to the US space shuttle program. In the future, Canadarm technology will form the basis of a permanent manned service centre in space.

Canada will spend $800 million on the service centre over the next 15 years, with Toronto-based Spar Aerospace the prime contractor, and six other Canadian firms as major sub-contractors. The space service centre is expected to yield $5 billion in spinoffs to the economy in such areas as robotics and computer intelligence and 80 000 person-years of work by the year 2000. Canadarm technology is also finding many other applications, such as mining and deep-sea exploration.

Almost all of the industrial robotic systems now in use in Canada are imported, mainly from Europe, Japan and the United States. Experts consider that the lead established by these countries is too far advanced for Canada to catch up. Japan currently has over 27 000 industrial robots operating in its factories. Japanese robots are well established in delicate assembly operations such as for videocassette recorders. The United States now has 15 000 robots. Both Japan and the United States have supported robot development with extensive state-backed research.

However, with hardware accounting for only 25 percent of the installation cost of robotic systems, considerable opportunities exist in the field of robotic software and systems development. Along with the increasing number of robots comes a growing need for software that enables robots to coordinate and cooperate with one another. Here, Canada—already a leader in the field of communications—can apply its knowledge of communications software to the design of internal communications systems for robots.

Wholesale adoption of robotics technology may be only a few years away. The use of these robots will challenge society to find productive channels for our human resources.



Computer-Integrated Manufacturing:
Factories on Autopilot

- *"The Automatic Factory is like the Holy Grail—something you approach but never reach."* Philippe Villers, President, Automatix Inc. (U.S.A.)

Software Works the Nightshift

The scene: Midnight at a deserted showcase "factory of the future." Inside, the sound of machines in motion, producing parts for tools and robots. Finished trays of parts are automatically stacked and removed for packaging and distribution. Countless details of production from microprocessors throughout the factory are relayed to a central computer. The factory operates untended by humans during the nightshift. The lights stay off all night.

Suddenly computer sensors detect a malfunction in one of the automated tools. Within milliseconds, production at this work area or "cell" is halted. A central computer calls the homes of the technicians on duty to request repairs. Suppliers and head office are automatically advised of any changes to the production schedule resulting from the breakdown.

This is the fully automated factory: still largely the stuff of management dreams and labour nightmares. Today only a few hundred fully automated factories are operating around the world. And, for the time being, most experts expect the factory of the future to remain just that. Introduction costs are high and paybacks are still uncertain.

But computers, data links, industrial robots and automated machinery are winning an increasingly central place in industrial production. In the process, they are inspiring a new vision of what manufacturing is all about.

Computer-Integrated Manufacturing

Computer-integrated manufacturing (CIM) is the term used to describe the fully automated factory in which a whole spectrum of manufacturing processes—from design, evaluation and manufacturing through accounting, inventory control and other business planning functions—are integrated and controlled by a central computer with minimum manual intervention. Production equipment workstations are linked by a materials-handling system to move parts from one workstation to another. There is maximum coordination and communication between all elements of the system.

The new factory is paperless. Information is shared throughout the workforce via computer terminal. The new factory is also leaner; parts warehousing is all but gone. Instead, suppliers tied in to the producer's data base deliver parts "just in time" as needed, or machines create them as they are required, as in "point of assembly" parts manufacturing.

It is more flexible; robots and other computer-controlled equipment form manufacturing "cells." Cells quickly adapt to new production requirements, exchange information and accept new designs and work patterns downloaded from a central computer.

- Planners at General Motors' Hamtramck facility in Michigan expect to cut the time involved in changing a cell from one model to another from 3 days to less than 10 minutes.

Once finalized, design and production data from the designer's workstation can be used to control the automated machine tools actually making the object or part. Final inspection of the product is automated, via new electronic sensors and vision systems.

Identification systems such as a simple bar code mean that, even after a product is delivered, its manufacturing history is on record. Problems in products returned for repairs can be traced through the production system using data recorded when the product was being designed and manufactured.

Quality at the new factory results from the extreme accuracy of measurement and precise control achieved with computerized machines and improved communications. Productivity can skyrocket: industrial robots are theoretically available for work all 8760 hours of the year.

- Chrysler Canada spent 750 000 hours training personnel to operate its new equipment at the Windsor, Ontario, assembly plant.

In the summer of 1983, bulldozers began pushing old assembly line equipment out of the Windsor plant through holes cut in the walls. Sixteen weeks and $400 million later, Chrysler's workforce returned to join 125 new robots in a completely redesigned, computerized factory. Production at the new factory is up 20 units an hour without increasing the number of jobs (a level that would have required 600-700 extra workers with the old equipment). Parts inventory levels have been cut from four days' worth to four to eight hours. In all, Chrysler expects the facilities to chop $2,500 off the cost of producing a new vehicle. Quality on the 18-km-long mini-van assembly line is considered the best in the company's history.

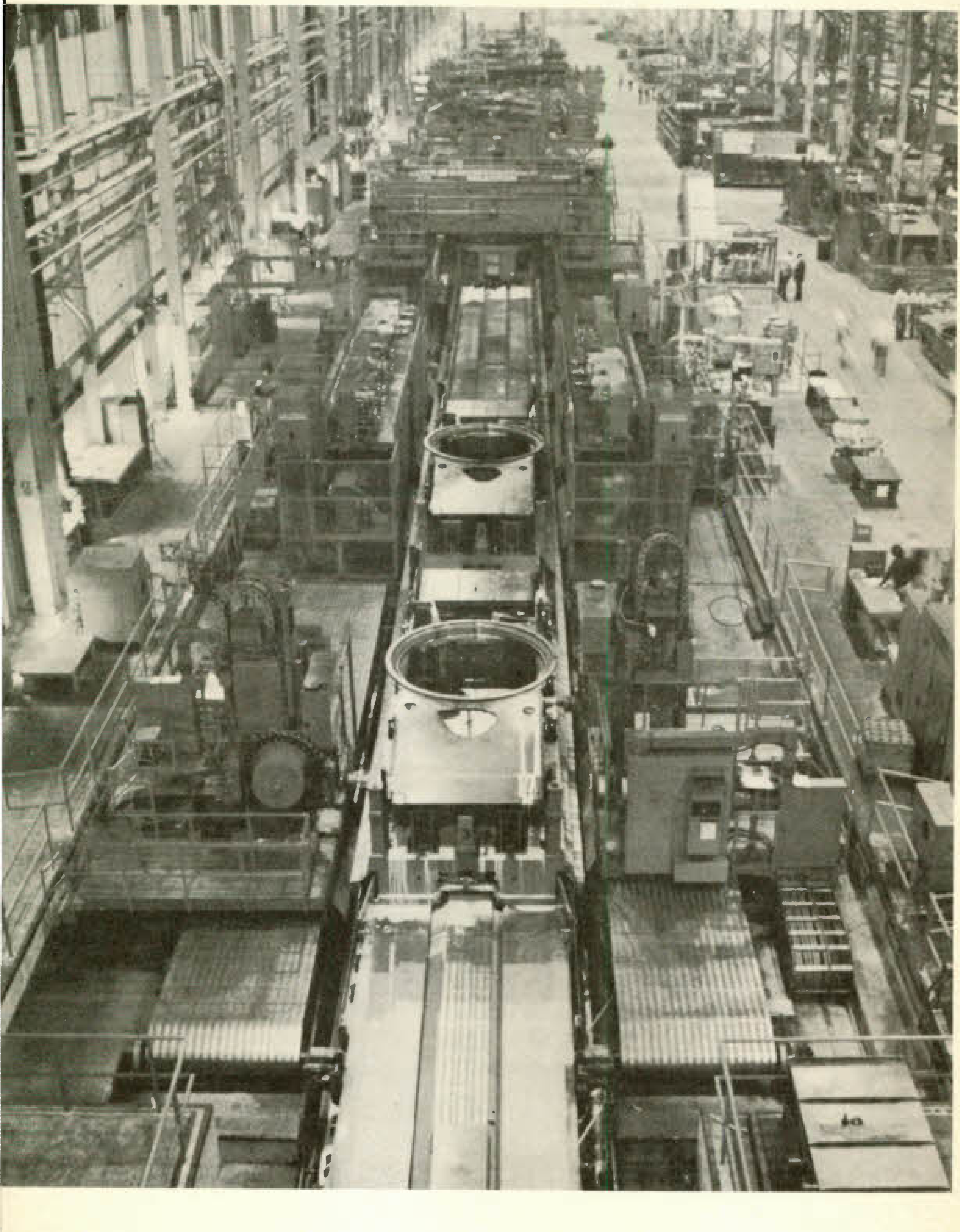
- General Motors of Canada plans to spend $2 billion to redesign its two Oshawa, Ontario, auto assembly plants, making Oshawa the largest vehicle-production complex in North America.

When the new Oshawa "autoplex" is restarted, it will be missing a key element of traditional mass production: the assembly line. Instead, automatic guided vehicles will move the cars to workstations as they go through the assembly process. The plant, being designed as a fully integrated, totally synchronized manufacturing system, is expected to increase annual car production by 20 percent. According to one US industry analyst, this will put Canada ahead of Japan in automaking technology.

Software Opens Up

Widespread acceptance of CIM throughout the manufacturing sector may be heralded by two recent developments: the trend towards "open computer software" and "open communications." Open computer software allows programs for previously incompatible computers to be transferred from one machine to another, while open communications allows incompatible computers to talk not only with each other but also with numerically controlled machines and robots on the shop floor. Integrated computers and industrial machinery will soon be off-the-shelf items for some applications as the Manufacturing Automation Protocol is more widely used.

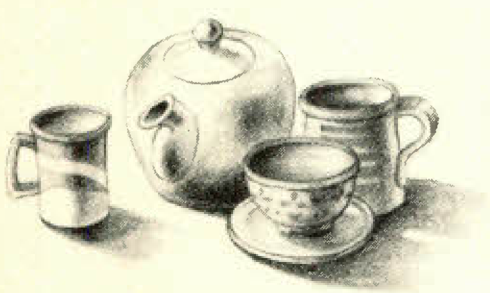
Along with the new gains in productivity will come new ways of working: a shortened work week, job sharing, flexible hours, new reward systems... But, beyond the qualitative changes in work, higher productivity means international competitiveness... and jobs for Canadians.



Lasers:
Light Rides a New Wave

In your hands you hold a hologram—a transparent three-dimensional image made, in this case, on a plate of photosensitive glass. When bathed in a diffused beam of laser light, the glass reveals a convincing three-dimensional image—a still life as it happens, depicting a teapot and three cups. Looking at the image is exactly like looking in on the scene through a window. Look straight through the plate of glass and you see the three cups and the teapot. From this angle, you can see the teapot's spout but not its handle. Now shift your perspective and peek from one side of the plate to examine the teapot's handle, hidden when the image is seen from a central point of view.

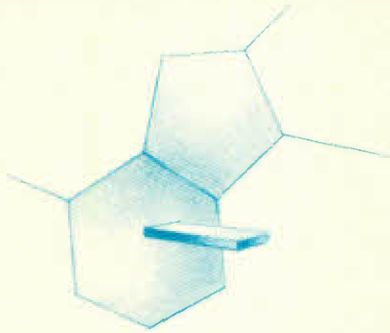
Simply looking at the life-like picture before you is impressive enough. But to appreciate just how different a hologram is from a conventional photograph, you may have to take more radical action... Throw the plate to the concrete floor beneath your feet. It shatters into hundreds of pieces. Pick up any fragment and squint through it: you'll still see three cups and a teapot. Now, however, you seem to be viewing the scene through a keyhole. The hologram is broken, yet in each tiny fragment the image of the scene is still in one piece. Contrast this experience with that of examining a morsel of a standard photograph, accidentally ripped to shreds. If you've got Grandma's big toe, that's all you've got.



The hologram in question was made with a *laser*, an invention as critical to unlocking the potential of light energy as earlier inventions were to harnessing the energy of fire. Invented in 1960, lasers now come in all shapes and sizes for use in thousands of new applications. Some industrial lasers produce light of terrific intensity, heating substances at the rate of a trillion degrees a second—more than enough heat to vapourize any earthly material. Others produce rays of extraordinary fineness to perform the most delicate microsurgery or to bump molecules into a new arrangement in chemistry.

The name is an acronym for the ungainly Light Amplification by Stimulated Emission of Radiation. To picture the most common type of laser—the helium neon laser used extensively in automatic supermarket checkouts—imagine a hollow gas-filled tube. Both ends of the tube are mirrored, one completely and one partially. When the gas trapped inside is energized by electrons from a cathode, it emits photons. Photons reflected back and forth in the mirrored tube stimulate the emission of other photons that are exactly in step, or in phase, with the original ones. This light is said to be coherent: of one wavelength or colour, with all the waves in phase. The emerging light beam can be compared to a single, pure and powerful musical note, contrasted with ordinary light which would be the equivalent of background traffic noise.

On its invention a quarter of a century ago, many scientists and engineers dismissed the laser as a mere curiosity—a "solution in search of a problem." Today, however, sales of laser-related electro-optical technology are booming, with an expected growth rate of at least 25 percent a year over the next decade. Lasers have moved out of the lab—where they've been performing sophisticated measurement and analysis work for years—and into the home, office, factory, artist's studio and battlefield.

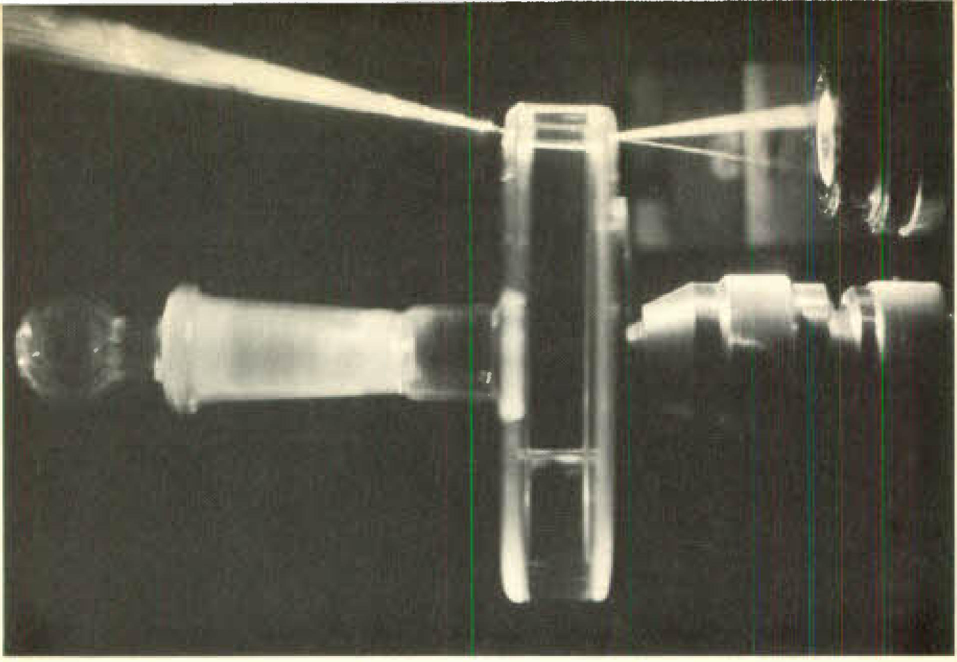


Lasers in the Factory

● Industrial lasers produce over two billion dollars worth of goods a year in the United States alone.

Lasers have proven superior to conventional tools in hundreds of manufacturing tasks. In materials processing, high-intensity lasers cut, drill, weld and anneal metals with unerring precision, eliminating saw blades, drill bits and clumsy welding machinery. And since they're electrically activated, lasers are easy to integrate into computer-controlled, automated processes.

Laser machinery is of growing importance in the manufacture of plastics, textiles and synthetic materials too. Some examples: perforating baby bottle nipples, cutting cloth for suits, husking peanuts and carving patterns on composite rollers for printing gift-wrap paper.



Lasers are becoming standard tools in sensing equipment, machine controls, counting, measurement and robot vision applications. Lasers are aligning lumber in sawmills and testing door fits in automotive factories. These devices are ushering in new levels of industrial accuracy and quality control. Conversion to the new technology is being pushed into smaller plants by large manufacturers eager for improved quality from their suppliers. Laser technology is an integral part of most industrial automation strategies and is expected to be a key performer in the computer-integrated manufacturing (CIM) systems of the next decade.

Lasers have invaded the sectors of materials handling and warehousing. Through the use of simple bar codes and optical readers–familiar to supermarket shoppers–the whereabouts of parts, finished goods and other stock can be automatically traced at all times and the information stored on computer. The same technology is used to keep track of books in libraries around the world. Now low-cost, hand-held readers place bar-code technology within reach of any small enterprise equipped with a personal computer.

Medical Lasers – Less Pain, Less Cost, Less Time

- One of the earliest uses of lasers was in eye surgery for attaching detached retinas.

In medicine, lasers are routinely used as imaging, diagnostic and surgical tools. Laser "scalpels" have the advantages of precision and of enough concentrated power to vapourize diseased tissue instantly with minimal trauma to nearby healthy cells. Tissue immediately adjacent to the cut is sealed off or cauterized by the heat, resulting in what surgeons call bloodless surgery. Tissue only a few cell-widths away from the cut remains undisturbed. Glass fibre probes can be threaded into crucial anatomical areas, such as the eye and inner ear, without requiring any flesh to be cut. Lasers are being used increasingly to detect and label cancer cells and, in combination with photosensitive chemicals, to destroy tumours.

Solid State of the Art

Solid-state lasers, as small as a grain of sand, are rapidly moving into the consumer market in compact disc players—the first successful consumer product of a major advance in optical storage technology.

Compact discs store sound signals as digitally encoded optical variations on the disc. When discs are played, a micro-laser in the player illuminates the surface, which is then "read" by a photo sensor which converts the signal into electrical impulses. The superior sound produced by compact discs results from an absence of distortion in the digital signal and the ability of the system to deliver more information about each sound.

The information storage ability of laser discs makes them a natural for computer data storage—a development that could have an astonishing impact on the availability of information. In theory, an entire library could be stored on one small disc. In a complementary research effort, lasers are being investigated for use in the next generation of computers, as super-fast optical switches and optical memories.

In computers, laser etching of chips will increase the number of functions performed by each chip. Other applications of lasers in the computer and electronic fields include new visual display systems, flat-screen cathode tubes and laser printers. Lasers are playing a larger part in traditional information technologies too. Already they're making printing plates and colour separations in the publishing industry. And high-resolution, laser-imaging systems are now being tested for tomorrow's television sets.

Might is Light

Inevitably laser development has also had an inspirational effect on the dark side of the human mind. The new technology is incorporated into a vast litany of military hardware, including sighting and range-finding equipment, aircraft and missile control, satellite surveillance, night-vision equipment, target designators and navigational equipment. Now the awesome budgets and considerable energies of the world's military machinery are racing to develop the use of mega-lasers to zap incoming missiles.

Light Lines

Lasers have also made possible significant advances in communications technology. In fibre optics, for example, pulses of laser light transmit information through fine strands of ultra-pure glass. As you will see in the next chapter, Canada's telecommunications industry has been a prime mover in the development of fibre optic systems, now replacing conventional copper phone lines around the world.

Telecommunications:
The World on a Wire

● *"Barriers to communications of time, space or systems incompatibility are disappearing. The only limits left may be those of imagination."* Northern Telecom 1984 Annual Report.

It's one part national character and one part national myth: a geographically dispersed people clinging to a common destiny across 10 million square kilometres of rugged landscape via rails of steel, copper wires and more recently by satellite and threads of light. We needed to develop superior communications technology to make it work at all. Since Bell's invention of the telephone here over a century ago, Canada has led the world with a series of communications firsts. Today telecommunications is still Canada's strong suit in international technology markets, our pivotal industry at the core of the burgeoning information age.

With the advent of the microelectronics revolution in the 1970s, the communications industry entered into a period of rapid development and change. Voice, data, print and image technologies began converging—blending into each other to form complex hybrid systems. Telephone transmission facilities became a highway for an increasing flow of computer data traffic. Old categories began breaking down as various business interests entered the competition for the right blend of technology and marketing to win in the mushrooming computer communications business.

Microelectronics has opened new horizons in telecommunications. Research expands at a hectic pace in an industry where "second best" has come to mean "out of the running." Northern Telecom alone will spend some four billion research dollars between 1985 and 1989.

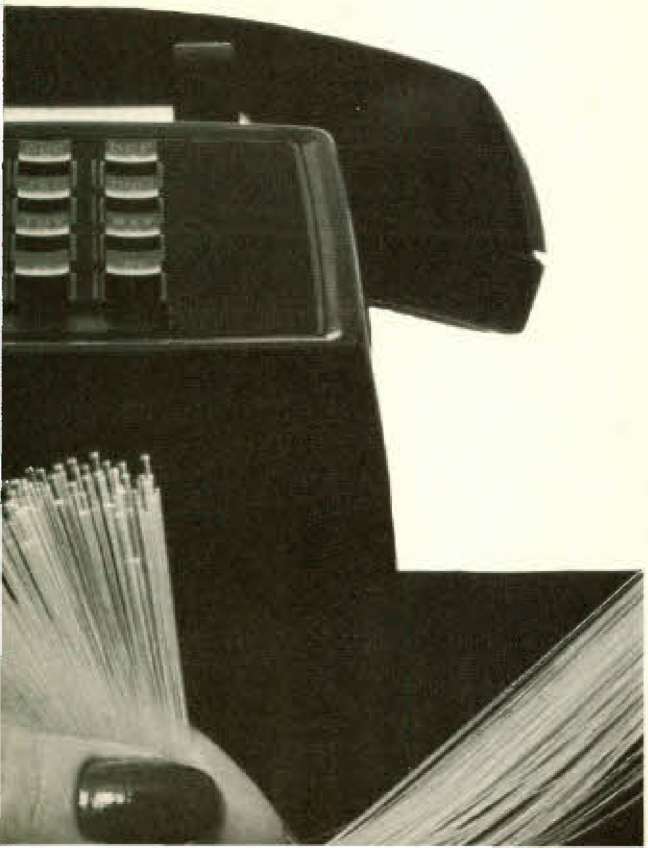
In the shadow of the giants, a number of maverick upstart firms have sprung to life and flourished, nourished by the inventive climate of new high-tech communities such as Kanata, Ontario—Canada's "Silicon Valley North."

The fruits of this surge of invention have profoundly affected the communications industry. Where 30 years ago thousands of operators were required to handle a million long-distance calls, today only a few dozen are required. New communications technologies such as digital transmission, digital automated switching, fibre optics and network software have dramatically improved the carrying capacity and reliability of the public communications network. Now these same technologies are the basis of new private "office automation" networks, linking voice and computer communications throughout an organization into a single, integrated electronic work environment.

Light Conversations

- A copper circuit can carry up to 22 telephone conversations at the same time. The equivalent fibre optic "circuit" can carry 8000.

Electro-optical communications systems use pulses of laser light to transmit signals through light-conducting strands of ultra-pure glass called optic fibre. The Canadian telecommunications industry is a prime mover in the development of these fibre optic systems—superior in every respect to copper wire transmission.



Fibre optic glass is a radical departure from earlier copper phone lines. By substituting photons for electrons and using glass fibre as a conducting medium, a given communications line can carry a tremendous amount of information. Digitally encoded signals sent on fibre optic networks are virtually distortion-free. Telephone conversations, computer data and electronic media share the same transmission line without electro-magnetic interference.

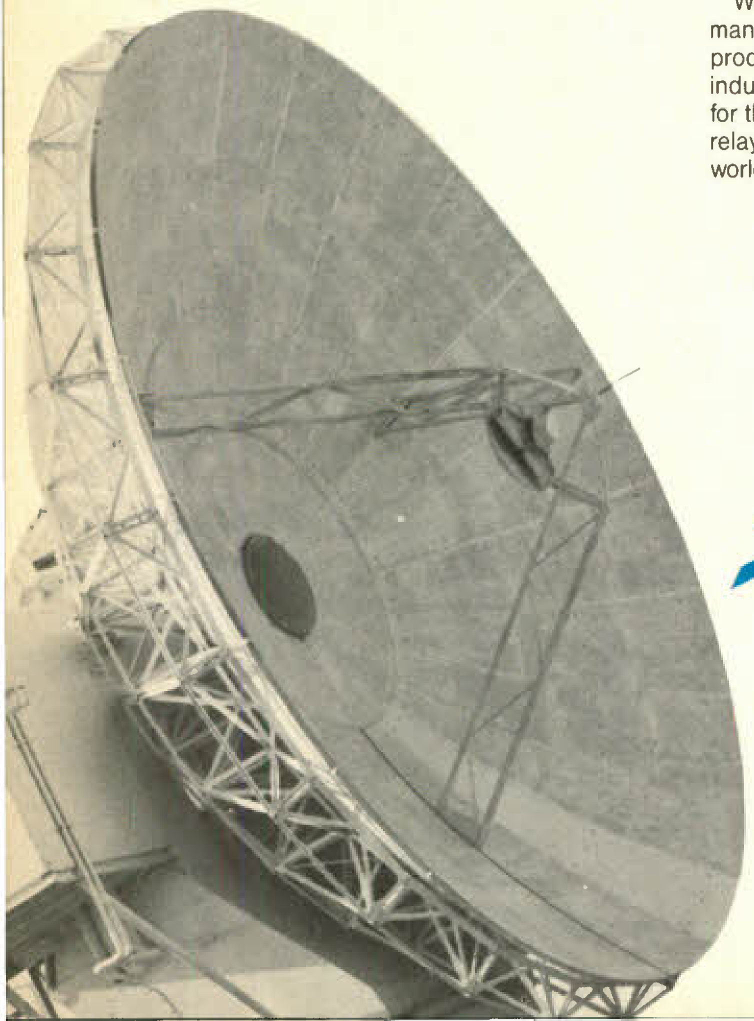
If achieving better results with less material input is the mark of a truly advanced technology, this is the textbook example. Fibre optic glass is made from silica or sand—one of the most abundant materials on earth. A telecommunications network made from glass uses a third of the electrical energy needed by conventional telephone networks, while saving on capital and labour too.

Within the next decade most of the world's telecommunications networks are expected to convert to fibre optics technology, creating a trillion-dollar market for electro-optics systems. One big winner: Saskatchewan's Crown-owned Sasktel, which began work on the world's longest fibre optic network in the early 1980s. The knowledge gained is expected to translate into substantial international sales for a newly formed Sasktel subsidiary established to market fibre optics expertise and technology worldwide.

Trans-oceanic fibre optic links are expected to give stiff competition to satellite communications in the years ahead. Since fibre optic circuits transmit more information, fibre optic home phone lines will be capable of carrying cable television and new computer-based services. There remains considerable uncertainty as to what computer services the market is interested in. Canada's publicly funded Telidon videotex system (text and computer graphics information relayed to a computer screen from a central data base source) has so far failed to catch on with consumers. A number of corporate efforts to tap into the home information market have met with similar consumer indifference.

One market which is hungry for new communications services is the contemporary business office. The microcomputer invasion of the early 1980s flooded offices with small stand-alone computer systems. As more and more computers appeared on more and more desks, managers began to realize that the machines have a formidable, if neglected, communications potential. For now, at least, the early 1970s vision of a wired city has given way to the 1980s reality of the wired office. Documents can be shunted back and forth from desk to desk electronically, without inter-office mail. Linked personnel can call information to their computer screens and simultaneously discuss it by phone.

The problem of linking, or integrating, all those computers is now a rallying cry for the telecommunications industry. Telecommunications equipment suppliers see an advantage in supplying complete office automation systems from the internal automated switchboard and communications network to hybrid desktop telephone/computer terminals. The watchword is compatibility. To facilitate office automation, networks need to provide communication between a wide variety of different office computers and equipment, as well as computers and equipment located at distant points.



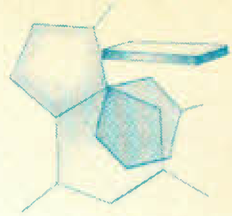
Computer data now accounts for some 25 percent of the traffic in the national telecommunications network and will supply much of the future growth in the industry. Most communications services being introduced today are aimed at the business community. Two private electronic mail networks are now in service, in addition to Canada Post's Intelpost system. The new services allow microcomputer owners to relay information electronically to other subscribers in the network. Also growing in popularity are facsimile machines which transmit copies of printed material over telephone or satellite links. The national edition of the *Globe and Mail* is made up daily in Toronto and sent by facsimile via satellite to local printing presses across the country.

With the growing acceptance of automated manufacturing technologies, such remote production could become common in other industries. In theory, machine instructions for the production of goods or parts can be relayed from design offices in one part of the world to production machinery in another.

Business and government are also prime clients for the many specialized data base services available across the country. These services give computer owners access to various kinds of information, from stock quotations and financial news to legal decisions. Although new optic disc technology could revolutionize the distribution of some information, providing suppliers with a means to publish large data bases for computer users, centralized time-sensitive information will continue to feed the telecommunications market.

Phones Go Mobile

Though now well into its second century, the familiar telephone clings to its dominance as the communications technology par excellence. Some 98 percent of Canadian homes have telephones, and we spend more time using them than any other nation on earth. The phone has become a primary business tool as well. Canada's pioneering cellular phone system is bringing the phone network to cars and trucks. Major airlines now offer in-flight phone services for executives whose working style is married to the mouthpiece.



Satellites

From the launch of the world's first geostationary communications satellite–Anik A, in 1970–outer space links between Canada's remote communities have become commonplace. Multi-channel satellites bring many of the benefits of urban life to northern and rural populations, including entertainment, tele-education, TV and radio broadcasting and telemedicine. As the TV commercial says, the innovative telecommunications technology now makes it possible for a doctor in Vancouver to listen to a child's heart beat in the Yukon.

Sophisticated new generations of Canadian satellites are expected to extend the communications significance of space. One breakthrough: a new mobile communications satellite–MSAT–is soon to bring two-way communications between any points on the Canadian map. The service is foreseen primarily as a security and policing tool for mobile voice and data transmission.

One Canadian consumer market that has responded as predicted to the new communications technologies is cable TV. Canada leads the world in consumption of cable TV services. Over 80 percent of Canadian homes now have access to cable television, with over 50 percent of the total market currently subscribing to some form of cable TV services.

Power of the Hour

Today's electronics technologies are creating new opportunities for Canada's telecommunications industry. The accent in the business is changing as companies founded on supplying the needs of domestic markets shift to a global perspective. And the world's growing appetite for information, along with Canada's considerable communications assets, spells a strong future for our number-one technical export.

Office Automation:
High-Velocity Administration

Call it the "office of the future," the "automated office" or the "integrated office." It is really today's office: more than any other work environment, at the front line of the microelectronics revolution. The 1980s are witnessing a radical change in the nation's offices, starting with the widespread adoption of desktop microcomputers for word and data processing. Typewriters are fast becoming office history. And according to some industry predictions, central paper files and office mail delivery may not be far behind.

A majority of working Canadians are now employed in some form of office work. The winds of technological change sweeping through Canada's offices are raising numerous questions about the future of this most important workplace: What effect will the increased productivity of office workers have on the availability of jobs? What opportunities for advancement will be available to workers in the system? What effect will the automated office have on the quality of working life?

The introduction of the telephone and the typewriter just over a century ago marked the beginning of mechanization in office work. A clutter of mechanical and electrical devices aimed at reducing office labour and increasing productivity followed: copiers, adding machines, dictation machines, etc. Despite these innovations, office work has remained labour intensive, with labour costs eating up an average 85 percent of office operating expenses. Levels of capital investment in the office have traditionally been low, compared to investment in other economic sectors such as manufacturing and agriculture.

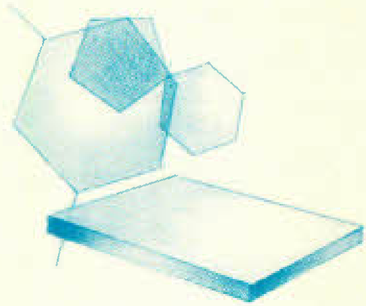
By the 1970s, productivity in Canada's offices was actually declining. Now capitalization is on the upswing with the accelerating purchase of information technologies. Potential increases in office productivity are enormous. With advancing computerization, white-collar work is being redefined.

- 342 000 microcomputers were sold in Canada in 1984.

A Terminal on Every Desk?

The first wave of office automation technology caught many organizations off guard. The advent of low-cost personal microcomputers and their rapid adoption by non-expert computer users simply defied previous experience with the mainframe computer world of specialized data processing departments.

In consequence, initial corporate purchases of small computers tended to be enthusiastic but haphazard. Wild computer purchasing in the early 1980s has resulted in a crowd of computers which are basically stand-alone installations often with little or no ability to communicate with an organization's other computer resources and personnel. In making the advantages of computer-based work (such as word processing, data base management and spreadsheet analysis) commonplace, the microcomputer revolution represents a significant advance. But the full potential of the new technology lies in integration: the linking of computers throughout an organization into a unified electronic work environment to take full advantage of the computers' communication power.



Head Office is Only a State of Mind

With the integration of computer and communications technologies–often called "informatics"–the context of office work is changing. Information from any part of an organization is available to anyone anywhere in the system. Routine operations such as ordering, billing, payrolling and keeping track of stock are automated altogether. Computerized links with suppliers and purchasers offer managers an up-to-the-minute "real time" picture of an organization's performance. Electronic mail and document transmission mean red tape is being computerized too. Documents and decisions requiring review or approval from various members of an organization can be automatically routed to the appropriate electronic workstations, speeding up the decision-making process.

The Paperless Office and Other Phantoms

Skills and job boundaries are blurring in electronic offices. Executives must learn to use the ubiquitous keyboard, not only to access corporate information, but, increasingly, to write reports and communicate with other employees in the system. Some corporations, anxious to see full use made of their investment in electronic hardware, have cut back on secretarial support staff, forcing managers to handle their own correspondence. The trend raises disturbing questions about the long-term future of secretarial work—traditionally an important job entry opportunity for women.

Even without such a drastic change in office procedures, the productivity improvements made possible by information technology may cut into the office secretarial and clerical job markets as fewer workers are able to accomplish more work.

One report recently predicted that 25 to 30 percent of office work could be completely automated. So far, however, the new technology does not seem to have resulted in a general reduction of office staff, partly because of the new services that have now become available.

Indeed, the pace of innovations in microelectronics technology has a habit of defying the best predictions. A few years ago, predictions of the paperless all-electronic office inspired sleepless nights in the office paper supply industry. As it turned out, the spread of microcomputers and printers has actually increased the appetite for paper in Canadian offices. Suppliers' sales have never been better. Similarly, while the new information technologies enhance the ability of organizations to access and process information, they also create a new demand for information. The final relationship between information supply and demand is still a big unknown in the office automation employment equation.

Canada's Expert Automators

- In 1974 AES Data of Montreal produced one of the world's first dedicated word-processing machines.

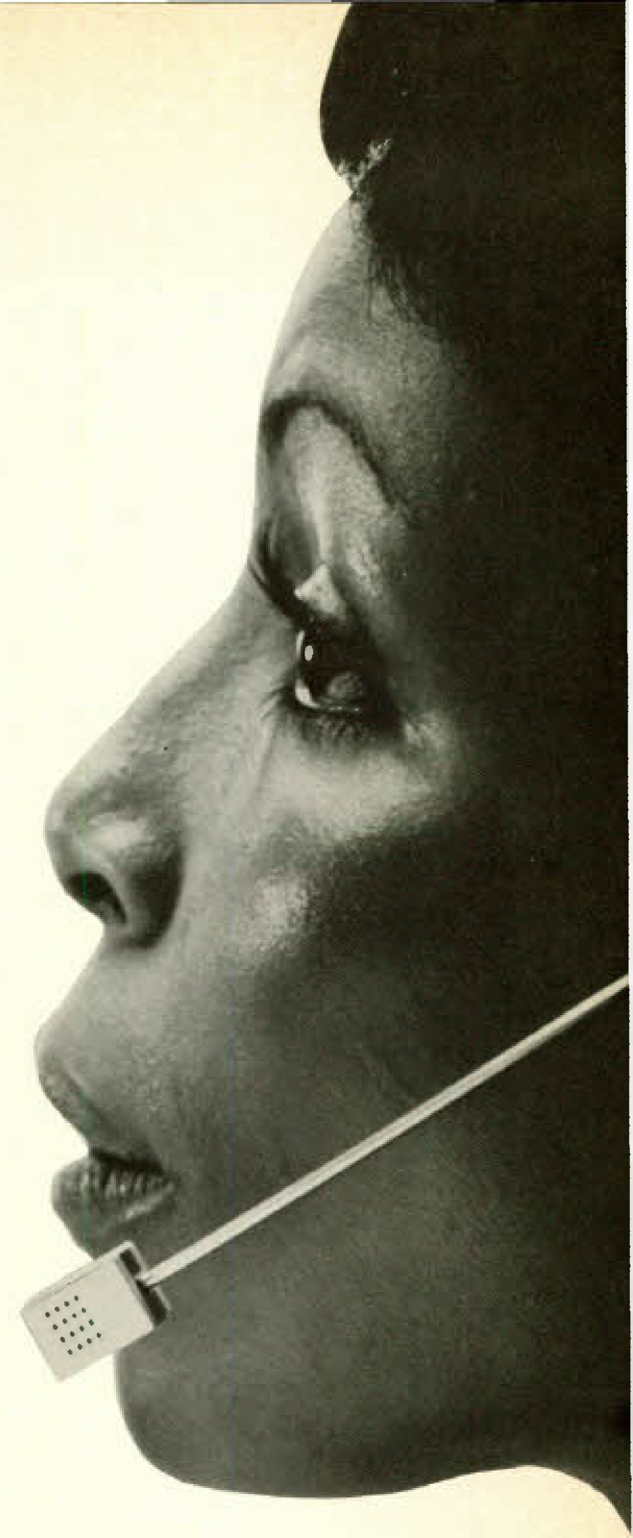
Many Canadian firms have built up expertise in office automation, through initiatives such as the federal Department of Communications' $12.5 million Office Communications Systems Program active from 1980 to 1985. The program was designed to test integrated office communications technologies in five different settings. Individual workstations equipped to execute a wide variety of tasks, including word processing, electronic messaging, analysis, document sharing, teleconferencing and other features, were linked together in various trial configurations. Some trials linked workstations between headquarters and remote locations. Others involved linking workstations at a single site.

While the tests proved the productivity advantages of integrated systems in numerous ways (field workers, for example, reported feeling much more involved with head office when it was immediately available via computer), they also emphasized the importance of making the technology easy to learn and of providing adequate training. But systems that don't deliver as promised or that impose long delays on users sharing common resources are quickly abandoned.

Despite the success of these comprehensive trials, most offices are adopting a "little by little" approach to office automation. Two Canadian firms are now offering a nationwide electronic mail service, accessible by microcomputer. Dozens of commercial data bases are in operation to service the demand for a variety of specialized information. New technologies such as optical disc readers may bring volumes of published data within reach of the microcomputer in the very near future and open the door to micro-based "knowledge processing" and "image processing."

Experts Bit by Bit

As automation advances, new developments in artificial intelligence will bring discriminating automated expert judgement into greater play. One example: A clerk at an insurance company receives a request from an agent for a policy to cover a client's new factory. Calling an expert system underwriter program to her workstation, she enters in the agent's name. Based on past performance, the system evaluates the reliability of the agent's information on the new facility. Next the clerk enters details about the factory itself: where it is located, the building's construction, the kinds of materials that will be used and stored there, etc. The expert system uses the information to ask the clerk appropriate questions. When the computer has all the necessary information, it comes to a decision about the policy, just as an expert underwriter would.



Ready or Not

Like other new high-productivity technologies, office automation may prove a serious challenge for Canada's sense of social wisdom. Whether or not our own offices experience a process of technological evolution or revolution remains to be seen. But the worldwide appetite for computer integration technologies also represents a new and largely untapped market for Canadian skills. With expertise already well established in Canada, systems to facilitate the integration of computer resources are expected to become a key export technology and point of entry to vast global markets in the years ahead.

Advanced Materials:

The Decline and Fall of the Age of Metal

- An experimental race car screams down the back stretch of a race track. At full power its 2-litre engine churns out 318 horsepower at 9500 rpm. The ultra-light engine is made from a new, heat-resistant, injection-moldable plastic.

- Respondents to a recent survey conducted by the Canadian Manufacturing Association ranked *advanced industrial materials* as the most interesting of the new technologies.

At the beginning of this decade, plastics replaced metals as the most common industrial material used in North America after wood and concrete. Now, a new generation of plastics and other synthetic materials is poised to alter the material composition of even more products of the industrial system, revolutionizing the way things are designed and made.

Stronger Lighter Faster Cheaper

Advances in materials science are producing tough new materials able to compete head-on with metals and other traditional materials in a growing number of applications and markets. Lighter, high-strength, easily formed materials offer engineers and industrial designers wide-ranging new freedoms and options. Corresponding advances in manufacturing technology are destined to bring highly automated plastics production techniques to heavy industry.

A Quiet Revolution in the Material World

- Six out of the last 13 Nobel prizes in physics have gone to materials scientists.

While the microelectronics revolution has captured much of the "high tech" limelight, the surge of invention in materials science is expected to have an equal impact on traditional industries and labour markets.

The materials at the leading edge of this quiet revolution seem familiar enough: plastic composite materials and polymers have been prominent since the 1950s. Ceramic—fired clay—products date to the dawn of human civilization. What's new is the growing ability to study, "image" and adjust the microstructure of materials to create desired performance characteristics. Hybrid combinations of materials further enhance strength and other properties, multiplying potential applications.

The New Composites – Hard at Work and Play

Composites are made by combining two or more dissimilar materials to obtain better performance and reduce costs. One familiar example: steel-reinforced concrete.

Today's composites are made by combining plastic resins with ultra-strong synthetic fibres such as Kevlar or graphite, often in combination with lower-cost fibreglass. Other approaches involve using metal "fibres" and "skeletons" and loose filler material such as talc or mica.

Advanced composites originally developed for space and defence applications are finding many uses in civilian aviation. Both De Havilland's Dash 7 and Dash 8 aircraft and Canadair's Challenger use fibre-reinforced composites in air-frame substructures where the excellent stiffness-to-weight ratios of composites translate into increased payloads and shorter take-off distances.

Today composites are playing a larger role throughout the mass transportation sector in light rail cars, boat hulls and urban transportation vehicles.

First-generation composites–polyester and epoxy with fibreglass–were quick to overwhelm the recreational boating industry, virtually ending wooden boatbuilding. The advanced generation of composite materials has also gained fast acceptance in recreational markets–in the form of virtually indestructible canoes and kayaks, super-strong sailboat masts and hulls, and even paddles and squash rackets. Now composites are moving into the automotive industry, although the processes involved have proved difficult to automate and adapt to industry production rhythms.

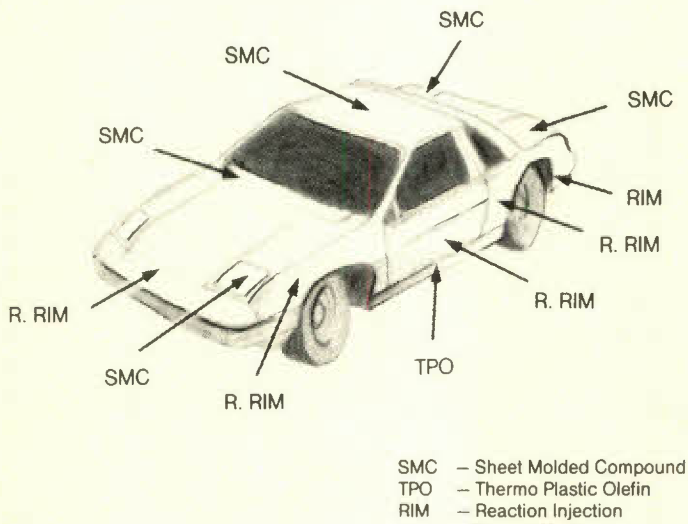
Engineering Plastics – Heavy Industries Lighten Up

Industry estimates anticipate that by the year 1990 plastics will make up 30 percent of the weight of the average North American car, replacing steel in a wide range of automotive applications. Plastic body panels, such as those employed on General Motors' Pontiac Fiero, are expected to become commonplace. Seats, underbodies, fuel tanks and even springs are considered prime targets for new materials substitution.

Potential cost reductions for manufacturers are considerable. Tooling costs for plastics are about half of those for steel. The new science of molecular architecture can change a polyethylene sheet–the cheapest plastic around–into a substance with the strength of steel. And new injection-molding techniques are opening the door to high-speed, automated production.

Plastic fastening systems are highly versatile and require minimum labour. Parts can be molded to snap into place. They can be fused together with radio frequency and bonded with adhesives. Most finishing processes will also be eliminated by the switch to plastic body skins. Colour and shine are molded right into the plastic skin materials. Plastics have always been good electrical insulators. Now researchers are creating electrically conductive plastic. And newly created medical plastics are even replacing some of the human body's membranes.

Canada has considerable expertise in the production of plastic resins. Plastics are an almost $8-billion-a-year industry here. Growth in 1984 was over 13 percent. Currently Canada's plastics industries employ 100 000 workers, many of whom work in smaller enterprises. One challenge for the industry lies in bringing technical advance to these smaller firms.



SMC – Sheet Molded Compound
TPO – Thermo Plastic Olefin
RIM – Reaction Injection Molded Urethane
R. RIM – Reinforced Rim

Ceramics – An Ancient Technology Takes On the Future

Technical ceramics–the mainstay of the microelectronics industry–are directly related to the everyday ceramics used to make earthenware dishes, tiles and bathroom sinks. The differences lie in the purity of materials and the precision of formulas and firing processes. Raw materials for technical ceramics are abundant and potentially inexpensive. And microelectronics research is fueling a ceramics knowledge explosion.

Ceramics engineers talk openly of a day when ceramic engines will replace metal engines in cars and aeroplanes. The diesel and gas turbine engines would operate at temperatures high enough to melt steel engines, achieving almost complete combustion, with resulting fuel efficiency gains of 30 percent. At this stage, prototype ceramic engines are prone to catastrophic failure–they can disintegrate in a cloud of dust. The lure of cost advantages is keeping research on the boil.

Canadian expertise in this area is concentrated primarily in the production of raw materials and electronics components.

Metals Fight Back

- Fibre optics are killing the market for copper wire. Scrap from wire replacement programs may depress prices into the next century.

- 1.5 million tons of plastic are used in plastic pipe and fittings annually in the United States, replacing about 5 million tons of metal.

Faced with fierce competition from synthetics, metal producers are sponsoring research into ways to keep products competitive. Advanced materials science is shaping stronger, lighter metals, targeted to specific market niches. Aluminum producers are making gains in the auto industry. New "glassy metal" technologies and simplified joining systems could help metals to fight back. But downsizing and substitution are altering the bulk markets. The outlook: only the most creative metal producers may prosper in the years ahead.

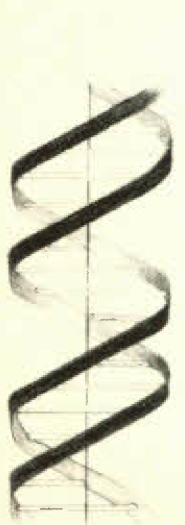
Biotechnology:
Harnessing the Double Helix

● Biotechnology: the application of biological systems and organisms to technical and industrial processes.

Though the science of biotechnology is barely 13 years old, a flood of new processes and products is already pouring out of the lab. In fact, the wide range of potential applications has some scientists labelling biotechnology the last great technical revolution of the twentieth century.

The breakthrough began with a microscopic strand of matter—the DNA molecule. From this elegant molecular information system, the characteristics of every cell in every living organism on earth are maintained and passed on to future generations.

The genetic code of DNA's twisted double helix molecule is a language universal to life—uniform and absolutely specific. Since all organisms contain DNA and all interpret DNA in the same manner, in essence all organisms are related. Now scientists are learning to read this code—to map the genetic characteristics of the world's plant and animal life and transfer genes from one living organism to another.



An Industrial Genesis

Industrial recombinant DNA technology followed the 1973 discovery that DNA can be transferred from one cell to another, endowing the host with some of the genetic abilities of the DNA donor. Researchers worldwide are working on transferring cellular genetic traits from the cells of large animals and plants to easily grown micro-organisms such as bacteria and yeast. They are also involved in endowing large plants and animals with new sets of desirable genetic traits.

At the moment the United States leads the research race, with Japan a strong contender. In Canada, estimates of new funds spent on or committed to biotechnology from all sources in 1983-84 are $300-350 million. About 40 percent of this came from federal sources. More than a thousand people in over a hundred Canadian companies and labs are actively involved in biotechnology work today.

In the near future, biotechnology will break into a number of industries critical to Canada's resource-based economy. Agriculture and the food-processing industries, forestry and forest products, pharmaceuticals and health care products, waste treatment and pollution control, the chemical industry and even mining will be affected by research now underway. Canada alone will produce biotechnology goods valued in excess of $20 billion by 1995. It has been estimated that biotechnology products and processes will be involved, in one way or another, in up to 70 percent of Canada's gross national product by the year 2010.

Green Revolution Turns a New Leaf

● Biotechnology is making agriculture more efficient and productive, but is also creating an environment that may force a high percentage of farmers out of business by the year 2000, according to a study by the US Office of Technology Assessment.

Biotechnology will substantially alter the agricultural industries' product. Micro-propagation and genetic engineering begin by greatly speeding up traditional breeding aimed at producing hardier and more productive plant stock. But they also allow scientists to endow agricultural crops with genetic abilities imported from completely unrelated plants.

● Topato = Pomato

Agricultural crops will gain frost- and drought-resistant capabilities—altering growing seasons and opening areas now marginal to agricultural exploitation. Photosynthesis—the ability of plants to convert light into energy—can be boosted to improve crop yields. Traits that improve resistance to disease can be incorporated into plant strains, cutting the need for pesticides. And pesticides themselves are undergoing a change as scientists develop micro-organisms to counteract various agricultural pests, replacing chemicals. In the immediate future?—stronger, more vigorous plant crops getting higher yields with fewer chemicals.

Research into the area of nitrogen fixation illustrates biotechnology's potential in agriculture. Today farmers around the world use 60 million tons of nitrogen fertilizer every year. But a few species of plants such as clover and alfalfa don't require additional fertilizer. These leguminous plants have learned to fix atmospheric nitrogen in the soil through a symbiotic relationship with rhizobium bacteria living at their roots. Numerous research projects are underway aimed at extending the ability to fix nitrogen to other species of plants such as wheat. At stake—an annual expenditure by Canadian farmers of $500 million for nitrogen fertilizers and improved long-term soil health.

Animal production and health care research promises similar advances for livestock producers. Bio-techniques accelerate breeding programs rapidly. An extensive array of new vaccines stand poised for introduction, as do disease detection and control with leading-edge technologies such as monoclonal antibodies. The next few years hold the promise of greatly improved herd vigour and health.

Biotechnological manipulations of the natural bacteria that help cattle and other ruminants digest food will increase production using less feed. Also on the horizon—new growth hormones, new techniques to control animal fertility and new methods to reduce newborn mortality.

Pine Clones

- *"We're interested in producing many identical copies of superior trees."* Dr. David Dunstan, National Research Council's Plant Biology Institute, Saskatoon.

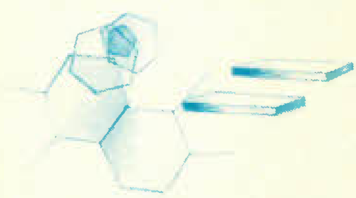
- A Laval research team developed a reforestation plan for the James Bay Energy Corporation, using trees inoculated with *frankia*, a micro-organism that fixes atmospheric nitrogen to accelerate plant growth.

Tree breeding is traditionally a long, slow process. Trees take many years to mature—to come to seed or show that a desired characteristic has indeed been passed on to new plants. Now techniques for culturing trees from cells let researchers screen thousands of different tree cells in the lab and induce cell samples to grow into new trees.

Forestry micropropagation brings genetic traits from different tree species together to produce better growth, disease resistance and other desirable qualities. Bacteria such as *bacillus thuringiensis* are already replacing spraying in forestry pest control programs.

Advocates of biotechnology foresee a tall future for cloned and fused-cell forestry stock—super-tall, fast-growing "elite" trees and new biotech-produced strains may restore life to Canada's depleted forest reserves.

Forestry researchers are looking to biotech micro-organisms to improve products and convert waste materials into new products. Lignin—a natural polymer occurring in wood—is a waste product of particular interest. Today, millions of tons of lignin are dumped into rivers in the course of paper manufacture. Biotechnology has prompted paper companies to view this pollutant as a potential resource. Breakthroughs in culturing micro-organisms on lignin and cellulose will open new markets and horizons for the lumber industry.



Human Health Care

- In the early 1980s human insulin, produced by genetically engineered micro-organisms, became available to diabetics as a replacement for animal insulin.

Genetically engineered micro-organisms are now used to produce an array of specialized substances in the pharmaceuticals industry. Propelled by high expectation of return on investments and the ability of the technology to produce substances for which no other practical source exists, pharmaceutical companies are leading the field in the introduction of biotech products.

The potential impact on human health care is vast. Monoclonal antibodies can be synthesized to diagnose and fight off viral infections. Interferons–substances that regulate the response of cells to infection and cancer–are being created to bolster the body's natural defences against diseases.

The micro-organism-produced antihemophilic factor offers hope for sufferers of hemophilia (a hereditary disorder that prevents blood clotting). New synthetic viral vaccines are being developed for diseases such as hepatitis B. A host of more traditional substances from antibiotics to human serum albumin can be produced more efficiently with the new technology.

The greatest health care breakthrough produced by biotechnology will come if efforts to synthesize vaccines against parasitic diseases such as malaria are successful. Hundreds of millions of people around the world currently suffer from life-threatening parasitic infections.

Other Applications

The use of micro-organisms in human culture dates to the beginning of civilization. Yeast transforms grapes to wine and leavens bread. Bacteria are used to produce cheeses and other foodstuffs in countries around the world. Today it is difficult to imagine a world without these products. Tomorrow the new micro-organisms may seem as familiar...

Micro-organisms will soon be producing new substances for the chemical and manufacturing industries. Special bacteria are being developed to detoxify industrial wastes. Microbial agents for digesting spilled oil are already in use. Organisms to leach and concentrate minerals are being investigated, as are microbes for oil extraction. One exciting trend–using micro-organisms to transform sewage into useful products.

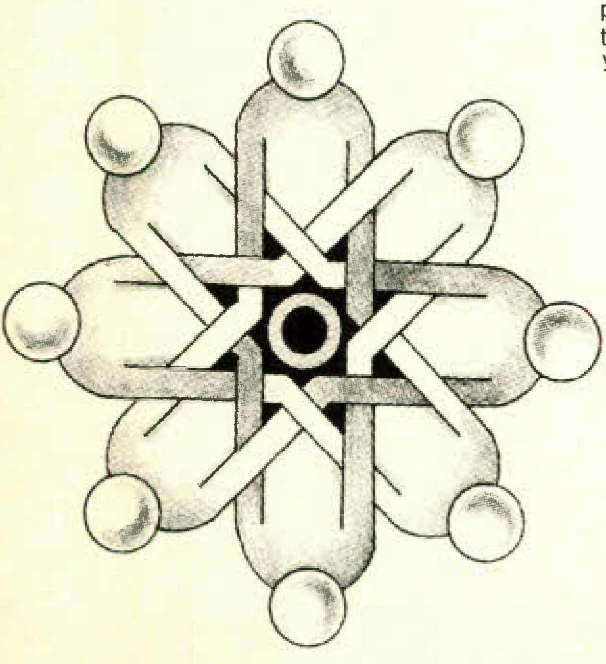
- *"Advances in the biosciences have opened a window of opportunity for Canadian industrial development... As biotechnology applications are relatively new, Canadian research groups can rapidly gain the critical expertise necessary to provide a foundation for commercial developments. However, Canadian groups must recognize and seize opportunities to cooperate, in order to be able to convert the scientific possibilities into commercial successes."* Annual Report, National Biotechnology Advisory Committee, 1984.

The Softer Side of Technology:
New Organizational Techniques

In addition to some of the "hard" technologies like robotics and CAD/CAM, there are other innovations, in organizational design for example, that may ultimately be as important to productivity and competitiveness.

Statistical Process Control (SPC): Quality as a Science

- Using SPC the Court Valve Company of St. Catharines, Ontario, became the first Canadian firm to receive General Motors' number-one supplier rating. In the 1983 model year, Court shipped three-and-a-half million pieces, in the form of 33 different components, to G.M.; there were no rejects.



In its simplest form, SPC is the use of basic statistical concepts to monitor how consistently a product fits engineering specifications. At various stages of a production run, tests are made to determine the conformity of the product with various critical characteristics such as weight and dimensions. Results are recorded and charted to show how the samples checked compare with specified tolerances. Minute variations recorded in the process can warn skilled SPC users of potential problems. Changes in the patterns of variation over time can be traced to a host of factors such as material quality, environmental conditions (heat, pressure, etc.), servicing intervals or operator skill. In this way SPC can not only show how well a particular product conforms to specifications, but can also be used as a diagnostic tool to predict and correct defects in the production process.

In Japanese hands, SPC has been used to promote an approach to work organization in which production and inspection are no longer separate and antagonistic but merged and self-supporting: production workers are their own inspectors. In Canada's automotive industry, more than 60 percent of parts manufacturers have given some SPC training to hourly workers in the last two years.

Certainly the pressure of demand from automobile assemblers—who have explicitly made SPC use by suppliers a condition for doing business with them—has led to a spectacular rise in this quality control technique since 1980. The percentage of companies using the technology shot up from about 7 percent in 1980 to over 80 percent today. For many production workers, the basic statistical concepts required by SPC represent a challenge; for management they entail considerable training costs. It may, therefore, be some time before Canadian industry can tap the full potential of SPC, moving beyond the recording and monitoring of SPC data to more sophisticated diagnosis and problem-solving.

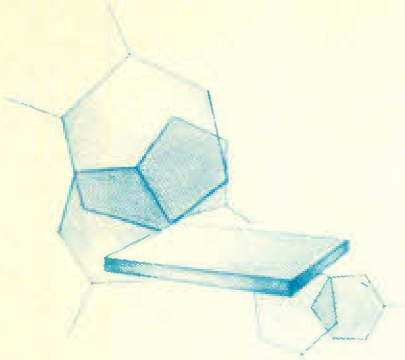
Just in Time or Not at All

- *"...in 1980 an auto assembler might have had several weeks' production of seats on hand. Now, assemblers may take hourly delivery of seats of the precise colour and materials required for that day's production. Planning is such that seats can be unloaded from the delivery truck in the exact order that they are required on the assembly line."* Report of the Automotive Industries Human Resource Task Force, January 1986.

The essence of the just-in-time (JIT) approach is to eliminate costly inventory. But the reduction of inventory itself imposes the need to identify and quickly solve production problems. It also imposes the very highest standards for quality control: if inventory is to be minimized (and the target is zero) there is no room for rejects. It is clear, therefore, that JIT and SPC go hand in hand.

The increased flexibility of delivery means ability to switch quickly to smaller production runs and, in turn, places a premium on quick changeover, increased machine utilization and enhanced preventive maintenance.

Like SPC, JIT is being adopted rapidly, particularly in the automotive sector. An interesting aspect of this process is that, just as the assemblers have required their suppliers to adopt SPC and JIT, those parts manufacturers will, in turn, tend to demand adoption by their own suppliers. Ultimately, the system will be founded on computer communications between assemblers and suppliers using common, industry-wide specifications and terminology. The engineering specifications on a CAD screen will be instantly translated into supplier identification, availability, cost and delivery data.



Organizational Innovation: A New Path to Effectiveness

People come from all over the world to see the Shell chemical plant in Sarnia, Ontario. It is a showcase for the socio-technical systems (STS) approach to workplace design. Shell and the local Energy and Chemical Workers Union together planned and implemented a plant design that explicitly acknowledges the needs and the contributions of the human side of enterprise as well as the requirements of its technology. This mutual accommodation of the technical and social systems of the organization is at the heart of STS. The relationship is viewed as synergistic and symbiotic—the *total* system is greater than the sum of its parts.

The basic building block of STS designs like Shell's is the self-regulating or semi-autonomous work group. Such a group (or team) typically takes responsibility for its own work assignment, technical training, overtime scheduling and hiring. Jobs are rotated and team members are encouraged to become multi-skilled by a pay-for-knowledge system in which the more skills they acquire, the more they are paid. Reliance on hierarchical control has been supplanted by group responsibility that fosters cooperation, flexibility and problem-solving.

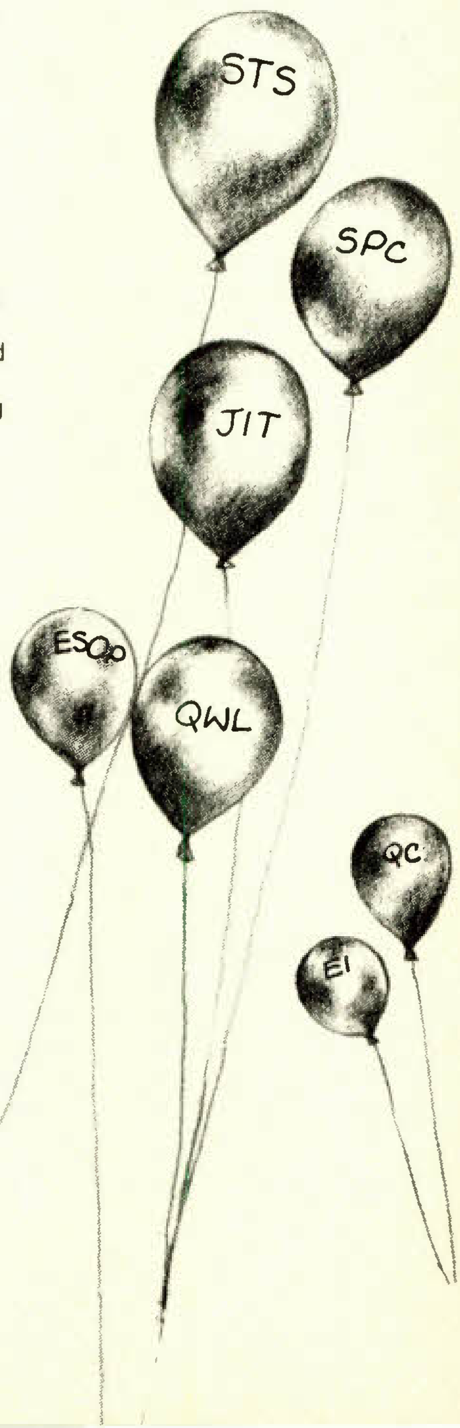
The results of this approach are impressive. Output levels are high, quality control and maintenance standards are excellent, absenteeism is the lowest of any of Shell Canada's plants, and grievances have been few. The company has been sufficiently satisfied to extend the STS approach to several other sites, and now proudly incorporates the "sociotech" success in its television commercials. Finally, the design has supported the development of an innovative and highly competent local union.

Shared Progress, Shared Profits

The STS approach also underlies the participative decision-making designed to develop skills and delegate authority in Canadian General Electric's highly acclaimed plant in Bromont, Quebec. This innovative design is also notable because it incorporates a gains-sharing plan that remunerates employees for cost savings that exceed established standards. In 1984 the plan paid each employee about an extra $1,000. The CGE gains-sharing plan is one of a variety of remuneration schemes based on improvements in cost or productivity performance (sometimes called "Scanlon" plans, after the steelworker who invented them, or "Improshare") or on profit-sharing—such as the employee stock ownership plan (ESOP).

Shell and CGE appear committed to a complete marriage of their social and technical systems. So, too, does Pratt and Whitney, whose new operations in Halifax, Nova Scotia, will incorporate not only the most advanced technology in the form of flexible manufacturing systems, but also the most innovative of work organizations. The company's senior vice-president of operations recently rationalized the approach quite simply: *"If we don't do this, it's ball game over, five or ten years down the road."*

Many Canadian companies, though they have not introduced the far-reaching total systems integration of the examples above, have nevertheless introduced particular elements of workplace innovation. Under the rubric of quality of working life (QWL) programs, for example, firms have implemented schemes of job enrichment and rotation, employee involvement (EI) in problem-solving teams or committees for information exchange, and the famous (or infamous) quality control (QC) circles popularized by admirers of Japanese management techniques.

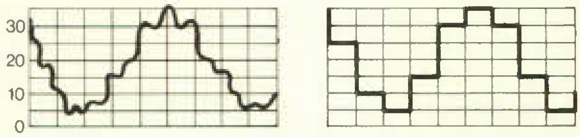


Glossary

A

AI — artificial intelligence–ability of machine to learn from experience and perform tasks normally attributed to human intelligence, e.g. problem-solving, reasoning, understanding natural language.

analogue — representation of information by electrical signal that varies continuously with information it is carrying (see also *digital).*



analogue *digital*

antibiotic — chemical substance administered to fight infections; produced using micro-organisms or synthetics.

antibody — protein produced by humans or animals in reaction to foreign substances called antigens; provides immunity to diseases.

antigen — substance (generally protein or carbohydrate) that stimulates production of antibodies, or reacts with antibodies already formed, when introduced into the body; sources of antigens include viruses and bacteria.

antihemophilic factor — fraction of whole blood that contains blood clotting agents; used to treat hemophilia (hereditary disorder that prevents blood clotting).

architecture — design of computer and way in which hardware and software interact; defines capabilities and limitations of computer.

artificial intelligence — (see *AI*)

ASCII — American Standard Code for Information Interchange (pronounced "askey")–industry-standard code used for exchanging information between machines, especially between computers and peripheral devices.

B

bar code — code that can be read by a wand or bar-code scanner; used to label retail products, factory parts and documents in libraries; universal product code is most widely used example.

batch processing — processing of different jobs, items, inputs or programs at the same time in one group (batch).

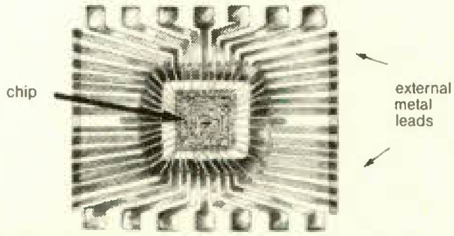
binary code — representation of numbers and characters using combinations of digits 0 and 1.

biochip — experimental electronic device that functions as integrated circuit; uses biological molecules as framework for semiconducting molecules.

bioelectronics — use of proteins in electronic devices such as biosensors and biochips.

biomass	organic matter that grows by photosynthetic conversion of solar energy.
bioprocess	process that uses living cells or their components to bring about desired chemical or physical changes.
bioreactor	vessel in which a bioprocess takes place under controlled conditions.
biotechnology	use of biological processes to provide goods and services.
bit	binary digit—smallest unit of information that can be stored and processed by computer; may assume only one of two values: 0 or 1 (on or off); represented electronically by a single pulse of electricity or absence of pulse.
buffer	temporary storage area for holding computer data until it can be processed.
byte	sequence of adjacent bits, usually eight, treated as single unit of information by computer; used as measure of memory capacity of system.
CAD/CAM	computer-aided design/computer-aided manufacturing—integration of computers into complete process from design to manufacture of product or plant.
CAE	computer-aided engineering—computerized creation and analysis of designs for error-checking, performance and economy.
CAI	computer-aided instruction (same as *CAL*).
CAL	computer-aided learning—application of computers as teaching machines; computer presents instructional material, monitors students' learning and adjusts presentation based on responses.
cathode ray tube	(see *CRT*)
CD	compact disc—form of optical disc that stores audio signals.
central processing unit	(see *CPU*)
ceramics	derived from Greek word *keramos* ("burnt stuff"); includes numerous brittle, hard, corrosion- and heat-resistant materials made by firing minerals (e.g. clay) at high temperatures.
chip	commonly used name for integrated circuit (IC).

C



CIM — computer-integrated manufacturing—concept of the totally automated factory in which all manufacturing processes are integrated and controlled by central computer.

CNC/DNC — computer numerical control/direct numerical control—linking of several numerical control (NC) machines via a data transmission network under central computer control.

code — language or set of rules that computers can recognize as instructions.

compact disc — (see *CD*)

compatibility — degree of interchangeability between different hardware, software, codes or languages.

compiler — program that converts computer instructions written in high-level languages such as FORTRAN or BASIC into binary-coded instructions that machines can interpret.

composites (reinforced) — materials created by bonding one material within a second material to control strength, stiffness and other factors.

CPU — central processing unit—the computer "brain"; contains all the processing circuitry for controlling interpretation and execution of instructions, e.g. retrieval, decoding, processing.

CRT — cathode ray tube—TV tube-like device that presents data visually; used in monitors and visual display terminals (VDTs).

cursor — movable, visible mark on computer display screen used to indicate where next character will appear.

D

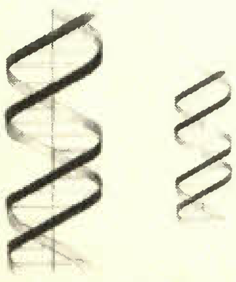
data base — structured collection of related information stored on mass storage device (e.g. disc).

digital — representation of information by electrical signal made up of pulses of discrete binary units (see also *analogue*).

disc — device used to store information.

dish (antenna) — dish-shaped aerial used for transmitting and receiving radio, TV and data signals via satellite.

DNA — deoxyribonucleic acid—molecular information system of all living organisms that determines individual hereditary characteristics.



DNC	(see *CNC*)
download	transferring of data from large machines to smaller ones.
downtime	period when system is not usable because of repairs or maintenance.
electronic mail	transmission or distribution of messages from one computer to another via telecommunications link.
electronic office	office environment that uses electronic means for text and data handling, information storage and retrieval, communications, etc.
electro-optics	branch of physics dealing with production of optical effects under the influence of an electric field.
ergonomics	derived from Greek words *ergon* (work) and *nomos* (natural laws of); adapting of work or working conditions to suit workers.
expert system	computerization of knowledge of experts in narrowly defined fields, e.g. medical diagnostics.
facsimile	machine that transmits pages of information over telecommunications link.
fibre optics	use of light or photonic energy to transmit voice, video and data through hair-thin fibres made of glass, silica or plastic.
fifth generation	term used to describe the most advanced generation of computers.
file	collection of related information treated as single unit by computer.
floppy disc	flexible, magnetic disc enclosed in protective container; used to store information for microcomputers.
FMS	flexible manufacturing system—machines interconnected by transport system and controlled by central computer; allows variety of parts to be processed at same time.
gallium arsenide	semiconductor material used in LEDs and increasingly in high-speed chips; allows electrical charge to flow 5-10 times faster than silicon; likely to form basis for future communications systems of extremely high speed and capacity.
genetic engineering	means of altering hereditary make-up of living cells.
genetics	branch of biology dealing with heredity and variation in animals and plants.
graphite	crystalline, soft, black form of carbon; occurs in nature and is also produced artificially; can be used as reinforcement for plastics.
grid	evenly spaced points on computer screen used to locate position.

H

hard copy	printed output, usually on paper, of image on computer or video screen, e.g. drawings, plots, lists and reports.
hard disc	magnetically coated disc made of rigid, ceramic-like material; used for bulk storage of computer data.
hardware	machines that make up computer system, i.e. mechanical, electrical and electronic devices.
holography	creation of three-dimensional images using split coherent wave source (e.g. laser beam) to record an interference pattern on film.
hormone	substance produced in living organisms that controls biological processes.
host computer	computer that controls other computers or a communications network.

I

IC	integrated circuit—semiconductor circuit in which electronic components are formed upon small wafer of material, usually silicon; also known as a *chip*.
image processing	processing of pictorial information by computer; includes enhancement of images, extraction of features, digital storage of images for transmission or later retrieval, etc.
informatics	derived from French "informatique"; concerned with information and its handling, especially integration of computer and communications technologies.
injection molding	shaping of metal, plastic or non-plastic ceramic shapes by injecting material into dies.
inoculation	introduction of disease agent into animals or plants to produce mild form of disease and render individual immune.
insulin	protein pancreatic hormone that stimulates cell growth by controlling blood glucose levels (insulin deficiency leads to diabetes); used to treat diabetes.
integrated circuit	(see *IC*)
interferon	cellular protein important in immune function and thought to inhibit development of virus in cells; used to fight cancer and other diseases.

J

joystick	lever used to control movement of display elements or to enter coordinate data manually on computer screen.

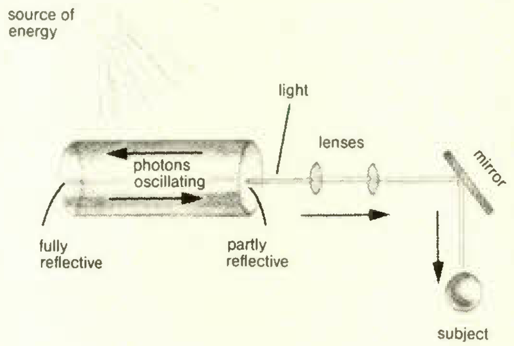
K

Kevlar	trademark of Du Pont Co.; an aramid fibre with light weight, high strength and stiffness, and stretch resistance.
knowledge processing	processing of knowledge using computer techniques.

L

LAN	local area network—communications system for linking several information processing units together at high speed over limited distances.

laser — light amplification by stimulated emission of radiation—device that produces high-intensity light; unlike light from conventional sources, laser light is coherent (i.e. light waves are in phase) and of a single colour/frequency (see also *maser*).



laser disc — (same as *optical disc*)

laser printer — super-fast electrostatic printer that uses a laser to create character images as dots of static electricity; dots are converted to printed image using metallic dust and heat process.

laser scanner — device used for reading and recording data.

LCD — liquid crystal display—electronic display device comprising liquid crystal hermetically sealed between two glass plates; crystals can be switched from opaque to transparent state to display data.

LED — light emitting diode—small, coloured, solid-state device that glows as electricity passes through it; used for numeric displays and indicator lamps.

machine language — instructions intelligible to computers; not normally comprehensible to untrained persons.

M

machine vision (or computer vision) — machines that can "see" by interpreting visual sensory input, often by number-coding points on grid to represent either light-intensity or distance values.

mainframe — originally used to describe racks (frames) holding CPU and memory of large computer; now commonly used to describe any large computer.

MAP — Manufacturing Automation Protocol—new industry standard allowing robots, NC machine tools and automatic guided vehicles to talk to each other and to host computer over coaxial cable.

maser — microwave amplification by stimulated emission of radiation; similar to laser, but emits coherent radiation at microwave frequencies; one of main uses is in ultra-precise time clocks.

materials processing/handling — transferring of materials from inventory to processing stations and from station to station.

memory — the part of a computer into which data can be entered, stored and retrieved.

menu — list of options from which users can select the task they want the program to perform.

microbiology — biology of micro-organisms, especially how they affect other forms of life.

microchip — (same as *chip*)

microcomputer — small computer built around a microprocessor.

microelectronics — branch of electronics dealing with extremely small electronic components.

micromechanics — mushrooming field that exploits the mechanical as well as electrical properties of silicon and other materials such as gallium arsenide and ceramics; widely used for monitoring air pressure in cars; applications as microsensors—smaller than the diameter of a human hair—for measuring sound, temperature, gas flows, acceleration, etc.

micro-organisms — single-celled organisms of microscopic size, e.g. bacteria, yeasts, viruses, fungi and algae.

microprocessor — single integrated circuit that is main controlling element of microcomputers; performs similar functions to central processing unit of large computer.

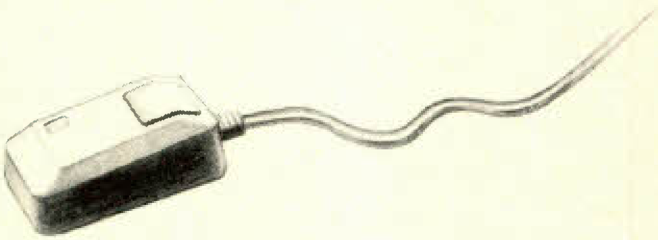
microwave — very short electromagnetic wave, particularly one with wavelength between 1 and 100 cm.

minicomputer — small- to medium-sized computer; can usually execute several programs concurrently.

modem — modulator-demodulator—device used to send and receive digital data over telecommunication lines.

monoclonal antibodies (mabs) — homogeneous antibodies derived from single clone of cells; they recognize only one chemical structure.

mouse — hand-held device that rolls around a computer desk; used instead of typed commands to operate computers.



N

natural language processing — use of natural languages such as English rather than computer languages such as FORTRAN or BASIC to program computers.

NC (numerical control) — use of numerical commands to control machine tools and similar equipment automatically.

network — set of interconnected computers that can exchange information over long distances.

nitrogen fixation — conversion of atmospheric nitrogen to compounds essential to growth; only limited number of micro-organisms can fix nitrogen.

node — in data-communications network, a point where one or more functional units interconnect transmission lines.

O

on/off line — describes whether or not peripheral equipment (e.g. terminal) is in direct contact with computer's central processing unit.

open communications — software that allows incompatible computers to talk with one another and with robots and NC machines on the shop floor.

open computer software — software that allows programs from incompatible computers to be transferred from one computer to another.

operating system — master control program that supervises operation of all other programs.

optical disc — high-density computer storage that uses lasers to read and record information, e.g. audio, video, data.

optical fibre — very thin flexible fibre, usually pure glass, through which light signals travel; can carry much more information than traditional copper wire.

optical reader — device that uses optical techniques to read data from card or document.

optical scanner — device that optically scans text or graphics and generates digital representations for computer processing.

opto-electronics — use of devices for transmitting and converting electrical signals to optical signals, or vice versa.

P

PA — programmable automation—PA tools differ from conventional automation in their use of computer and communications technology; can perform information processing as well as physical work, be programmed for a variety of tasks and communicate directly with other computerized devices.

peripheral — device separate from central processing unit that can be connected to and controlled by computers, e.g. printers, plotters, keyboards, joysticks, graphics screens, discs and tape drives.

pesticide — substance used to destroy or repel insects and other pests.

pharmaceuticals — medical products intended for use in humans, e.g. diagnostics, drugs and vaccines.

photon — quantum or unit particle of radiant energy; has indefinite lifetime, no mass and no electric charge.

pixel — picture element–individual dot on computer display screen.

plastics — materials formed through application of heat, pressure, or both; before final fabrication of plastic products, most materials exhibit more or less plasticity.

plotter — device used to make hard copy of image stored in computer.

polymer — substance made of very large molecules formed by union of many simple, chemically linked molecules; naturally occurring polymers include cellulose and proteins; plastics, concrete and glass are synthetic polymers.

R

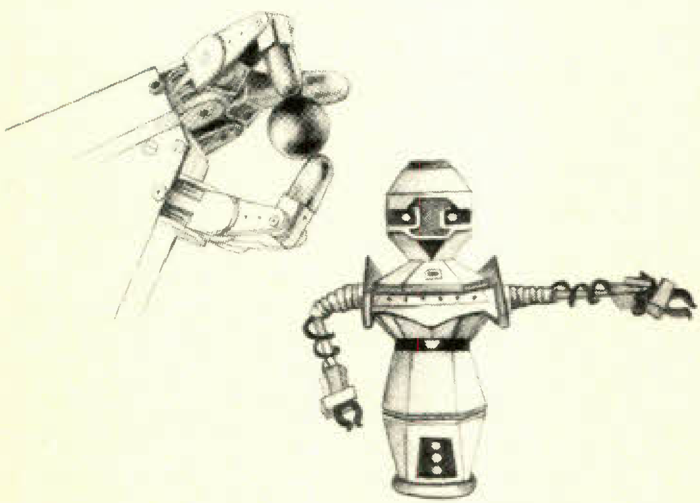
RAM — random access memory–main memory of computer, from which data can be stored and retrieved directly without user having to work through from beginning; its contents are held temporarily.

real time — the actual time in which events (e.g. computer data entry) take place; an event is recorded simultaneously with its occurrence.

recombinant DNA — joining of DNA from different organisms; allows genetic material of cells to be manipulated.

rhizobium bacteria — type of nitrogen-fixing bacteria capable of forming nodules on roots of leguminous plants such as clover and beans.

robot — machine that can automatically do tasks normally controlled by humans; mostly used to perform repetitive tasks on assembly line.



S

T

ROM — read only memory—memory chip that permanently holds instructions or data and cannot be modified; used to control and execute computer programs.

semiconductor — material whose electrical conductivity falls between a conductor (e.g. metals like copper) and an insulator (e.g. glass).

sensor — device whose input is a physical phenomenon (e.g. light, heat, pressure) and whose readable output is a quantitative measure of that phenomenon.

shell — an expert system without a knowledge base; simple shells usually include user interface, inference system and software tools for entering expert knowledge.

silicon — most abundant element next to oxygen in the earth's crust, occurring naturally in compounds such as sand; the semiconductor widely used in integrated circuits.

Smart Card — type of credit card still under development that will contain small computer chip; will allow data from other credit cards to be stored and transactions to be automatically deducted from credit limit; also called integrated circuit card (ICC).

software — programs that run on a computer; they instruct the hardware in performing tasks.

solid-state device — electronic device made of solid material, with no moving parts; e.g. transistors, chips.

synthetics — substances or products made by chemical synthesis.

telecommunications — transmission of signals over long distances.

teleconferencing — a way of having a conference with people in distant locations using telecommunications links; main types are computer conferencing and video conferencing.

teletext — way of broadcasting information as part of normal TV signal; with decoder and keypad, viewers can select electronic pages of text and graphics.

Telidon — Canadian videotex system.

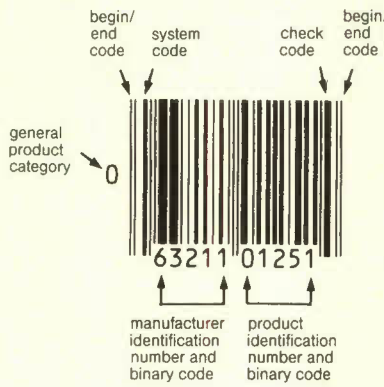
touchscreen terminal — terminal with screen sensitive to touch; computer can be controlled by touching positions on the screen.

transponder — device that receives and transmits data; signals can be retransmitted at different frequencies.

turn-key — complete system sold in ready-to-use state, including all hardware and software needed for particular applications.

U

universal product code — a bar code attached, by international agreement, to most consumer products and used to identify and describe them; can be read by optical scanner at time of purchase and the information can be used to produce automatic receipts and to record transactions.



V

VDT — visual display terminal—device equipped with cathode ray tube that displays information visually; generally connected to a keyboard for entering and editing information; often used as synonym for VDU (visual display unit).

videodisc — disc that contains recorded sound, text, graphics and/or moving pictures for playback on TV or computer screen; read by laser scanner.

videotex — system that allows two-way communication with a computer; users can retrieve text and graphics stored in a data base by pushing buttons on a keypad or pressing a touchscreen terminal.

vision system — ability to scan items and determine where they are; system's logic tells a robot what to do.

VLSI — very large-scale integration; VLSIs are integrated circuits with at least 64 000 bits of memory.

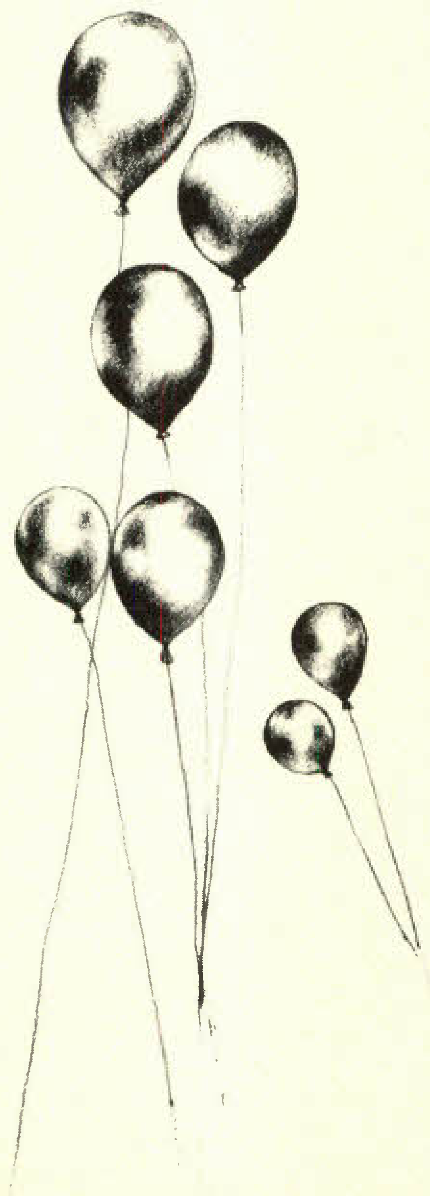
EI	employee involvement—EI programs provide regular means of giving employees information, obtaining feedback and involving them in problem-solving.
ESOP	employee stock ownership plans—these enable companies to allocate stock to employees, usually based on salary or seniority.
flexitime	way of organizing working time that allows workers to come and go as they choose, within certain limits, as long as they work a prescribed number of hours each week.
gains-sharing	schemes that allow workers to share the gains from increased productivity by earning a bonus; they include Improshare and the Rucker and Scanlon plans.
industrial democracy	may take the form of labour participation in national economic planning or on boards of directors, or of workers asserting their rights and responsibilities through more conventional means like collective bargaining.
just-in-time (JIT) inventory management	reduction of inventory levels through delivery of parts to assembly line as needed.
organizational effectiveness	umbrella term that covers numerous workplace innovations (e.g. QWL, STS, EI and gains-sharing) that emphasize human needs while improving productivity.
participative decision-making	schemes used to tap workers' expertise and provide sense of commitment; they run the gamut from outright worker ownership of the enterprise, through representation on the board of directors, to opportunities for information exchange.
pay-for-knowledge	approach to remuneration that supports concept of multi-skilling; workers are encouraged to learn to perform variety of functions, and the more they learn, the more they are paid.
quality control (QC) circles	small groups of employees, engaged in day-to-day operations at the plant level, that help identify production problems, devise plans for solving the problems and help put solutions into practice.
QWL	quality of working life—takes into account not just hours and pay but opportunities for fulfilment and satisfaction associated with working, e.g. how jobs are designed and remunerated, and job satisfaction through involvement in decision-making.
semi-autonomous work groups	work is organized so that groups take major responsibility for decisions such as hiring, workflow, scheduling and quality control.
SPC	statistical process control—use of basic statistical concepts to monitor how consistently products fit engineering specifications.

STS

socio-technical systems—approach to working that explicitly incorporates needs of both technical and social (human) aspects of organizational design.

venture team

team of workers formed to "buy" an innovation from an individual or section in an organization and to bring that idea to the commercialization stage.



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