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Applications of Microelectronics in a Canadian Context

report

rapport

Applications of Microelectronics in a Canadian Context

Ministry of State for
Science and Technology,
Industry Branch,
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Alain Letendre

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OBJECTIVE

The objective of this report is to identify key areas of microelectronic technology which would be most appropriate as possible "core technologies" for Canada.

BACKGROUND

Since the invention of the electron tube, electronics has invaded every aspect of our everyday life. With the advent of microelectronics, this development has simply exploded: computers are found in the classroom, the type-writer is being replaced by word-processors, events happening on the other side of the earth are seen instantly on television sets.

A number of factors will increase the rate of diffusion of microelectronics. First, microelectronics permit the introduction of many more functions at a much lower cost than mechanical or discrete electronic parts. Second, microelectronics could be instrumental in sparing energy and materials.

The potential applications of microelectronics are so numerous as to give free rein to the imagination: the domestic robot, the wired city, the electronic cottage, all technologically feasible.

A previous report on microelectronics published by the Ministry of State for Science and Technology described the enormous importance of microelectronics' applications in the 1980's.

In fact, while the trade balance for electronics in Germany, United States and Japan is positive and increasing, this same balance has been negative in Canada (Fig. 1) and it can be expected that the trade deficit will increase.

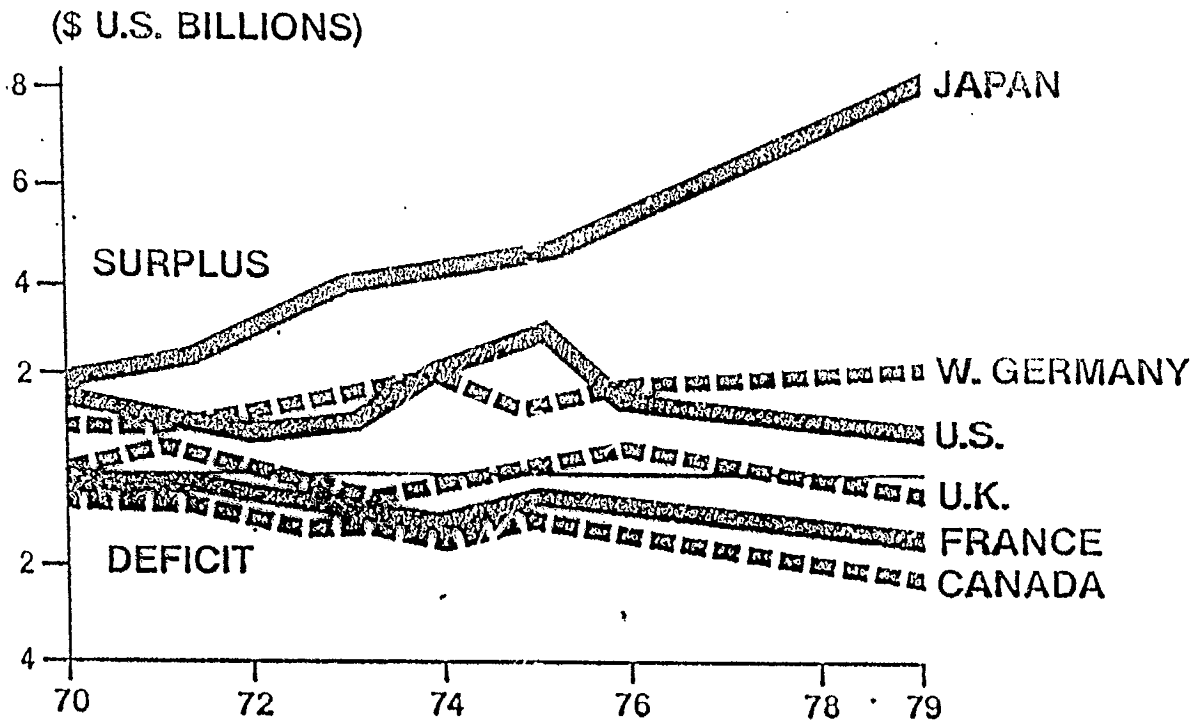

Fig. 1. Electronic Balance of Trade
(Source: Microelectronics - Canada at the Crossroads, Conference given by Mr. K. Revill to the Interdepartmental Committee on Future Studies, December 5th, 1980)

USE OF THE TECHNOLOGY

This report retained five broad classes of applications: communications, data processing, office equipment, robotics, and miscellaneous products incorporating microelectronic elements.

All these fields intermingle. As an example, communication technology is the basis of the office of the future. When a topic was common to more than one field of application, it was arbitrarily assigned to just one of these broad fields to avoid duplication.

For each of these broad classes, the development of technology was analyzed, Canadian expertise was surveyed and market projections were gathered from diverse litterature sources. Specific applications were then choosen in fast growth markets, either to counteract threats on the Canadian economy or to take advantage of opportunities offered, particularly where Canada shows strong leadership.

COMMUNICATIONS

Communications are an essential aspect of the information technology. Telephones, television, computers networks, electronic mail, and electronic fund transfer are all dependent on communication technology.

In its submission to the Consultative Committee on the Implications of Telecommunications on Canadian Sovereignty (Clyne Committee), the Science Council of Canada emphasized Canadian technological leadership in fibre optics, satellite technology, and interactive terminals.

In addition, Canada has the most advanced telecommunications networks in the world and new services are evolving at rates unthinkable only a decade ago. The next decade will witness the emergence of new services like interactive terminals (Telidon), facsimile terminals, electronic mail, and many other devices, all fitted in their own premises and operating over the public telecommunication networks. The technology to provide those services is becoming available and the main constraints on further development will be - what do customers want and how much are they prepared to pay?

Microelectronics has had a huge impact on communications.

First, it reduced the cost of communication equipment: on terminals to provide the interface between people or machines and communication channels; on switching machines which establish the link; and, on the equipment that processes signals so that they can be transmitted. Second, microelectronics improved the reliability of communications because chips are less subject to failure than discrete transistor. Finally, by reducing the size of equipment, microelectronics was an important factor in the development of satellite telecommunications.

The communication industry is the Canadian electronic industry. In 1979, sales of communication equipment represented a value of \$ 2.5 billion or 46% of total electronic sales. In this sector, 76.4% of the Canadian market was satisfied by domestic shipment and communication equipment was our biggest export of electronic products.

Canada is recognized as a world leader in telecommunications. The industry is dominated by Northern Telecom (which had sales of \$ 1.9 billion in 1979) but smaller companies can compete successfully on this market as Mitel has shown (Fig. 2). There will be very good opportunities for Canadian compagnies as world market is forecast to soar from \$ 33 billion in 1977 to \$ 82 billion by 1990 for telecommunication equipment. (1)

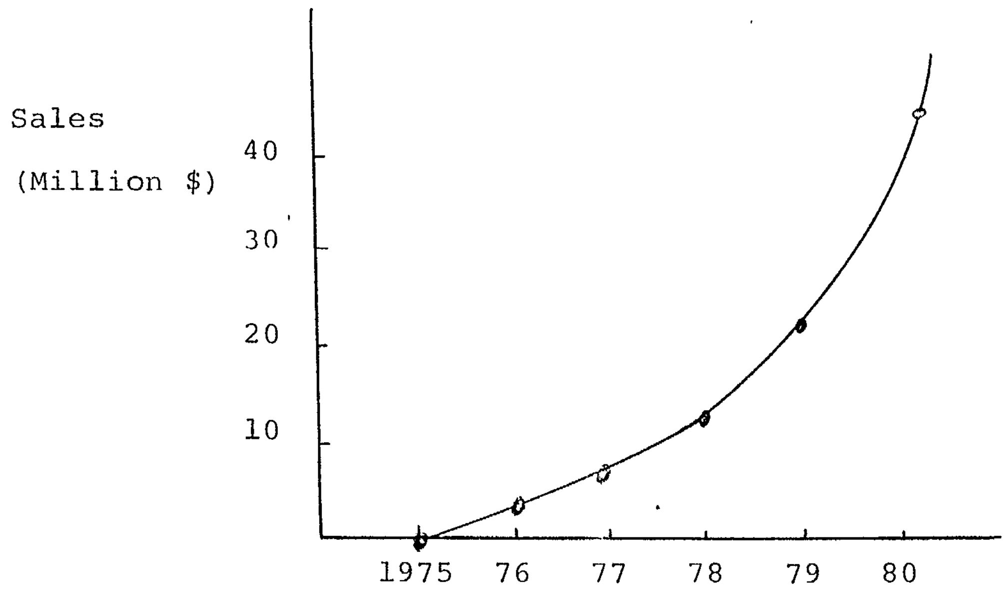

Fig. 2 Growth of Mitel Corp.
(Source: Mitel Annual Report)

Communications will be flooded with new products: echo-cancellers on a chip, intelligent telephones which remember frequently called numbers, electronic switchers to forward calls automatically, mobile terminals and many others. Some of these products already exist and will be made cheaper, smaller and more efficient with micro-electronics, others will be completely new products. Some of these developments require special consideration: fibre optics, communication satellites, Telidon, data communication equipment and electronic funds transfer.

FIBRE OPTICS

Fibre optics can best be described as small glass fibres which can trap a light beam entering one end of the fibre and carry it to the other end. By modulating the light beam, information could be carried on it the same way information is carried by electricity in copper wires. Fibre optic communication systems have been included in this section because they will necessitate sophisticated electronic circuits to code, to emit, to receive, and to decode the signal.

Fibre optics have big advantages over coaxial cable links: wide bandwidths, lack of crosstalk (where a signal on one line is overheard on an adjacent line), immunity to inductive interference, and ability to deliver many more signals at much lower cost than conventional cable links. Other advantages are their smaller diameters and lower weight.

The Canadian communication network is now reaching its limits: available and cheap communication band-widths are in short supply. Fibre optics could be the solution to this impass. In addition, because of their potentially low costs and wider bandwidth, they could handle digital communication advantageously.

Projections indicate that markets for fibre optics will develop very rapidly over the decade and beyond. Sales of electro-optical transmission equipment (a combination of fibre optics and microelectronic chips) could be worth about $ 670 million by 1985 and nearly $ 2 billion by 1990. [(2)] These projections only describe markets within industrial countries where networks are already well established and where fibre optics will be gradually introduced. The world market may prove to be much larger.

Fibre optics will likely replace conventional equipment in the following areas of transmission equipment: telephone, cable television, satellite ground terminal, industrial automation, computer, and military transmission systems.

Current centres of expertise in the manufacturing or use of fibre optics are Northern-Telecom, Canstar Communications (Division of Canada Wire and Cable Company), Foundation Electronic Instruments, Imapro, Madsen Electronics, etc...

This market could offer an unparalleled opportunity for the Canadian telecommunications industry. Canada being a leader in this emerging technology, this opportunity must not be lost.

COMMUNICATION SATELLITES

After two decades of development, satellites have greatly improved terrestrial communication systems, by increasing the quality and reducing the cost of global telecommunications.

Satellites present many advantages in the Canadian geographic and demographic context: they are indifferent to geography and distance which are a source of additional cost and noise in terrestrial systems; they are more efficient than terrestrial networks for point-to-multipoint services and for direct broadcasting; they have a greater information carrying capacity and a greater flexibility due to the higher bandwidth and the lower noise.

Some factors are limiting the development of satellite telecommunications: the spectrum is becoming crowded and available orbits are being filled. Even though there is physically ample space for a very large number of satellites on geosynchronous orbits, there is a limitation on the spacing between satellites: the spacing is dependent on tolerable interference from earth stations illuminating adjacent satellites and from satellites illuminating other earth stations.

Future development will be in data compression to reduce the bandwidth, new modulation techniques will increase the capacity of a given channel for transmitting digital data, and higher frequencies will be used which will permit the use of smaller and cheaper ground station antennas.

Since cost is important and is directly related to the size and weight of the electronic components, micro-electronics was a driving factor in the development of satellite communication networks. In addition, without the reliability of integrated circuits, it would have been almost impossible to make viable satellite systems. The present trend to higher complexity in chips will accelerate the development of those systems by reducing costs and by improving capabilities.

In addition to broadcasting, remote sensing and data transmission, those networks will be used for medical, educational and social services, tele-conferences, and electronic mail.

World sales of small earth terminals should increase at an average of 20% a year to reach a value of $ 150 million a year by 1986 and sales of peripheral equipment are expected to be about $ 50 million at the same date. (2) Canada has many companies with a high level of expertise in this field: Canadian Astronautics, COM DEV, DIPIX Systems, Imapro, MacDonald Dettwiler and Associates, Miller Communications Systems, NORPAK, SED Systems. Those companies have a high level of expertise and are technological leaders in some fields like image processing.

TELIDON

In order for information systems to reach their full potential, there must be a proliferation of simple-to-use terminals at a cost within the reach of the average Canadian.

Britain, France, Germany, Japan, and Canada have begun field trials of interactive computer-based information systems called videotext. These systems connect subscribers to computer data bases to retrieve stored information. The system uses a television set as a display.

In August 1978, the Department of Communication announced the introduction of a second generation system, called

Telidon. It can provide subscribers with a wide range of information including anything from entertainment information to airline schedules. It could also be used to calculate budgets, to store private data, or to play computer games. The next generation of Telidon terminals could provide direct terminal-to-terminal communications, electronic mail and electronic newspapers.

Telidon is much more advanced than competitors' products. It can present graphics in a wide variety of colours with a tonal range and resolution unmatched by foreign systems. Another plus of the Canadian system is that the way of storing information is independent of the communications media or the receiving hardware so that terminals will not become obsolete.

As integrated-circuits become more powerful, the price of those terminals will drop appreciably so that Telidon terminals could be as common as television receivers and telephone sets in a not so distant future. The market would be enormous, (possibly some $1 billion over the decade in Canada) but its growth will depend on the ability of information suppliers to anticipate users' needs.

DATA COMMUNICATION EQUIPMENT

Today, computers can communicate between themselves and to distant terminals. Tomorrow, with the development of electronic mail, Telidon and other data, text and picture tele-transmission, the market for data communication equipment should grow at some 20% a year.

There is presently a booming demand for multiplexers (e.g. Gandalf Data Communications), front end processors (e.g. Cableshare), network controllers (e.g. Hitech Canada), and modems (e.g. Gandalf Data Communications).

Most data communications are carried on leased lines which are selected for their quality, and which enable higher transmission rates. The digital information is modulated, transmitted, and finally demodulated. Canadian modems (modulator-demodulator) are among the best in the world but this market is threatened by the emergence of digital data-communication networks (which are less noisy and less subject to crosstalk) and by VLSI chips permitting the modem to be built into terminals.

As for front end processors (interface between communication system and information processing system), telephone companies are threatening to move the front end into the network itself and PBX (Private Branching Exchange) suppliers (e.g. Mitel, Northern-Telecom) are designing PBX systems that can serve as front end processors.

Digital multiplexers will represent an exploding market with shipment value almost tripling during the current decade. This could be an opportunity not to be missed by Canada.

ELECTRONIC FUNDS TRANSFER (EFT)

EFT system refers broadly to any electronic system used to implement financial transactions. As such, EFT has been with us for some time. Some companies send a magnetic tape containing payroll information to the computer of a designated bank and have the accounts of their employees automatically credited. Multi-branch banking uses an on-line computer to allow one branch to alter accounts held in another branch. "Money machines" available on a 24-hour, 7-day basis, permit users to make certain transactions without actually going into a bank.

Some forecasters are predicting increases in the prevalence and use of EFT. They go as far as saying that we are entering the era of the "cashless society". Cards, or some other form of identification would be used in all transactions in the place of money. Analysis of these claims suggest that they may be premature.

In fact, customers might refuse to lose their cheque book float which is the extra cash at their disposal until cheques are cleared and the account debited. It was found that customers make heavy use of float especially during holidays and weekends. Cheques also represent the advantage of offering a stop payment facility should the consumer wish to cancel a transaction. On the other hand, the cost of handling money and of processing cheques, and the wider use of credit cards, will push toward deployment of EFT.

Predicasts (USA) has predicted that sales of teller machines, automated tellers, retail electronic funds transfer and point-of-sale terminals will surge from $ 995 million in 1978 to over $ 2 billion by 1990, (3) but Canada has no industrial capacity in EFT.

SWITCHING SYSTEMS

In recent years, manual switchboards connecting office telephones to public trunks have been increasingly replaced by computer-controlled Private Branch Exchange (PBX). These can forward calls, remember frequently called numbers, redial numbers when the line is busy, and choose the least costly line for long-distance calls.

A new trend is emerging with PBXs which can handle telephone calls, data processing and word-processing communications because one network is used instead of two.

This market will certainly grow 15 to 17% annually over the next several years. With 54% of the total market, AT & T dominates this sector but Canadian companies show good performances: Northern Telecom has 10% of the market and Mitel, 4%. (4) Considering the growth of this sector and Canadian expertise, PBXs represent a good opportunity for agressive Canadian companies.

CONCLUSION

Tomorrow's society will be characterized by an explosion in communication technology * which will include electronic mail, electronic funds transfer, teleconferencing, computer networks, satellite telecommunications, home information retrieval systems and others. Canada is recognized as a world leader in communication technology so this sector should be a priority in a Canadian microelectronics strategy, particularly in switching systems, digital multiplexers, fibre optics and small earth terminals, and peripherals for satellite telecommunications. A word of caution should be added: Canadian success, abroad, might be limited to some extent as foreign governments tolerate non-tariff barriers.

*Arthur D. Little estimates that the world will spend $ 640 billion on telecommunication equipment over the decade.

COMPUTERS

Today, it is impossible to find any task which requires the processing of large amounts of information that is not performed by a computer. As microelectronics has increased the performance of computers, shrunk their size and reduced drastically their price, lesser tasks are also being handled by computers. Those factors have been even more important for the development of mini and micro-computers.

All computer systems, regardless of their size, consist of four basic elements: input-output ports, memories, a central processing unit (CPU) and peripherals. In the present section, the last three will be analyzed.

CENTRAL PROCESSING UNIT (CPU)

The principal impact of microelectronics on the CPU was to greatly improve performance because smaller devices are inherently faster than larger ones: the current can switch them faster because of their lighter load. As an example, the time required to execute an operation, for a mainframe computer, has dropped from 150 nanoseconds in the early 60's to 5 nanoseconds today.

Microprocessors have taken over the CPU and helped to develop new architectures. Arrays of microprocessors now replace the complex circuitry of the past. In some design, microprocessors are assembled one after the other and each one performs an operation on the data before transferring the results to the next processor like an assembly line. Another design consists in an array of microprocessors: all the microprocessors do identical processing on many data. Some microprocessors perform special functions like instruction fetching, control of the arithmetic logic unit, ...

There is a trend today toward distributing the processing of some information throughout the computer system to bring some relief to the CPU. Today, we have "intelligent" disk drives, "smart" terminals, ...

MEMORIES

The general principle of storage is to "write" data electrically or magnetically in a specific physical location in the memory which can be addressed the same way a word in a book can be specified by a page and a line number.

Data storage is an area of compromises: fast storage is expensive and cheap storage is slow. As a consequence, systems are designed with a hierarchy of storage media ranging from very high speed semiconductor memories to high-volume moving head discs and archival storage such as magnetic tape.

The technology of digital storage is the most rapidly changing sector in all microelectronics. In electronic memories, because of the regularity of the storage array, cell design can be optimized and very high component densities can be achieved. State-of-the-art memories have presently a capacity of 64K bits and Japaneses are rumored to have an experimental 256 K memory.

The most widely used memories are random-access memories (RAM's) where data can be written or read at any location. The computer market has an insatiable thirst for RAMs so that those memories always serve of proving ground for latest developments in microelectronics.

As the storage capacity increases, more on-chip logic will be incorporated to give a more powerful interface: multiported operation, error detection and correction, access by name rather than address.

Estimates for RAMs demand differ considerably but the lower figures still forecast a growth rate of 50% a year: The market for RAMs is literally exploding (see Fig. 3).

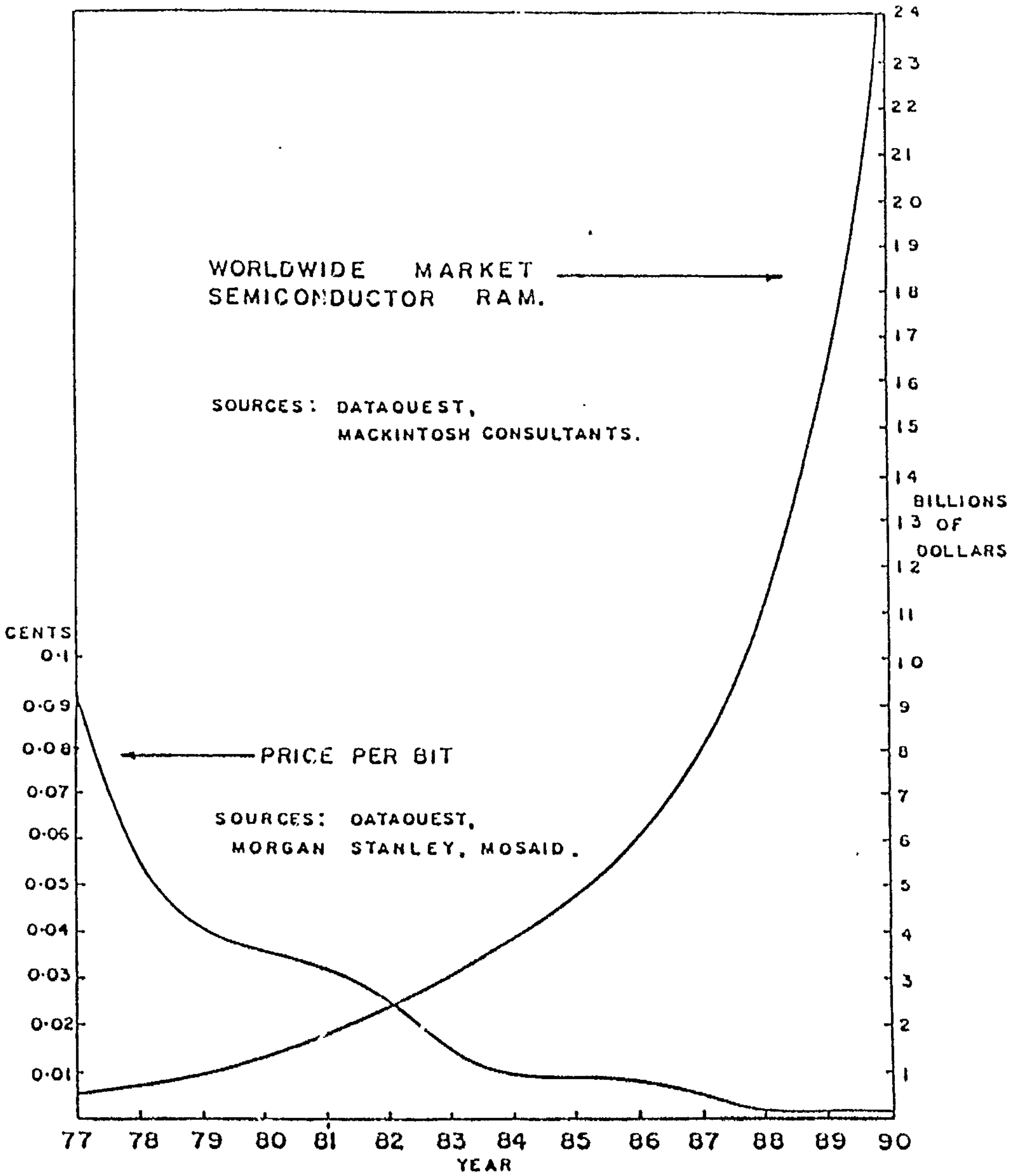

Fig. 3. Forecast of RAM market and prices

Source: <u>VLSI MOS RAM Market - Status and Future</u>

published by MOSAID INC.

Another kind of memories are read-only memories (ROMs) where the information is permanently stored when the chip is manufactured. Since they are designed for specific applications, series are small. ROMs are used to provide the control programs in pocket calculators and in microprocessor-driven appliances, to store programming languages in microcomputers, ... The market for ROMs should then be closely related to the market of microprocessors. The Dutch Advisory Group on Microelectronics forecasts that sales of microprocessors would soar from $ 470 million in 1978 to $ 6 billion in 1990. (1)

Canada has a design house which is widely recognized by the industry, Mosaid Inc., but no manufacturer of memory chips. Unfortunately, the entry cost of a manufacturing facility is in the order of $ 70 million and technology is moving so rapidly in memories that huge investments are necessary just to follow the current.

Magnetic storage devices work on the same principle as a common tape recorder. Although magnetic storage devices cannot be considered microelectronic, microelectronics is fruitfully applied to improve their performance. Microelectronic fabrication technology is helping to shrink the size of heads by appropriate deposition of magnetic materials and metal windings. The resulting heads are cheaper and extremely lightweight. They yield higher bit densities on the recording surface and they can support very high data rates. Microelectronics permit also the implementation of error-correcting codes in the system. Fixed-head discs and drums are being replaced by moving head storage now that a single spindle stores over half a billion bytes.

The charge coupled device (CCD) is a long string of MOS* transistors coupled together to form a chain. A charge placed at one end of the chain is passed from one transistor to the next until it reaches the end at which time it is placed back into the beginning of the chain. Information can be stored on such a device by placing (or removing) charge from this endlessly looping cycle of "charge positions". Storage is much like a message written on a loop of paper which is rotated around to be read over and over again. Like CMOS*, CCDs work on the principle that a moving charge is maintained with much less power than a static charge. Moreover, CCDs can get extremely high packing densities. The primary application of CCDs is in non-volatile memories for computers. Such memories could be portable (like books) since they could operate from batteries.

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* MOS: Metal Oxide Semiconductor
CMOS: Complementary Metal Oxide Semiconductor

Bubble technology is one of the few technologies that uses something other than micro-transistors in its design. Bubble memory operates like magnetic tape in that messages are recorded by having regions of opposite magnetic polarity imposed over a background of uniform polarity. These small domains of opposite polarity are called "bubbles".

Bubble memories use a magnetic film on orthoferrite or garnet to get a background of uniform polarity magnetic field. Unlike the field on magnetic tape, the field in bubble memories can flow in closely controlled patterns so that the bubbles move around (they fizz). As they move along in their patterned flow, they can be read by electronic circuits. The main disadvantage of such devices is that they require a permanent magnet, coils, and a controlled magnetic field. This presents serious packaging problems. Their significant advantage is that memory is retained when power is turned off. While CCDs and bubble memory cannot compete with normal semiconductor memories in terms of speed of operation, they may eventually serve as a replacement for tapes and discs in some applications.

Superconductive tunnel junction devices exploit the ability of electrons, under certain conditions, to penetrate (tunnel) through energy barriers which would stop them under normal conditions. To perform this feat, the circuits using them must operate at temperatures near absolute zero. This requires them to be immersed in liquid helium - a definite operating disadvantage. Their advantage is that they are compact and extremely fast. It is expected that Josephson memory cells, which use superconductive tunnel junctions, will be 10 to 100 times faster than today's fastest memories. Still in early development, such circuits are expected to find applications only in the next generation of large, powerful computer systems but Canada has no industrial base in this field.

Reel-to-reel and cassette tape have no long-term growth potential since they will eventually be replaced by floppy or hard discs and bubble memories.

The floppy disk (or flexible disk) and bubble memory are likely to emerge as the most popular magnetic media. Today's $ 2 billion market for rigid disc drives could drop by an order of magnitude during the decade to be replaced by floppy disks.(6) Floppy disks could represent a good opportunity for Canadian companies like Cremanco Systems, Dynalogic and Innovative Computers Systems.

On the long term, the continued development of semi-conductor storage will enable it to replace low-cost magnetic media.

PERIPHERALS

Peripherals include all ancillary equipments necessary to fully use computers: external memories (see above), data entry and data output equipment.

Old methods of data entry, keypunch, card reader, and paper tape punch/reader, are in serious decline. They will be replaced mainly by keyboards. This market grows presently at a yearly rate of 15 to 20%. Keyboards make up an estimated 18% of the total data entry market. This percentage will have jumped to 46% by 1988. (6)

To bridge the gap between massive past investments in nonelectronic data entry devices like typewriters and to improve efficiency, optical character reading systems (OCR's) will grow at a rapid rate, particularly in word processing. Voice recognition may take over but this is only expected in the longer term.

Video terminals should account for a major share of the market before the end of the decade and, in the longer term, they could virtually eliminate the use of paper as a medium for information representation. The display of present terminals raises difficulties with lighting and reflections, reading of the characters becomes tiring after a time, the picture is not completely stable, ... New developments like flat panel plasma displays should improve the acceptance of video displays. Because of microelectronics, "intelligence" is becoming so cheap that the market for "smart" terminals should develop quickly in the 1980's: they were representing 15% of the data output market in 1978, but they will take 28% of this market in 1988. (6)

Printers are a market which is expanded rapidly by numerous technologies: laser, ink jet, xerographic printing. The demand will be for low cost, letter quality intelligent printers for small businesses. With newest developments in microelectronics, another interesting sector will be teleprinters which will see their share of the data output market double to reach 21% of this market by 1988. (6)

With developments in microelectronics, it could become attractive for computer manufacturers to incorporate their operating systems into the hardware, thus preventing plug-compatible companies from producing equivalent products and locking users to manufacturers more rigidly. If this happens, it will seriously threaten terminal manufacturers.

Canada has quite a few manufacturers of terminals (e.g. Comterm, Cremanco Systems, Goodwood Data Systems, Norpak, etc...), optical character readers (e.g. Hitech Canada, Leigh Instruments), printers (e.g. Comterm), floppy disk drives or controllers (e.g. Cremanco Systems, Dynalogic, Innovative Computer Systems), and at least one company involved in bubble memory subsystems: Dynalogic.

THE SMALL COMPUTER REVOLUTION

As shown by Fig. 4, the computer market will still be strong during the next decade. The fastest growth will be in shipment of minicomputers (including micro-computers): today's sales of $ 3.5 billion will increase to some $ 50 billion in 1990. (7)

In this group, the "home" or "personal" computer is reorienting itself to business applications such as general bookkeeping, financial projections, word-processing, ... In fact, 80% of Radio Shack's TRS-80 sales are for the small business market.

A number of factors are responsible for the trend towards minicomputers. First, microelectronics have cut prices so drastically that they now range from $ 1,000 for a minimum microcomputer to some $ 200,000 for a complete minicomputer system. Second, simple languages like BASIC make it possible for non-professionals to write their own programs. Third, the gradual build-up of libraries

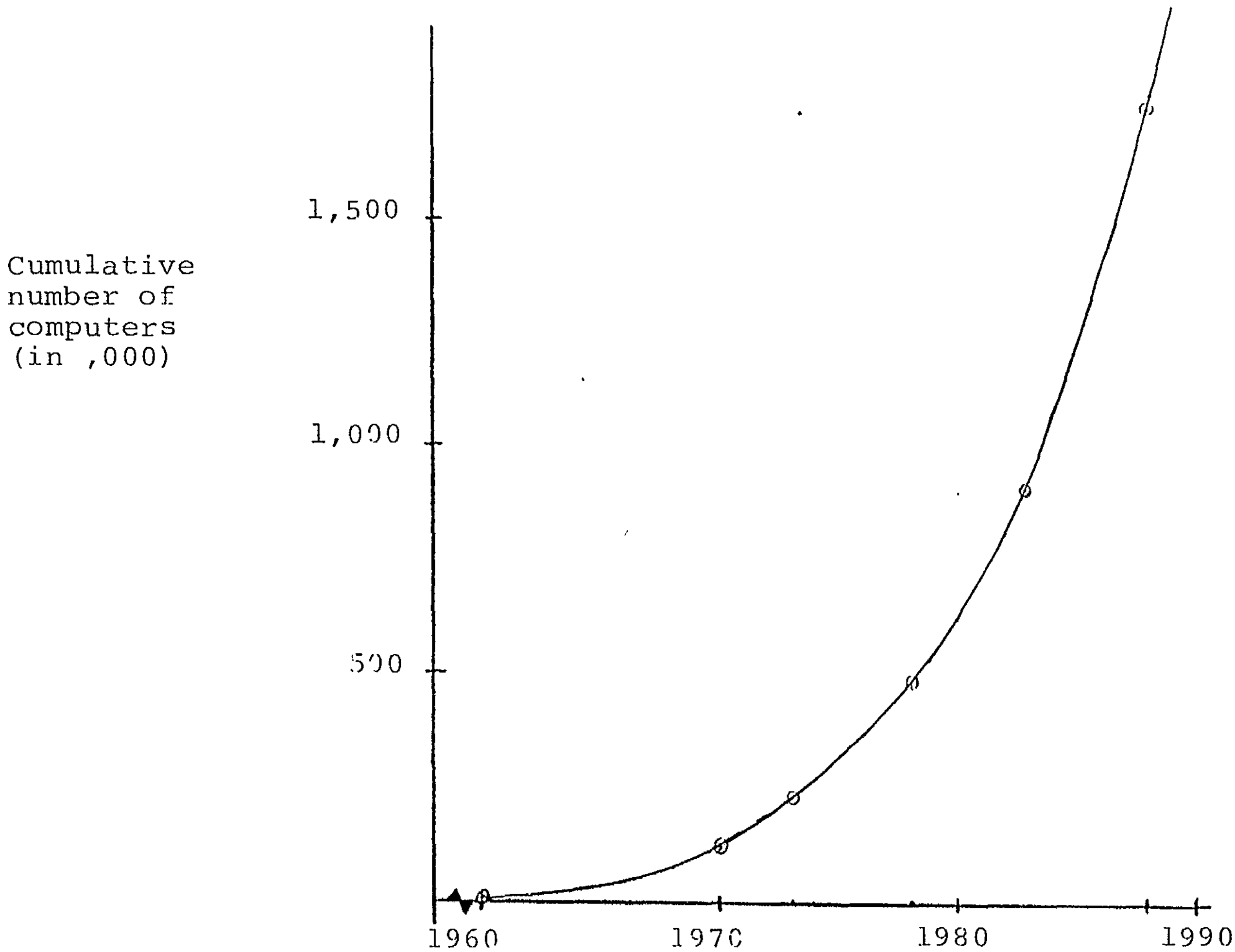

Fig. 4 . Cumulative number of computers, 1960-1988
(Source: <u>The Impact of Microelectronics</u>, p. 52)

of programs has widened the field of computer applications. This factor is important as no programming expertise is to be found in small companies. It was seen in a previous section that word-processors have been a fast growth market but they could be threatened in some market segments by small personal computers used both for word-processing and data-processing at a much lower cost than dedicated word-processors. In fact, according to Commodore, the most common business use of their PET computer has been for word-processing.

Up to now the most frequent use of mini-computers has been to link them to mainframes computers to ease the load of the bigger system, but future improvements in cost and in performance will increase usage of mini-computers in the standalone mode. In addition to small businesses, professionals, authors and freelance journalists and others could be a potential market for the smaller systems.

Canada has a wide base of mini and micro-computer manufacturers: Cremanco, Dylanogic, Geac Computer, Innovative Computer Systems, Matrox Electronic Systems, Megatel Computer, Volker-Craig, Zapsystems... Their sales account for only about 2% of the $ 2 billion a year

Canadian market. They have to face such giants as Data General, Digital Equipment of Canada and Hewlett-Packard, but they are coming with an innovative range of products. The market for small business computer systems will expand so rapidly that Canadian companies could have an opportunity to increase their share of the market.

COMPUTER SERVICES

A whole range of enterprises provide computer services: system houses, software vendors, and computing centers.

In the early days of computing, software was usually given away with the purchase of a computer. It was also freely exchanged between users. It is no longer the case as software costs now exceed those of hardware. Application software is now sold by hardware manufacturers, independant software companies, and processing services firms.

There is presently a trend to be discerned towards the use of standard packages for the routine aspects of business data processing like payroll calculations, stock control, ... There is also an emerging trend to provide "user-oriented" packages which permit non-specialists to use computers. As microelectronics drive down the cost of memory resources, new programming languages are appearing which are easier to learn but which use hardware more extravagantly. Eventually, some form of automatic programming could emerge.

The software products market can be expected to grow at 21% annually at least to the middle of the decade and the domestic market could reach a value of $ 1 billion by 1985. (8) The best strategy for Canadian companies would be to specialize in selected fields like resources as they are unlikely to compete effectively with American companies in general and standard applications like payroll programs.

System design is so intimately tied to the introduction of new computers that this sector should grow at a rate related to computer shipments. Part of this service will continue to be provided by hardware manufacturers. Canada has a wide range of system and software houses firms: Computech Consulting Canada, Digital Methods, Harrison Williams and Associates, Hitech Canada, T.P. Sharp Associates, and Systemhouse.

When computers were a very expensive piece of equipment, many data processing companies were created to provide time-sharing and remote batch processing. Hardware is becoming cheaper so that competition from newly established houses intensifies. This industry must face another threat: the invasion of mini-computers. On the other hand, the entire computer industry is confronted by a shortage of competent, trained personnel which is a serious constraint of the mini-computer revolution. The market of computing centers could grow at some 17 or 18% per year at least for the next few years. (9)

Canada has a strong base of computing firms (Computel, Dataline Systems, Canada Systems, Datacrown, IST,...) and very good communication capabilities provided by Dataroute, Datapac, and CNCP's Infopack.

The Canadian computer services industry is highly competent and is a world leader in technology. This sector is growing at a fast rate; it then represents a good potential for Canadian companies, particularly because it has a high percentage of Canadian ownership (79%) as opposed to the hardware sector (8.6%).

CONCLUSION

Sales of mini and micro-business computers are expected to increase at least ten-fold during the decade and demand of peripheral equipment (video terminals, optical character readers, printers, floppy disks, and bubble memories) for these systems should increase accordingly. This is a market at which Canadian companies could aim.

The Canadian computer services industry (system design, software vendors, and computing centers) is highly competent and is a world leader in technology. This sector is growing at a fast rate: it represents a good potential for Canadian companies.

OFFICE EQUIPMENT

For the last 10 years, average capital investments for the average blue-collar worker have been in the order of $ 25,000 while investments for the office white-collar were a meagre $ 2,000 which explains the difference in productivity growth between the two groups. These facts probably point to one of the reasons why productivity in services has been increasing less than in primary and secondary sectors. Over the next decade, investments in that sector might be at least five times higher than today.

Automation in the office is the natural consequence of the desire to increase productivity and efficiency.

WORD PROCESSING

With word-processors, a document can be electronically memorized. Subsequently, the typist can introduce corrections, additions, or can delete words or whole paragraphs before having the machine print the final copy. The word-processor can automatically paginate the document after having divided the text into pages of specified length, it can edit and merge different parts of the text to form a new document. It can sort and select files in numerical or alphabatical order which is particularly useful for manipulating address lists. Finally, some units have arithmetic and statistical capabilities to perform arithmetic tasks, print statistical tables, and complex equations. The text is automatically printed, simply displayed on a CRT screen for consultation or sent electronically to the other end of the country where a similar machine can print the text. Text processing has just entered the field of data communications, so that the future points to a growing participation of different technologies in establishing an integrated office environment: communications and computing.

Three developments have triggered the office revolution. First, manpower-related expenses rise every year. Second, the cost of word-processing equipment has dropped drastically in recent years. Third, word-processors can multiply by a factor 3 the productivity of a typist. As an example, if one wants to change the position of two paragraphs, an instruction is simply given to the machine ordering the permutation, rather than retyping the whole text.

Further clarification should be given about the price of equipment. Microelectronics development to LSI (and to VLSI during the next decade) by reducing costs per byte, has shrunk WP hardware costs from some $ 40,000 four years ago to $ 10,000 today. A variety of factors will prevent a further decline in price. The main factor is the increasing cost of software compounded to the shortage of qualified programmers. This cost will be counteracted by decreases in the cost of hardware, particularly in memories which are the proving ground of VLSI technology. If chip shortages happened, this would represent an additional factor in price stabilization.

Future word processors, for the same price, will be equipped with more capabilities and new functions. A new trend is emerging with the development of total word processing/data processing information systems like products of JTS Computer Systems Ltd. of Downsview, Ontario. File management, electronic mail, smart photocopiers, and automatic telephone switching equipment (PABX) will become integrated to word-processing in the near future, through communication networks.

ELECTRONIC ARCHIVES

The long-term storage of machine readable documents is the final destination in the evolution of electronic text processing. In its simplest form archives will consist of old documents prepared and kept on a permanent basis at the outer levels of the text system. Important files, policy manuals, and internal reference documents are examples of material that would be stored in some form of electronic memory accessible by the text computer.

When such archives become more common, reference texts such as dictionaries will appear. Later, more specialized books and journals will be published in machine readable form. The most obvious economies will be in the reduction of the need for paper and in the faster access to stored files.

By the time archives are developed, input/output terminals will themselves be sophisticated micro-computers which might be programmed to actually read and "understand" the text. One could, for example, instruct a desk-top terminal to: review all internal memoranda and return with file numbers of all documents dated February to March 1985 which refer to XYZ Corporation and their European marketing plan for power turbines. Such terminals will go beyond software protocols and begin some form of text and content analysis.

ELECTRONIC INTRA-OFFICE MAIL

An electronic office mail system is simply a data link within an office building. It operates much like a private telephone exchange, the only difference being that text-terminals are hooked up and text, rather than voice being transferred. This capability automatically exists in communicating word processors.

The main advantage of intra-office electronic mail will be a marked reduction in paper used for the preparation of memoranda. Other advantages of such a system are the speed of information transfer and an enhanced ability to have more people work on the text of the document.

In the next few years, as most offices acquire electronic office equipment and become interconnected on data communication networks, inter-office electronic mail will gradually replace the current postal service because it will be much cheaper and faster to send a document electronically, over a wire, to the other end of the country than to mail it.

SMART PHOTOCOPIES

The smart copier could be a combination of traditional photocopier with a laser character generator and a communication interface to other office equipments. With this technology, the shape of the letter to be printed would be called from memory and imaged on dry silver paper by a modulated laser. The Canadian copier market should reach $ 1.1 billion by 1985. This product would be a natural addition to word-processing and electronic mail. The only Canadian manufacturer which could be related to copiers is Delphax Systems of Mississauga (partly owned by Canadian Development Corp.).

MARKET FOR OFFICE EQUIPMENT

In North America, such a large portion of the economy is occupied by office workers that the potential market for word processors and related equipment is enormous. The North American

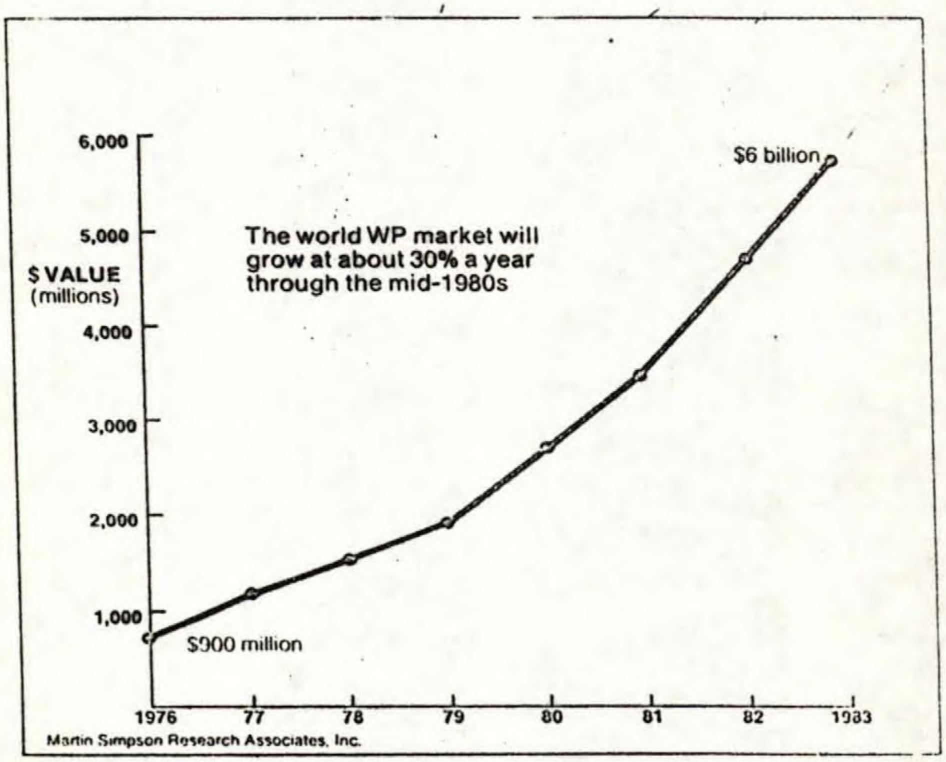

Fig. 5 - World W.P. Market Growth

Source: J. Marchant. Word Processing: New Perceptions

Canadian Business, August 1979

market represents actually sales in the order of 400-800 millions of dollars. It could increase to 2 billion by 1982, or some $ 100 million in Canada. (10) The world market for word processors can be expected to grow at a rate of some 30% a year, at least in the first half of the 1980's. It should be remembered that projections in that sector are revised upwards every single year.

Canada has quite a few manufacturers of word processors: AES Data, Micom, Fortin Electronics, Geac Computer, ... A few of these companies have opted for very specialized markets. Paraphrase Systems Ltd. aims at the legal sector while Zapsystems Ltd. concentrates on small companies in the travel industry. As shown in Figure 6, growth can be impressive in the W.P. sector: AES sales have increased 5 fold in just two years.

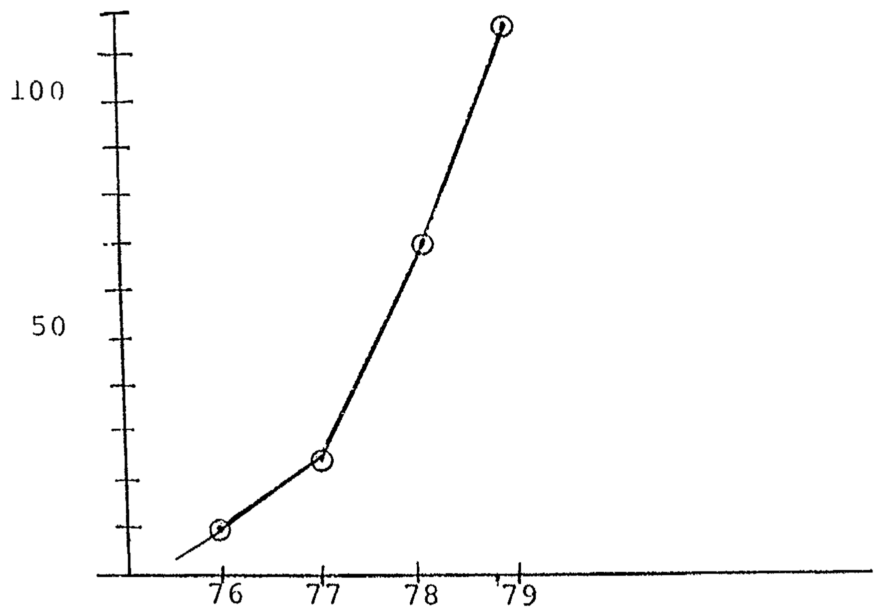

Fig. 6 AES Data Sales

Source: J. Marchant. Word Processors New Perception. Canadian Business August 1979

Another example is Micom with sales of $ 15 million in 1978 and sales of some $ 40 million in 1979.

OPPORTUNITIES, NEEDS AND THREATS

As shown in Figure 5, the sale of electronic office equipment is going up all around the world. This sector could represent an interesting solution to increase Canadian productivity in the service sector. If Canada fails to follow this world movement, it could be faced with a comparative disadvantage in the international trade.

As shown by AES Data Ltd., there are opportunities in the field of word-processing and other high-technology office equipment. In a world market growing at 30% a year, Canadian companies can compete aggressively since domestic technology is at world level in word-processing. In fact, 70% of AES Data's sales in 1978 were on international markets. Over the next decade, word processors as such will represent just the tip of the iceberg. Other equipments in file management, office electronic mail, and office facsimiles will appear. In 2000, 70% of all messages could be in electronic form. Bell Canada is already preparing itself with its Displayphone which is a data processor, a terminal, a modem, and a telephone.

CNCP will introduce Infotext later this year to link word processors thus providing electronic mail to subscribers. Future equipments will have to incorporate communication capabilities like is actually the case for AES Data "AES Plus" stand alone systems or for Micom's units which can perform electronic mail functions. Canada being a leader in telecommunication technology and being at world level in computer applications, high technology office equipment represents an interesting opportunity for domestic manufacturers.

CONCLUSION

Office workers represent an increasing percentage of the Canadian workforce. Automation of the office becomes a natural response to a will of increasing productivity and efficiency in the service sector. If Canada fails to follow this world movement, it will certainly have to face a comparative disadvantage in international trade. This is a growth market and Canadian technology is at the world level in word-processing. Other equipment in file management, office electronic mail, and office facsimiles will become increasingly important so that Canadian expertise in communication and in computer applications can be put to good use in this field. Word processors with office communication systems should be retained in a Canadian strategy.

CAD/CAM

CAD

Computer-aided design (CAD) is simply the use of computer graphic capabilities in the engineering design function. The designer draws his work on an electronic tablet that responds to the movements of an electronic stylus or directly on the CTR screen with a light pen. The computer stores data and simple commands can rotate the drawing to show a different point of view, zoom in or out, or introduce modifications into the design. For example, the computer can be instructed to display a drawing of a refinery, then zoom to show a detailed portion, add a new tank, and move a wall.

CAD can not only improve the productivity of engineers and draftsmen by eliminating time-consuming and repetitive tracing. It can also do "smart" work like the analysis of stress points, the verification of tolerance between parts and the simulation of either the crash of a bullet on a plate of steel or the reactivity of a new drug. Quality is improved because design modifications can be tested at very low cost.

Up to now, CAD has been applied to mechanics, electronics, architecture, and cartography. Presently, the mechanical sectors are strongly accelerating adoption of this technology. New applications are beginning to surface like in the preparation of clothes' grade and the design of shoes.

The present world market for CAD is evaluated at one billion dollars and is growing at a rate of 30 to 35% per year. It is a market strongly concentrated in United States: of world expenses in CAD, 50% are in North America, 35% in Europe, and 15% in Japan and the rest of the world.[11] CAD use in Canada is rather limited to the Department of Public Works, CADSYS Ltd, Canadair, Pratt and Whitney Aircraft, Mitel, and a few others.

The most interesting aspect of CAD is that the systems in use are easily interfaced to the manufacturing functions. The design engineer can create the tools he needs on the computer. He can now machine the part he wants directly on the screen. Once this set of instructions is in the memory of the computer, the computer itself can drive a robot to machine the desired part. This is the automatic factory or CAD/CAM.

ROBOTICS

Today's robots are not yet the version popularized by Hollywood and they will not be at least until next century. Industrial robots may best be described as an artificial arm or hand, driven electrically, hydraulically or pneumatically, and controlled by a computer to perform a number of coordinated operations of a repetitive nature on a workpiece.

The Robot Institute of America defines a robot as a "reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices, through variable programmed motions for the performance of a variety of tasks".

Technology

There are essentially two classes of robots: servo-controlled and nonservo-controlled. With the latter, the tool can stop only at the fixed end point of each axis while a servo-controlled robot can be programmed to stop at any point within its range of motion. There are two forms of robot control: point-to-point and continuous path. A point-to-point robot can be programmed to stop at any predetermined point but the tool's movement cannot be controlled between these points. A continuous path robot can have its movement precisely programmed.

Programming is the function which makes robots so attractive. There are three basic programming methods for industrial robots:

1) A first method consists in programming the robot through the desired positions and locations by means of a remote teaching console.

2) A second method requires the robot to be physically manipulated through the desired motions which are memorized and then played back by the robot. This approach avoids debugging problems.

3) A third method relies on prerecorded programs which permits faster reprogramming when a library of programs has been built up.

Factors of development

Up to a recent past, the introduction of robots on the shop floor has been rather slow for a number of reasons. The major reason was that no factory manager would have dared to have robots to be controlled by a central computer as the whole production line would have been dependent on the whim of that single computer. Microelectronics will have a great impact on robots. The control unit is not only becoming much less expensive and more powerful, but it can be built directly into the robot so that the information is processed where the robot is without the necessity for central control.

In fact, today, the average robot costs some $ 40,000 (in a range from $ 7,500 to $ 150,000) and cost approximately $ 4.80 an hour to run. Robots can be expected to become more versatile and less expensive but the mechanical, hydraulic, and electric constructions will be limiting factors in price reduction.

Another driving force comes from the competition of low-wages countries. Finally, it will become increasingly hard, in advanced industrial countries, to find workers to do dangerous or boring work which requires a combination of physical work and a minimum of brainpower. In fact, robots have been applied in unpleasant work (paint spraying), physically exhausting work (loading/unloading) and in work which presents short and long-term risks like temperature extremes, radiation, and toxicity.

Robots can be put to work 24 hours a day, 7 days a week, they do not take coffee breaks, are not subject to physical exhaustion, emotions, and other human niceties. Their payback period is usually between 2 and 3 years although it can sometimes be just one year. Not only do they increase competiveness by saving labour costs and producing faster, but they can improve quality, then yields, because they can repeat endlessly the same task with a high level of repeatability as opposed to their human counterparts.

Because production runs are usually short in Canada, robots are very attractive since the robot can work easily on a new production run when a program library has been built up. In conventional assembly line, it can take months to alter or renovate component machines as demonstrated by car manufacturing.

Applications

Up to now robots have been used in spot welding, die-casting, plastic injection, paint spraying, forging, machine and press loading/unloading, heat treatment, ... (see Table 1). New uses are appearing. Unimation has been asked to design a robot that pluck chickens, a robot is tested in Australia to shear sheeps, Mitsubishi is working on a robot that can visually distinguish different species of fish and separate them into various bins. It can then be seen that applications are almost infinite. In Canada, robots could be applied not only into manufacturing, but also in the natural resources sector and for work where climatic conditions are adverse.

Future applications will depend on the capabilities of the next robot generation. The next stage of development in robotics will be smart robots which can make decisions. A lot of research is currently done on vision to solve the problem of feeding workpieces from disarrayed bins. Another area of development is the design of tactile sensing to measure size, shape, temperature, softness or vibration of the object grasped by the claw.

International view

As shown by Table 2 which describes the present geographic distribution of robots, Japan and United States are the countries mostly involved in robotics. It should be noted that Japan is currently introducing robots at a rate five times faster than United States. It can be seen that Canada shows a real poor performance with less than 150 robots compared to its main trading competitors, and a base of robot manufacturers which is almost non-existent.

1. WORKPIECE GRIPPED BY ROBOT

1.1 Transfer

1.1.1 Simple transport operation

For example:

From fixed position to fixed position

1.1.2 Complex transfer

For example:

From conveyor to conveyor
Palletizing
Stacking
Packing
Sorting

1.1.3 Loading/unloading of equipment

For example:

Casting
Pressure die casting
Injection moulding
Metal working
Cold/hot pressing
Heat treatment (furnaces)
Glass cutting
Soldering
Brazing

1.2 Manipulation and process

For example:

Forging
Fettling
Investment casting

2. TOOL HANDLED BY ROBOT

2.1 Metal working

For example:

Flame cutting
Grinding
Pneumatic chipping

2.2 Joining

For example:

Spot welding
Arc welding
Stud welding

2.3 Surface treatment

For example:

Paint spraying
Enamel spraying
Glass fibre and resin spraying
Sprinkling enamel powder
Ceramic ware finishing
Water jet cleaning
Applying sealing compounds

2.4 Inspection

For example:

Dimensional checks

2.5 Others

For example:

Glass gathering
Marking

3. Assembly by robot

(still in development stage)

For example:

Automobile alternators
Electric motors
Electric sub-assemblies

Table 1. Classification of robot applications
Source: The Microelectronics Revolution, p. 187

COUNTRY	NUMBER OF ROBOTS IN USE
Japan	4,000
U.S.A.	3,000
Sweden	1,000
Germany	600
Italy	500
France	300
England	200
Canada	150

Table 2. Geographic distribution of robots in 1979
(Robots costing more than $ 45,000 Cdn) (See note)

Source: La Robotique en France . (Conference given by Mr. Fourastier to the Interdepartmental Committee on Future Studies) Nov. 5th, 1980

Note :Analysts currently report the number of robots in each country according to a wide set of robot definitions. Then, these figures vary widely from one source to the other so that the above figures should be taken cautiously as they indicate just a qualitative order.

The market for robots is forecasted to grow at a rate of at least 35% per year through the 1980's.(14) World sales of robots should be between 2 and 4 billion dollars, by 1990 according to some analysts, as early as 1985 according to others. In fact, sales are increasing exponentially as shown in Figure 7. By cutting the costs of today's $ 45,000 robots to $ 10,000 by 1990, demand could be as much as 200,000 units a year.

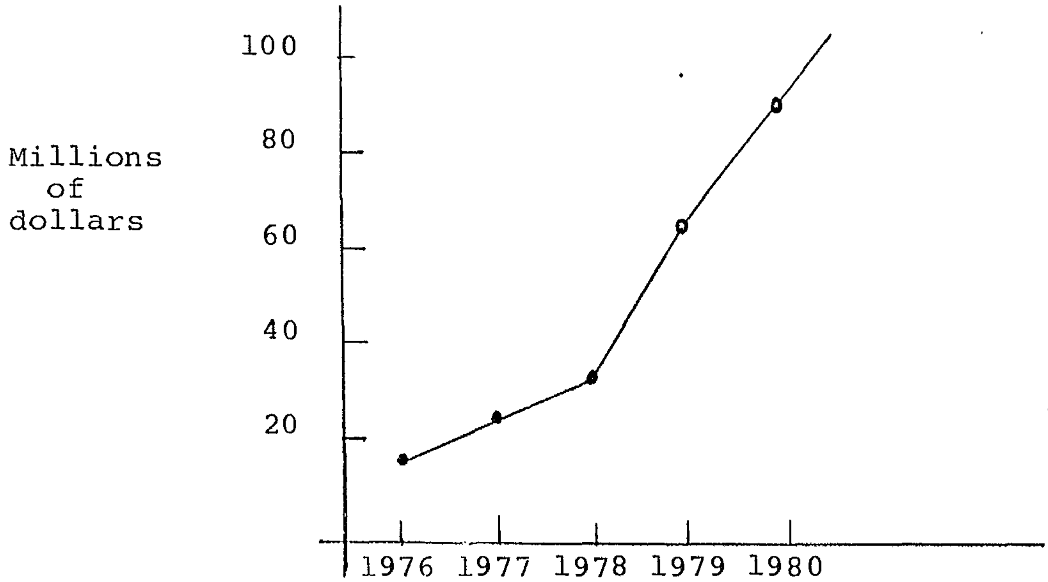

Fig. 7 Sales of robots in millions of dollars
Source: Robots Join the Labour Force.
Business Week, June 9th, 1980, p.63

A forecast by the American Society of Manufacturing Engineers and the University of Michigan predicts that: by 1982, 5% of all assembly systems will use robotic technology (15% by 1987), by 1985, 20% of labor in the final assembly of cars will be replaced by automation and by 1988, 50% of labor in small-component assembly could be replaced by robotic technology. (14)

While discussing the robots market, it should be remembered that Canada has no domestic robot manufacturer even though some universities like the University of Waterloo have expertise in robotics technology. The only known Canadian robot has been developped by Leigh Instruments. It is a robot with vision and pattern recognition capabilities for small parts handling. Most manufacturers are in Japan (e.g. Kawasaki, Mitsubishi), in United States (e.g. Unimation, Cincinnati Malacron), in Sweden (e.g. ASEA), in Germany (e.g. Kuka), and in France (e.g. Renault).

The main factors limiting diffusion of this technology will be a lack of awareness by manufacturers, a shortage of application engineers and maintenace technicians, and labour apprehensions. Up to a recent past, another factor was related to robot's reliability, but shut down time has been reduced to 2-3% (Unimation).

CONCLUSION

Even though the desirability of manufacturing robots domestically should receive serious attention in the future, the most urgent need for Canada is to promote introduction of robots in the country. All major countries are adopting robots at a fast pace and Canada will have to follow the movement if it wants to remain competitive on the world scene.

Canada is a leader in many technologies, particularly in telecommunications but if the Canadian production structure becomes archaic, this leadership will be eroded quickly. A first step has been made when the National Research Council recently agreed in principle to build a centre for research in advanced manufacturing and production techniques (including robotics and application of micro processors in processes) in Winnipeg.

MISCELLANEOUS APPLICATIONS

The incorporation of integrated circuits into miscellaneous products will have an enormous impact. Microelectronics could enhance the performance of existing mechanical products, it could extend considerably the existing product line or simply replace many mechanical parts at reduced cost. Finally, it could lead to the creation of entirely new products which can only be achieved with microelectronics.

Consumer products will represent a large market for the application of microelectronics but it will first be restricted to top-of-the-line models to repay development costs and to limit demand as the firm is building production capacity. In the longer term, products will be less costly and less diversified because it will be very cheap to add features to cheaper models since all models will use the same microprocessor.

In addition to video games, microelectronics will invade the whole area of control like in washing machines, central heating systems, home security systems, and ovens. Microelectronics are already applied in television sets, Hi-Fi equipment, cameras, watches, ... In cars, it could be used to regulate engine performance to reduce emissions, and to improve fuel economy. It will be found in dashboard displays and it will control different safety features like brakes, collision avoidance systems and others. Potential applications are limited only by the imagination.

Microelectronics is presently applied in various instruments ranging from "smart" oscilloscope to telemetry (e.g. tele-heart-monitor). It is also found in industrial control: batch processing control in petrochemicals, plant monitoring, radiation monitoring, . . . In the coming decade, there should be a marked acceleration of all those applications.

Presently, entry costs are low and products can be designed rapidly and inexpensively, but as simpler applications are completed, entry costs will surge. It is then important that firms enter early into this market.

Miscellaneous applications of microelectronics are enormous, but their rate of introduction will depend mainly on two factors. First, shortages of skilled personnel will be a serious constraint. Second, adoption will depend on the ability of the industry to anticipate potential applications of microelectronics and to define products that will use this technology.

NEEDS FOR FEDERAL ACTION

This report found the following aspects of microelectronic technology to be the most appropriate as possible "core technologies" for Canada:

1. rapid introduction of robots in the primary and secondary sector;

2. switching systems, digital multiplexers, fibre optics and small earth terminals, and peripherals for satellite telecommunications;

3. micro-computers and peripherals like video terminals, optical character readers, printers, floppy disks, and bubble memories;

4. computer services and software;

5. communicating word processors; and,

6. products and industrial processes incorporating microelectronic elements.

The Federal Government should encourage investments in the manufacturing of these applications and it should stimulate the development of Canadian expertise in the design of the equipment listed above.

This report stressed opportunities in manufacturing of electronic equipment, but it will also be necessary to stimulate utilization of this technology in four broad areas which could improve productivity: robotics, communications, computing, and office of the future.

Since Canadian companies are small, the Federal Government should promote standardization so that Canadian manufacturers could avoid dispersion of their limited resources.

APPENDIX

List of manufacturers and suppliers of electronic equipment in Canada.

OFFICE EQUIPMENT

JTS Computer Systems
4544 Dufferin St., Unit 20
Downsview, Ontario
M3H 5X2

AES Data Ltd.
570 McCaffrey St.
St.Laurent, Québec
H4T 1N1

Mikros Systems Ltd.
1 Scarsdale Road
Don Mills, Ontario
M3B 2R2

Micom Co.
5250 Ferrier St. 2nd Floor
Montreal, Québec
H4P 1L4

Micos Inc.
1590 Matheson Blvd.
Mississauga, Ontario
L4W 1J1

Fortin Electronics
660 King Edward Street
Winnipeg, Manitoba
R3H 0P2

Zapsystems Limited
705 Progress Avenue
Unit 63
Scarborough, Ontario
M1H 2X1

Ashworth Automation Ltd.
315 Steelcase Road E.
Markham, Ontario
L3R 2R5

Beta Systems Inc.
1760 Kingsway Road
Port Coquitlam, B.C.

Datamex Ltd.
14 Leswyn Road
Toronto, Ontario
M6A 1K2

A.B. Dick Co.
94, Brockport Drive
Rexdale, Ontario
M9W 5C5

Four-Phase Systems Ltd.
560 Denison St., Unit 9
Markham, Ontario
L3R 2M8

Intelterm Systems Ltd.
5000 Dufferin Street N.
Downsview, Ontario
M3H 5T5

K.O. Mair Associates Ltd.
40 Beech Street
Ottawa, Ontario
K1S 3J6

MLPI Business Systems Inc.
2255 Sheppart Ave. E. #A110
Willowdale, Ontario
M2J 4Y1

Mohawk Data Sciences
85 Idema Road
Markham, Ontario

Nelma Electronics Ltd.
1707 Sismet Road
Mississauga, Ontario
L4W 2K8

Network Data Systems Ltd.
3425 Harvester Road, Ste. 215
Burlington, Ontario
L7N 3N1

Polaris Business Systems Ltd.
151 Esna Park
Markham, Ontario

TRW Data Systems
270 Yorkland Blvd.
Willowdale, Ontario
M2J 1R8

Paraphrase Systems Limited
80 Bloor Street West,
Suite 1402
Toronto, Ontario
M5S 2V1

Northern Telecom Ltd
33 City Centre Drive
Mississauga, Ontario
L5B 2N5

COMPUTERS AND PERIPHERALS

COMPUTERS

Cremanco Systems Limited
7 Banigan Drive
Toronto, Ontario
M4H 1G4

Dynalogic Corporation
141 Bentley Avenue
Ottawa, Ontario
K2E 6T7

Geac Computer Corporation Limited
350 Steelcase Road West
Markham, Ontario
L3R 1B3

Innovative Computer Systems Corporation
2655 Weston Road
Weston, Ontario
M9L 1V8

Matrox Electronic Systems Ltd.
5800 Andover Avenue, T.M.R.
Montreal, Québec
H4T 1H4

Megatel Computer Corporation Inc.
150 Turbine Drive
Toronto, Ontario
M9L 2S2

Volker-Craig Limited
266 Marsland Drive
Waterloo, Ontario
N2J 3Z1

Zapsystems Limited
705 Progress Avenue, Unit 63
Scarborough, Ontario
M1H 2X1

Fortin Electronics
660 King Edward Street
Winnipeg, Manitoba
R3H 0P2

Nabu Manufacturing Corp.
485 Richmond Road
Ottawa, Ontario
K2A 0G3

Patrick Computer Systems
449B - 491 Portage
Winnipeg, Manitoba
R3B 2E4

Norango Computer Systems
801 York Mills Road
Toronto, Ontario

Consolidated Computer
2421 Lancaster Road
Ottawa, Ontario
K1B 4L5

Cybernex
1257 Algoma Road
Ottawa, Ontario
K1B 3W7

PERIPHERALS

Cremanco Systems Limited
7 Banigan Drive
Toronto, Ontario
M4H 1G4

Dynalogic Corporation
141 Bentley Avenue
Ottawa, Ontario
K2E 6T7

Innovative Computer Systems Corporation
2655 Steelcase Road West
Markham, Ontario
L3R 1B3

Comterm Limited
545 Delmar Avenue
Pointe Claire, Québec
H9R 4A7

Goodwood Data Systems Ltd.
P.O. Box 210
Carleton Place, Ontario
K7C 3P4

Hitech Canada Limited
Suite 103
68 Highway 7
Ottawa, Ontario
K2H 8P5

Leigh Instruments Ltd.
2680 Queensview Drive
Ottawa, Ontario
K2B 8J9

Consolidated Computer
2421 Landaster Road
Ottawa, Ontario
K1B 4L5

Dy-4 Systems
1573 Laperrière Ave.
Ottawa, Ontario
K1Z 7T3

Matrox Electronic Systems Ltd
5800 Andover Ave
Ville Mont-Royal, Québec
H4T 1H4

COMMUNICATIONS

Manufacturers of Telecommunications Equipment

Northern Telecom Ltd.
33 City Centre Drive
Mississauga, Ontario
L5B 2N5

Spar Aerospace Ltd.
825 Caledonia Road
Toronto, Ontario
M6B 3X8

Canadian Marconi Company
2442 Trenton Avenue
Montreal, Québec
H3P 1Y9

Leigh Instruments Limited
Post Office Box 82
Carleton Place, Ontario
K7C 3P3

Canadian General Electric Company Limited
Post Office Box 417
Commerce Court North
Toronto, Ontario
M5L 1J2

Mitel Corporation
Post Office Box 13089
Ottawa, Ontario
K2K 1X3

COMMUNICATIONS

SUPPLIERS

AEL Microtel Ltd.
4664 Lougheed Hwy
Burnaby, B.C.
V5C 5T5

Develcon Electronics Limited
108-103rd Street East
Saskatoon, Saskatchewan
S7N 1Y7

ESF Limited
1780 Albion Road
Rexdale, Ontario
M9V 1C1

ENA Datasystems Incorporated
268 Galaxy Boulevard
Rexdale, Ontario
M9W 5R8

Fanon Electronics of Canada Limited
80 Alexdon Road
Toronto, Ontario
M3J 2B4

Gandalf Data Communications
9 Slack Road
Ottawa, Ontario
K2G 0B7

Glenayre Electronics Ltd.
1551 Columbia
North Vancouver
British Columbia
V7J 1A3

International Systcoms Ltd.
4900 Fisher Street
Montreal, Québec
H4T 1J6

COMMUNICATIONS

SUPPLIERS

Leblanc & Royle
514 Chartwell
P.O. Box 880
Oakville, Ontario
L6J 5C5

M.A. Electronics Canada Limited
3135 Universal Drive
Mississauga, Ontario
L4X 2E7

Motorola Canada Limited
3125 Steeles Avenue East
Willowdale, Ontario
M2H 2H6

Quindar Products Limited
7523 Flint Road Southeast
Calgary, Alberta
T2H 1G3

Interdiscom Systems Limited
87-1313 Border Street
Winnipeg, Manitoba
R3H 0X4

Raytheon Canada Limited
400 Phillip Street
Waterloo, Ontario
N2J 4K6

SED Systems Ltd.
P.O. Box 1464
Saskatoon, Saskatchewan
S7K 3P7

Sinclair Radio Laboratories Limited
122 Rayette Road
Concord, Ontario
L4K 1B6

SWITCHING AND PBX SYSTEMS

AEL Microtel Ltd.
4664 Lougheed Hwy
Burnaby, B.C.
V5C 5T5

ITT Communications Division
175 Dawson Road
Guelph, Ontario
N1H 1A1

Plessey Canada Limited
300 Supertest Road
Downsview, Ontario
M3J 2M2

Siemens Electric Limited
7300 Trans Canada Highway
Pointe Claire, Québec
H9R 1C7

TERMINALS

AEL Microtel Ltd.
4664 Lougheed Hwy.
Burnaby, B.C.
V5C 5T5

Comterm Limited
545 Delmar Avenue
Pointe Claire, Québec
H9R 4A7

Dynalogic Corporation
141 Bentley Avenue
Ottawa , Ontario
K2E 6T7

Norpak Ltd.
P.O. Box 70
Pakenham, Ontario
K0A 2X0

Volker-Craig Limited
266 Marsland Drive
Waterloo, Ontario
N2J 3Z1

COMPUTER-BASED SYSTEMS MAKERS

AES Data Ltd.
570 McCaffrey Street
Montreal, Québec
H4T 1N1

Computing Devices, Divison of Control
Data Canada Limited
P.O. Box 8508
Ottawa, Ontario
K1G 3M9

Control Data Canada Limited
50 Hallcrown Place
Willowdale, Ontario
M2J 1P7

Digital Equipment of Canada
100 Herzberg Road
Kanata, Ontario
K2H 8K8

PRIMARY CABLE TELEVISION EQUIPMENT

Delta Benco Cascade Limited
124 Belfield Road
Rexdale, Ontario
M9W 1G1

Jerrold, Division of General Instrument of Canada
87, Wingold
Toronto, Ontario
M6B 1P8

RF Communications Ltd.
120 Gibson Drive
Markham, Ontario
L3R 2Z3

TELECOMMUNICATIONS SYSTEMS

AEL Microtel Ltd.
4664 Lougheed Hwy
Burnaby, B.C.
V5C 5T5

Canadian Astronautics Limited
1024 Morrison Drive
Ottawa, Ontario
K2H 8K7

Dees Communications Engineering Ltd.
6475C, 64th Street,
R.R. # 3, Delta
British Columbia
V4K 3N3

DIPIX Systems Limited
1785 Woodward Drive
Ottawa, Ontario
K2C 0P9

Electrohome Limited
809 Wellington St. North
Kitchener, Ontario
N2G 4J6

Ferritronics Ltd.
222 Newkirk Road
Richmond Hill, Ontario
L4C 3G7

Goodwood Data Systems Ltd.
P.O. Box 210
Carleton Place, Ontario
K7C 3P4

Omicron Data Systems Limited
159 Oneida Drive
Pointe Claire, Québec
H9R 1A9

Miller Communications Systems Limited
39 Leacock Way
Kanata, Ontario
K2K 1T1

TELECOMMUNICATIONS SYSTEMS

Positron Industries Incorporated
4810, Jean Talon West
Montreal, Québec
H4P 2N5

Tele-Radio Systems Limited
301 Supertest Road
Toronto, Ontario
M3J 2M4

MacDonald, Dettwiler and Associates Ltd.
Airport Executive Park
3751 Shell Road
Richmond, B.C.
V6X 2W2

COMPONENTS

Amphenol (Canada) Ltd.
44 Metropolitan Ave.
Scarborough, Ontario
M1R 2T9

Anatek Electronics Limited
240 Brooksbank
North Vancouver
British Columbia
V7J 1C2

COM DEV Ltd.
155 Sheldon Drive
Cambridge, Ontario
N1R 7H6

Epitek Electronics Ltd.
100 Schneider Road
Kanata, (Ottawa), Ontario
K2K 1Y2

Lazer Tech Limited
235 Nugget Ave. - 18
Scarborough Ontario
M1S 3L3

Linear Technology Inc.
3435 Landmark Road
Burlington, Ontario
L7M 1T4

Optotek Limited
1283 Algoma
Ottawa, Ontario

Precision Electronic Component
19 Hafis Road
Toronto, Ontario
M6M 2V6

Pylon Electronic Development Company Limited
2300 Victoria Street
Lachine, Québec
H8S 1Z3

COMPONENTS

Renfrew Electric Co. Limited
349 Carlaw Ave.
Toronto, Ontario
M4M 2T2

Varian Associates of Canada Limited
45 River Drive
Georgetown Ontario
L7G 2J4

Foundation Electronic Instruments Inc.
1974 Courtwood Crescent
Ottawa, Ontario
K2C 2B5

Imapro Inc.
West Royalty Industrial Park
Charlottetown, P.E.I.
C1E 1B0

Madsen Electronics Ltd.
1074 South Service Road
Oakville, Ontario
L6J 5B4

Canstar Communications
Division of Canada Wire and
Cable Company Limited
1240 Ellesmere Road
Scarborough, Ontario
M1P 2X4