CAD/CAM AND ITS IMPACT ON THE MANUFACTURING INDUSTRY

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Abstract

From 1960 to the present great strides have been made, and are continuing to be made, in the use and application of real time process computer control systems, particularly for control of continuous processes in the resource based industries. A similar dramatic change is now beginning to take place in the discrete parts secondary manufacturing industry where the cost effectiveness of micro processors and mini computers has suddenly made possible a wide variety of new applications in Computer Aided Design and Computer Aided Manufacturing (CAD/CAM).

CAD/CAM systems have many similarities, and embrace many of the same technologies as real time process computer control systems, but they also contain important differences in technological emphasis. These differences focus attention on new industry sectors where CAD/CAM will introduce widespread change plus a potentially substantial socio-economic impact.

The paper will describe CAD/CAM systems from these points of view, and will describe the function and activities of the CAD/CAM Technology Advancement Council that has been established to encourage and assist in the adoption of this important new technology in Canada.

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Introduction

Real time computer control of industrial processes had its first beginning in 1959 with the computer control of a catalytic polymerization unit at a Texaco refinery in Port Arthur, Texas.[1] [2]. Other pioneering applications quickly followed in the early 1960's, most notably for metal rolling[3, 4, 5], cement plants[6, 7, 8, 9], electric utility[10, 11] chemical and other refinery processes. The hardware, software and process knowledge and control developments of this period have been reviewed elsewhere[12, 13, 14]. Today process computer control is a widely accepted and widely used technology for plants and processes having a highly valued product throughout.

A similar but different revolution, occuring some 15-20 years later, has now commenced in the general manufacturing industries, particularly those producing discrete parts, as distinguished from those using continuous processes. Although previously not economically attractive, the use of computer systems has now become practical in discrete parts manufacturing due to continued advances in computer technology. As a result there has been a constant improvement in computer price/performance ratios and most recently the microprocessor in particular.

Generally referred to as Computer Aided Design and Computer Aided Manufacturing (abbreviated CAD/CAM), this technology is expected to have a widespread and significant impact on many sectors of the manufacturing industry.

The paper will review this activity with reference to its impact in Canada, and the CAD/CAM Technology Advancement Council which has been established to encourage the development and use of this technology.

Advances in Computer Technology

Since the computer is obviously the common element, and is at the heart of virtually all CAD/CAM systems, it is worthwhile to briefly examine the technological advances that have made such systems possible. In so doing however, it should be clearly established at the outset that in CAD/CAM systems the computer is basically being employed as an available tool. Much of the technology used in CAD/CAM applications, and which must be further developed for their extension, is of a systems, mechanical and manufacturing engineering nature. A great deal of this needs to be and is being developed "in-house" by the user. It would be a mistake therefore to consider "CAD/CAM" as a product developed and supplied solely, or even primarily, by the electronics industry.

Basically it is the continued improvement in the performance/cost ratio of available computers that makes applications like CAD/CAM possible. This in turn is possible primarily because of the continued miniaturization of logic and memory devices, embodied today in the term "micro-electronics", and typified by the ubiquitous and pervasive microprocessor.

Canada's first computer arrived by boat in 1952 from Feranti in Manchester England and was installed at the University of Toronto where it became known as the Ferut Computer. It had a fixed point add time of 1.2 ms., and a multiply time of 2.2 ms. Division was accomplished by a reciprocal subroutine which took 95 ms. Working storage was on the face of cathode ray tubes, called Williams tubes after Prof. F.C. Williams, their inventor, and required periodic refreshing due to the decay and eventual loss of information despite the automatic recycling of the bit patterns. The first computer in the Canadian manufacturing industry, to the writer's knowledge, was installed by Orenda Engines Limited in 1956, followed soon by others for more general and non-defence related industrial design[15].

Figure 1 illustrates the constantly expanding base and scope of computer applications. There is an old tale in the computer industry of how one of today's major computer corporations first estimated the world market for computers in business and industry. This was at a time when several of the world's first computers had just been built for research and scientific purposes, but their commercial use had not yet begun. Their estimate for the foreseeable future was that the world market could absorb and employ about 5-8 computers. Starting from such small beginnings the use of computers in business, industry, government and academic institutions has been expanding ever since. In 1978, computer user expenditures in the U.S.A. were estimated at approximately $42 billion.(16) For the manufacturing industry users this represented 0.7¢ per dollar of sales.

Basically each year improvements in cost and performance of computers, coupled with an expanding awareness by more and more people of their capability, has made possible a continual supply of new application areas. There are many ways of plotting or recording this cost and performance trend, much of which in turn is based primarily on advances in micro-electronics technology, very large scale integration (VLSI) and the microcomputer in particular. For example, the number of components per circuit (gates/chip) has doubled every year since 1959, resulting in an increase in components per circuit of 1024 every 10 years(17). With the use of electron beam etching and other techniques this trend in miniaturization is expected to continue until other physical limits are reached, such as the dielectric breakdown strength of silicon, heat removal ability and the percentage of chip area that can be allocated to circuit wiring(18).

At the user level improvements in the price/performance ratio of computers, or the cost/calculation, are difficult to track over the variety of problem types and computer architectures available to the user, but have kept improving every year by a factor of about 32% for memory costs, 23% for logic and 11% for communications(19). Improvements of 10 to 1, or more, every ten years mean that a calculation costing $1000 in the early days of computing would cost only $10 in 1972. On this basis the same calculation will cost only $1 in 1982 and 10 cents in 1992. Economic changes such as this keep opening up new waves of applications as long as the organization and development of applications know-how and the "people cost" of programming can keep up. For example, the expenditure of the USA Manufacturing industries on computer graphics equipment, software and services alone is projected to grow at a 22% annual rate, increasing from $251 million in 1977 to $316 million in 1978 and $1.5 billion in 1986 according to a leading market research firm[20]. There are quite clear signs, however, of the "programming limit" being reached on many new potential computer applications, hence applications such as those in communications and word processing, where the microprocessor is transparent to the user, (rather than being programmed by the user) are achieving the highest growth rates in applications and sales.

Does Canada need CAD/CAM?

This is a valid and important question. The answer in the long-term lies in the structure of the economy, not only as it exists today but as it will eventually exist in the future. One can identify four basic economic sectors, with long-term outlooks as follows:

1. Non-renewable resource - which eventually will be depleted.

2. Renewable resources -which are reaching natural limits and therefore becoming constant in output.

3. Secondary manufacturing - the long-term future growth opportunity.

4. Service sector - limited by a natural maximum ratio to the sum of 1+2+3.

Canada's labour force grew linearly from approximately 7 million in 1964 to 11 million in 1978, an increase of 285,000 new jobs needed per year, which is more than 1,000 new jobs per working day[21].

The importance of the manufacturing sector as a key source of job creation is therefore obvious. This is given high prominence in the newly issued report no. 29 of the Science Council of Canada "Forging the Links - a Technology Policy for Canada"[22]. The source of the Council's concern arises from the observation that the strength of the manufacturing industry sector in Canada is declining, relative to the rest of the world, and that this decline, as cited by the following statistics, is greatest in high technology products:

- From 1970 to 1975 Canada's share of world exports slipped from 6.1 to 4.4 percent, a decline of 28 percent.

- From 1970 to 1975 Canada's share of world trade in manufactured exports dropped from 5.6 to 3.8 percent, a decline of 32 percent.

On a more positive note, more recent figures, since devaluation of the Canadian dollar, show a reversal of these previous trends.

Some of the declining strength reported by the Science Council might be attributable to a growing self sufficiency of the developing nations, and a more uniform balance of world production of goods. However, during the same time period Japan, Germany, France and Sweden all increased their percentage share of world trade in manufactured goods. Furthermore, from 1970 to 1977 the proportion of the Canadian market served by imports grew from a 26 percent level to a new level of 31 percent. As stated in the Science Council report "these changes indicate that Canada is moving <u>away</u> from an industrialized economy, back to one based on the export of raw materials". As stated in another report, "We are in danger of changing from a branch plant economy to a warehouse economy"(23).

However, these are symptoms, not causes. As every control engineer knows you influence the behaviour of a process by changing and adjusting its inputs, not simply by measuring and thinking about its outputs.

The Science Council report gives special attention to the new wave of change in industrial production methods taking place because of advances in microelectronics and microprocessor technology. These new electronic products are not only causing sweeping changes within the electronics industry but in turn have significant impacts on other forms of industrial production; hence the names "the third wave of industrial revolution", the "microelectronics revolution", or "CAD/CAM".

These represent both opportunities and threats. As the Science Council report sees it:

"Canadian industry is threatened on two fronts: by the danger that much of its traditional manufacturing activity will become non-competitive through pressures from the industrializing Third World, and by its inability to exploit new avenues of industrialization made possible by advanced technology. In this sense, Canadian Industry is uniquely threatened." but

"Canada is ill-prepared to face many of the significant challenges necessary in a transfer to an industrial system based on high-technology innovation and adaptation".

Viewed in a more positive way one notes the June 1, 1979 announcement of budgetary and other measures aimed towards a new national priority for achieving expenditures for R&D of 1.5% of GNP by 1983[(24)]. This target is a significant increase and reversal of a ten year trend, because R&D effort in Canada slipped steadily from a high of 1.28% in 1967 to 0.92% in 1977[(25)]. To be effective most of this increase must take place in industry. Fortunately, that is already the direction of the trend. From 1963 to 1977 the percentages distribution of R & D Expenditures by performer shows a government decrease from 41.7% of the total to 31.4% while the proportion done by business enterprises (partly funded by government) increased from 38.7% to 44.7%. R & D performed by universities accounts for the remainder, and increased from 19.6% of the total to 24.4% during the same time period.

If effort on R & D is to increase, and especially that part done in business enterprises, it is important to examine the underlying reasons for undertaking R & D in industry. Most of this is applied research and development. Virtually all of this is conceived with the development of new products or processes in mind.

It is important therefore to recognize that business allocations of funds for new product development are based on:

a) an awareness of technological opportunity for improvement, <u>and</u>

b) an awareness of a market opportunity that will permit payback of the funds expended, <u>and</u>

c) available funds and personnel for development

Allocations of funds for new process development are based on:

a) an awareness of a technological opportunity for improvement, <u>and</u>

b) an awareness of the economic justification through cost saving or increased output for the plant in question, <u>and</u>

c) available funds and personnel for development.

Several points should be noted with respect to these decision factors. In allocating funds for either product or process related R&D it is not simply the technological opportunity that is an essential factor, but rather the <u>awareness</u> of that opportunity. Most control engineers are aware of the often significant difference which can exist between the real value of a signal, and the measured or perceived value of that signal. Decisions by management and technical personnel are based on their known or perceived knowledge of a situation. This may be less complete or less up to date than the real situation. This is why accurate and timely technology transfer, with minimum error and delay in its transmission and assimilation is an important ingredient in the R & D process, especially as it applies to the industrial development of new products and processes.

The presence of the word "and", linking the factors "a, b, c" should be noted. It is not sufficient to have ideas without markets, or funds without the technical knowhow to apply them wisely. They all must be present. It is "a" and "b" and "c" that are required. Unfortunately much time and effort can be lost in seeking to prove whether the problem or missing "link" is "a", or "b" or "c".

The importance of doing things at the right time should also be noted. Canadian industry represents too small a percentage of the world total to be able to pioneer very many things for the world at large, although there can always be some. Real leading edge pioneering takes special effort, progress is slow, costs may be high, there is a high risk of costly mistakes and exploring blind alleys due to the lack of precedent.

On the other hand, no company or country can afford to lag far behind - - especially in industrial R & D, for this is a continuous process. Today's sales, revenues and earnings are essential to pay for today's R & D, which in turn will make possible tomorrow's sales, revenues and earnings. If the chain is broken, or development falls behind, a decline sets in which makes revitalization all the harder, or even impossible.

Recognizing that awareness of technological change, and awareness of the economic justification of new production technologies are key factors in the industrial process, the Department of Industry Trade and Commerce established in 1978 a CAD/CAM Technology Advancement Council with objectives and memberships as defined in Table 1 and Table 2. This is an industry/academic/government body with membership primarily from industry. The objectives are focussed primarily towards users in industry.

The resources of the council are limited, since the industry and academic members are contributing their time and energy to its objectives on a voluntary basis and it is a part time activity for all. The council wishes to cooperate and contribute to all activities that it can, in line with the objectives and duties stated in Table I. Letters to this effect have been sent to a large number of technical societies, universities and research organizations in Canada.

The Council will from time to time be disseminating CAD/CAM information of a general nature. This will include papers on CAD/CAM usage in Canada and in other countries, including case histories of specific applications, listings of supplier capabilities in Canada and current information on worldwide CAD/CAM activities.

The main channels for making this information available will normally be through established journals and trade publications rather than by direct mailing, and through co-sponsorship of conferences and seminars.

Two publications on CAD/CAM, prepared prior to the council's formation, are already available at no charge from Publication Distribution, Department of Industry, Trade and Commerce, Ottawa K1A 0H5. The first, entitled "CAD/CAM and Canada", is a reprint of articles on CAD/CAM applications in Canada. The second "Computer Aided Design and Manufacturing in Canada" is a directory of firms and organizations in Canada supplying CAD/CAM products and services. A new series of articles on CAD/CAM applications, with emphasis on economic justification, has been commenced and will continue to appear as appropriate material becomes available, mostly in the following journals and eventually also in collected reprint form. Contributions from authors for this series are welcome.

Journals currently participating in the CAD/CAM series of papers.

- Canadian Machinery and Metal working
- Canadian Data Systems
- Canadian Controls + Instruments
- Materials Management and Distribution

- Design Engineering

- Engineering Digest.

Although there are differences, certain analogies or linkages of historical significance have been noted and can be drawn between process computer control systems and CAD/CAM systems.

Figure 2 presents data on the introduction of process computer control systems in Canada and elsewhere. The data is interesting in that it shows a rate of growth in Canada similar to the USA, but with delay in starting and a phase lag of approximately 4-5 years, especially at the outset. As time progresses, and the numbers increase, one might expect to see the traditional 10:1 ratio attributable to the relative sizes of the economies. The data indicates a 10:1 reduction plus a 3 year phase lag in the intermediate years; eventually reaching a 10:1 ratio and with little additional lag some 10 years after the technology introduction first began. The importance of minimizing lags in technical development has already been cited above. In attempting to accelerate the introduction of a new technology, there is substantial leverage in attempting to do so by the provision of information which will reduce the time lags especially in the early formative years.

Figure 3 illustrates another phenomenon exhibited in the introduction of new production technology. There are three phases or stages to this process which can be represented as follows:

Phase 1 - <u>The R&D phase</u> - Most technical advances, including process computer control applications, started this way for the first few installations. Often called "green-fielding", somebody had to try the new unproven concept simply to see if it could be made to work. Somebody had to be first. Usually if new techniques aren't tried this way, they don't start at all.

Phase 2 - The detailed economic justification phase - In this phase all the expected results of each proposed project must be predicted as accurately as possible, their impact on current operations estimated in financial terms and compared to the development cost budget.

Phase 3 - The proven system stage - After many successful installations have been reported and accepted, the once pioneering application now becomes accepted as a way of life. Once a large number of people are using the technology, including one's competition, and obviously in a successful way, lengthy justification studies have lost their place. It becomes more important to get on with the job, to get new systems installed and operating, than to collect and analyse data in a conjectural way.

Figure 4 illustrates that process computer control systems in the pulp and paper industry have followed this trend[42]. The dramatic change in installation rate, amounting to a "snap-action", on transition from the economic justification phase to the accepted system stage should be noted. In phase 2 by comparison the number of new installations is still limited by numbers of available people and by caution - - i.e. limited by the number of knowledgeable people available to do economic justification studies and by management insecurities or caution. On reaching phase 3 this constraint is largely removed because such detailed economic justification studies are no longer needed. A completely different rate of orders, installations and use of the technology then results. Suppliers who base their market and sales projections, in the traditional way, on a linear extrapolation of past experience can be caught quite unaware by the user sudden acceptance and forward surge in market activity. Users, especially small companies, also find it difficult to foresee or forecast the transition accurately, because they cannot be expected to be aware of breakthroughs coming in the supplier's technology or to be aware of industry trends as a whole. Hence a dramatic "CAD/CAM revolution" can be about to take place, even though many potential users in the manufacturing industry are unaware of it. Only those very close to the leading edge installations may be in a good position to anticipate and predict the trend. One takes note, therefore, of the statement by the president of General Motors, Mr. E.M. Estes. "I think it is fairly safe to say that within 10 years computers will control about 90% of all the new machines in G.M.'s manufacturing and assembly plants"[26].

One of the subtleties associated with such a pervasive technology, with such a diversity of applications, and with contributing developments taking place and in motion in so many separate places, is that it is easy to think that not much is happening, when in fact a tidal wave of change is approaching. The "fully automatic factory" may be only a concept, or may only be realized in a few special cases. However on a narrower front the marriage of computer operated production equipment with computer programmed industrial robots and other materials handling equipment into sub-systems known as manufacturing cells or "flexible manufacturing systems" could become a widespread reality in the very near future.[27, 28]

CAD/CAM is expected to have a widespread impact on the Canadian manufacturing industry spread across many sectors as follows.[29] These estimates have been arrived at by considering jointly the economic contribution of each sector to the total GNP, and the probable impact of CAD/CAM technology on that sector.

		% of total impact
Manufacturing Industries		49.1
Transportation Equipment	8.3	
Metal fabricating industries	7.6	
Electrical products industries	4.6	
Food and beverage industries	5.2	
Primary metals industries	4.8	
Paper and allied industries	3.0	
Printing, publishing & allied industries	2.7	
Leather, textile, knitting, clothing	3.7	
other manufacturing industries	9.9	
Construction Industry		8.4
Transportation, Storage and Communication		11.0
Wholesale trade		10.9
Retail Trade		5.5
Public Administsration and Defence		6.0
All other, not specifically identified above		9.1
Total		100 %

It will be noted that the above figures give estimates for the relative impact of CAD/CAM technology on major sectors of the economy, but do not estimate the magnitude of the impact in absolute terms. This is much more difficult to estimate. It has been the subject of a major study in the USA[30] and has been the subject of much discussion and debate in other countries, most notably the U.K.[31-36]. One writer, highly familiar with the U.K. evaluations, sees the Canadian manufacturing industry as being particularly vulnerable to the negative effects of the micro-electronics revolution unless strong and immediate measures are taken to adopt this technology[37].

A senior computer industry executive in the U.S.A. cites the computer as a vital factor in productivity improvement and estimates that over the last decade computer usage has provided at least 15% of the 2% annual growth in productivity in the U.S.A. He further estimates that this can be improved even further due to new computer price/performance ratios being achieved, and that an incremental percentage point improvement in productivity achieved in this way could accelerate economic growth in the USA sufficiently to drive unemployment down to 3.4% by 1990[38].

A Comparison of CAD/CAM and Process Computer Control

It is useful to consider some of the similarities and differences between CAD/CAM and process control. As indicated in Table IV both are real time, embedded, computer implemented, systems. The term "embedded" means that the computer is not employed in a stand alone configuration, but is employed within a system configuration that involves other types of equipment as well. Increasingly, and especially with microprocessor applications, the computer's presence may not be obvious to the eye since it may even be contained within other forms of equipment, instrumentation, machine tools, test equipment and so forth. Both process control and CAD/CAM systems use sensor based inputs, but these account for a greater percentage of the input information processed in process control applications than in CAD/CAM. In CAD systems much of the initial input information is of human origin. However, as the information handled progresses through the various stages of the design process, there is an expanding data base of information to be handled, in which more and more information has been computer generated in previous phases. Consequently a declining percentage can be attributed to the initial statement of requirements and human input that initiated the process. Thus data base design is much more important in CAD/CAM, and a much more severe system design problem, than in process control.

In processs control the computer outputs are mainly transmitted to electronic instrumentation controllers, or to valve actuators as in the case of direct digital control (DDC). A reasonably well developed systems methodology has developed in this area, although it is by no means static or complete.[39]

Most CAD systems today still produce drawings and other forms of hard copy output as an essential communication media, although the linking of the CAD output to the CAM input, and subsequent elimination of drawings and paper as an unnecessary intermediate step, has been undertaken in selected instances. A notable example in Canada is an integrated CAD/CAM system for the design and production of dies used to produce aluminum extrusions[40].

A significant difference exists in that application of process control computer systems, at least in the initial 1960's development period, were almost exclusively restricted to large scale plants and processes. Only large plants and major processes, which were already capital intensive rather than labour intensive, had the volume of product throughput necessary to achieve the savings necessary. When the minimum price for a process control computer system was $250,000, savings in the order of $500 per day were essential[41]. Unless the process to be controlled had a product value throughtput in the order of $15,000 per day ($4 million per year) or more, it was not likely a candidate for computer control. Reductions in the cost of computer systems by a factor of 10 to 100 have totally altered that situation. Computer aided manufacturing systems are now reaching the discrete parts manufacturing industry and other sectors which are much less capital intensive. Because of this, the socio-economic impact of CAD/CAM can be expected to be much greater than has been the case for process control. This is a two edged sword, because it can either create new wealth and employment, or particularly if not used, could be a major cause of non-competitiveness and economic decline.

Conclusion

Since 1959 the technology for the application of computers to the real time control of industrial processes has been under continuous development. Dramatic reductions in the cost of computers have taken place and today there is a much greater capability worldwide for the implementation of such systems.

Initially, and for some time following, these applications were limited to capital intensive processes which alone had the high production and value of product throughput necessary to achieve the substantial cost savings which would then make installations of expensive computer hardware economically attractive and worthwhile. Consequently, savings initially were primarily due to more efficient use of the plant, materials and energy, or improvements in quality control. Since these plants and processes were generally already highly mechanized the labour displacement effects were relatively minimal.

Reductions in the cost of computer systems have now taken place whereby applications of computers to the direct operation of production processes in secondary manufacturing is now possible and has commenced on a wide scale. Improvements in productivity even greater than before are likely. However, the labour displacement effects of this new wave of activity are likely to be much more significant, because the manufacturing and other processes affected are much less capital intensive than before.

The successful introduction of this technology into a national economy requires an optimal strategy because it could be overdone or underdone. If underdone, the manufacturing industry could become internationally non-competitive. Exports would fall, and imports would rise

The effects may be clearer to visualize if a single firm or organization is considered. If the competitive situation became acute and the firm could not sell its products, everyone in the firm could face a loss of employment. Alternatively when the new technology is applied, and productivity improvements realized, the labour displacement effects are limited to a much smaller number of employees. If at the same time the new production efficiency is used to enter new markets, and make possible the production of new products and services, the net impact can be positive rather than negative. It is also a dynamic optimal control problem because timeliness is important. Phase lags due to technology transfer, and more importantly technology diffusion, could be highly detrimental.

The desired positive outcome can only be achieved if there is a very full and widespread understanding with cooperation and support by industry, government, labour and the public at large.

One has only to look back to the time when entire populations were engaged in meeting basic needs for food, clothing and shelter, and then to consider the advances in productivity that have taken place, to realize that our whole society today depends for its very existence on the development and use of the technology which has made it possible. How else could we afford time for the pursuit of arts, craft, literature, hobbies, sports, entertainment, leisure and travel? How else could society afford and establish all the capital investments and services that are ours to use and enjoy; roads, highways, homes, buildings, schools? Because much of what we see today began before we were born, or has been built by our fellow citizens, it is easy to think of expecting these things as a right rather than as an earned privilege. It may seem easier to think of demanding ones "rights", than to recognize and focus on the basic means of production. If we are to have wealth to distribute in the future we must focus on the mechanisms for the creation of wealth, as much as on the mechanisms for its distribution. That means there must be a continued development of technology, innovation and an attendant reward for risk.

Table I

CAD CAM TECHNOLOGY ADVANCEMENT COUNCIL

Terms of Reference

MAJOR ROLES

- To provide a focal point for the acquisition and dissemination of information concerning these technologies.
- To identify general areas where Canadian industry can successfully utilize these technologies and to make these opportunities known to both potential users and suppliers.
- To recommend possible actions to encourage the rapid adoption of these technologies.

ACTIVITIES

- To provide a centralized source of timely knowledge about existing technology, including the assessment of technological development abroad, and to publicize these findings through seminars, meetings, publications and other forms of media.
- To promote liaison and constructive working relationships between the various interested parties capable of contributing to the greater use of these technologies by Canadian industry through seminars, workshops, and formal or informal meetings, in co-operation with existing professional and industrial associations and societies where possible.
- To maintain liaison with foreign organizations and associations which are engaged in fostering technological improvement and increased productivity in manufacturing, through the application of these technologies.
- To undertake studies or investigations to identify general areas in Canadian industry where economic application of these technologies are possible and to communicate this information to interested parties.
- To make recommendations to the Department of Industry, Trade and Commerce regarding initiatives to encourage the use of these technologies, and to stimulate the design, development, production and marketing in Canada of the related products and services.

Table II

MEMBERS OF THE CAD/CAM TECHNOLOGY ADVANCEMENT COUNCIL

J. Nassr (Chairman)
CAPCL
Montreal, Quebec

J. Davies
Maclean-Hunter Limited
Toronto, Ontario

R. Fielding
Alcan Products Limited
Kingston, Ontario

W. Beairsto
Canada Systems Group
Toronto, Ontario

H.T. Watt
Computer Assembly Systems Ltd.
Brockville, Ontario

J. Kershaw
Chicopee Manufacturing
Kitchener, Ontario

A.M. Lount
CADSYS Limited
Edmonton, Alberta

J.K. Pulfer
National Research Council
Ottawa, Ontario

J. Scrimgeour
Department of Industry, Trade and Commerce
Ottawa, Ontario

B. Smith
Bell Northern Research
Ottawa, Ontario

F.O. Price (D. Dunbar)
for Canadian Manufacturers Association
Toronto, Ontario

Professor D. Bonham
University of New Brunswick
Fredericton, New Brunswick

J.E. Crozier
McMaster University
Hamilton, Ontario

J.R. Dickinson
University of Western Ontario
London, Ontario

Professor D. French
University of Waterloo
Waterloo, Ontario

N. Gardner
Department of Industry, Trade and Commerce
Ottawa, Ontario

J. Vincent
Department of Industry, Trade and Commerce
Ottawa, Ontario

Table III

SUMMARY OF CAD/CAM TECHNOLOGY

Computer Aided Design	-	Product design and analysis including graphic design, functional analysis, stress strain analysis, heat and material balances, simulation and modelling, data reduction and analysis and cost estimating of the proposed product or system to determine fitness of purpose and economically optimized production.
Customer Order Handling	-	Record keeping, tracking and reporting on the status of individual customer orders, particularly when part of an integrated on-line system.
Production, Material & Inventory Control	-	Scheduling and information handling pertaining to material requirements planning, inventory control, facilities planning and order scheduling, particularly when related to an integrated on-line system.
Automated Production	-	Numerical and computer control of machine tools, lathes, milling, boring machines, pattern and fabric cutting, welding, brazing, plating, flow soldering, casting, flame cutting, spray painting (all of these exist and are under further development).
Automated Material Handling	-	Integrated materials handling using computer operated conveyors, robotic units, etc.
Automated Testing	-	Automated inspection of machined parts, testing of electronic components, circuits and products, automated material inspection and grading using sensor based computer systems, pattern recognition.
Automated Packaging	-	Computer implemented coordination of material and information in packaging, bottling, labelling and weighing systems.
Automated Warehousing	-	Computer implemented order picking and material handling for both work in progress inventory and finished goods inventory. Automatic label reading, routing of packages, parcels, baggage in shipping, sorting and distribution centers.

Notes: - CAD/CAM technology will yield its greatest economic and productivity gains when all or most of the above application areas are married or joined together to form an integrated system. Hence there is a strong development trend in this direction.

Table IV

SOME SIMILARITIES & DIFFERENCES BETWEEN CAD/CAM AND PROCESS CONTROL

Attribute	Process Control	CAD/CAM
Computer implemented	Yes	Yes
Real time sytem	Yes	Yes
Embedded System	Yes	Yes
Sensor based inputs	Main source for most information in system (Pressure, temperature flow etc, etc.).	Minor portion of information in system. Mostly events, timing, etc.
Input of human origin	Minor portion of information in system. (set points, etc.)	Major source of information.(Design configurations, production status, order status, information).
Expanding data base	No	Yes
Process control	Major purpose is feedback or feed forward control in classic sense. Major process units included within these loops, process gains & dynamics important.	Orientation is more towards the mere handling, timing, release etc. of large volumes of information.
Output interfaces	Set point stations, valves, etc.	Plotters, machine tools, wiring machines, flame cutters, robotic units, automatic test equipment.
Predominant user industries	Chemical, petroleum, steel, pulp and paper.	Discrete parts manufacturing, (transportation equipment, machinery, etc.)
Socio-economic impact	Modest	Much larger
Main period of pioneering	1960-1975	1975-1990

Fig. 1 - The Expanding Base of Computer Applications

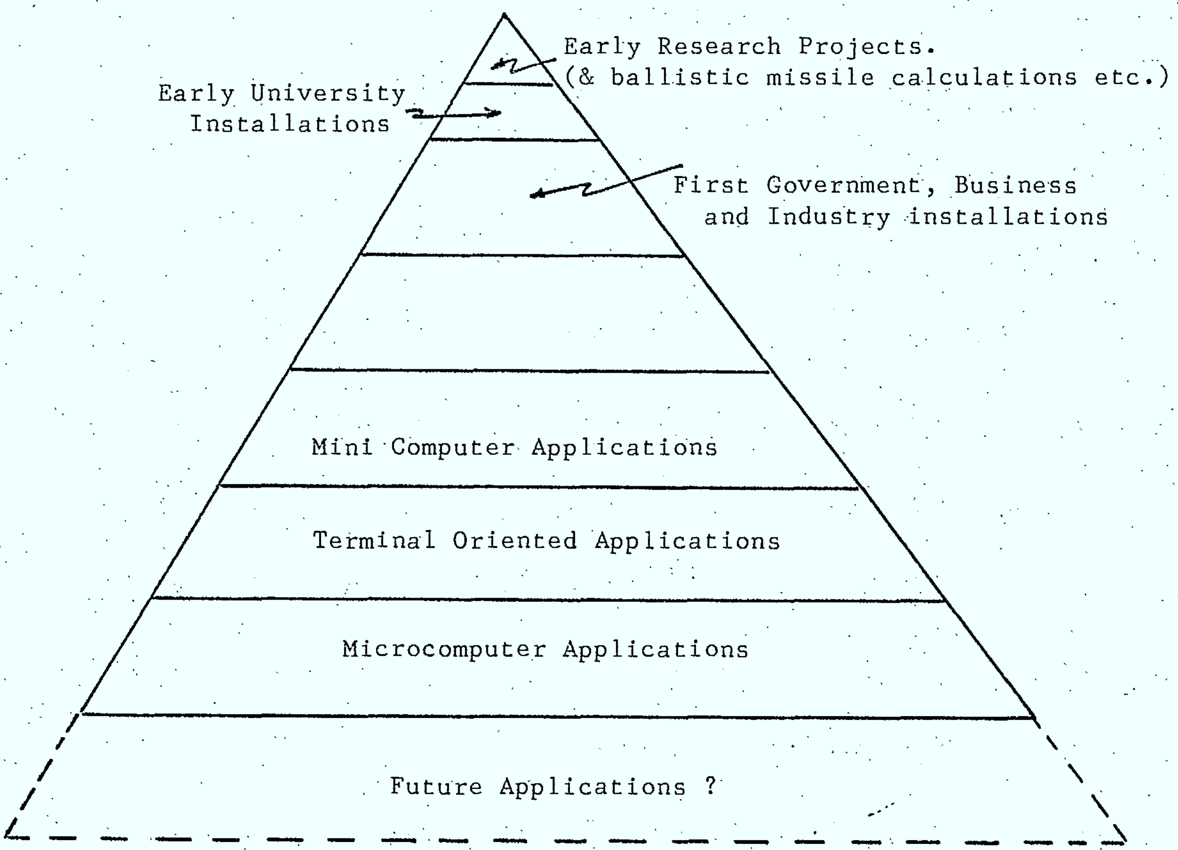


Fig. 2 - Growth in Process Control Computer Installations

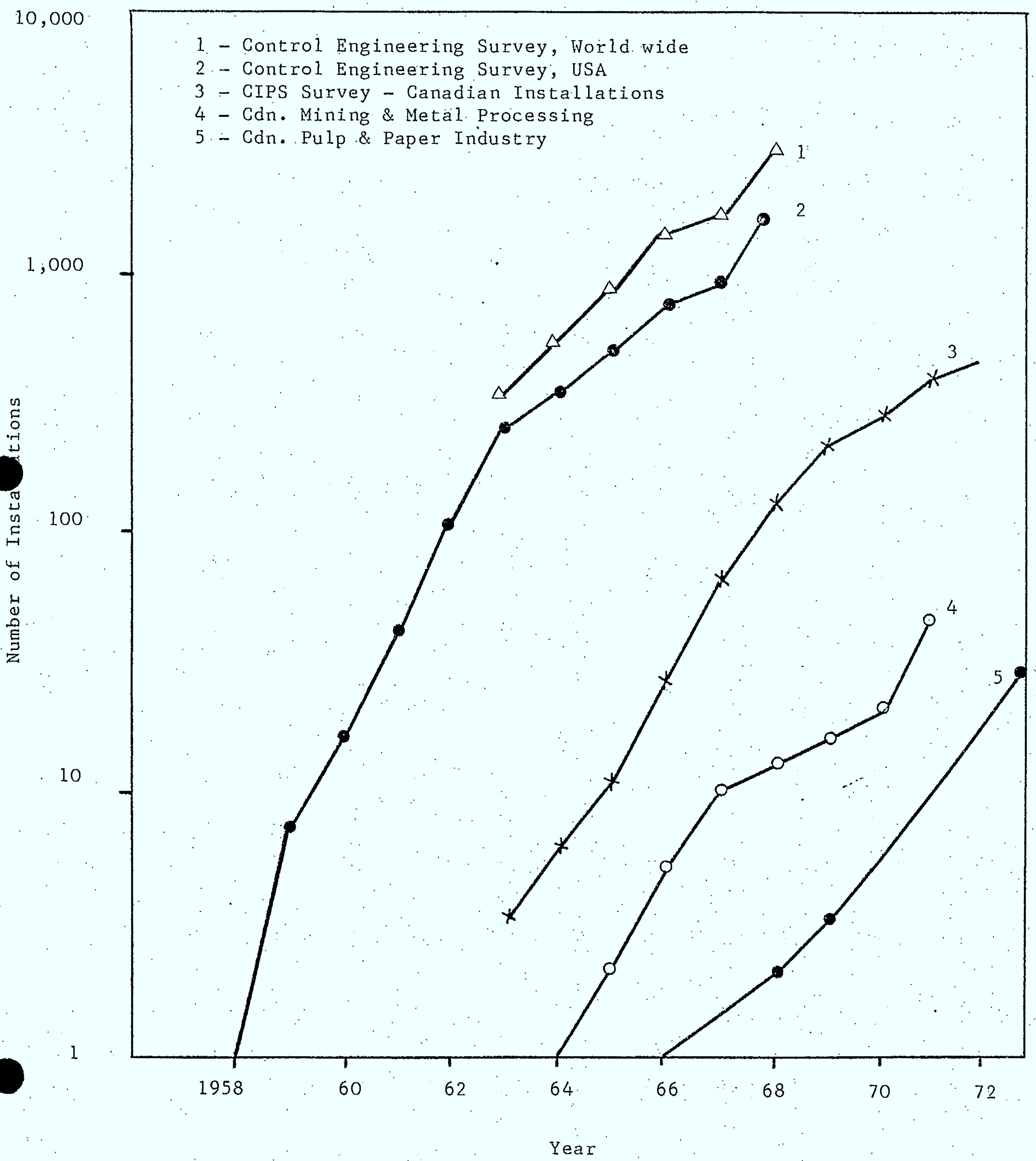


Fig. 3 - Phases in the Introduction of a New Technology

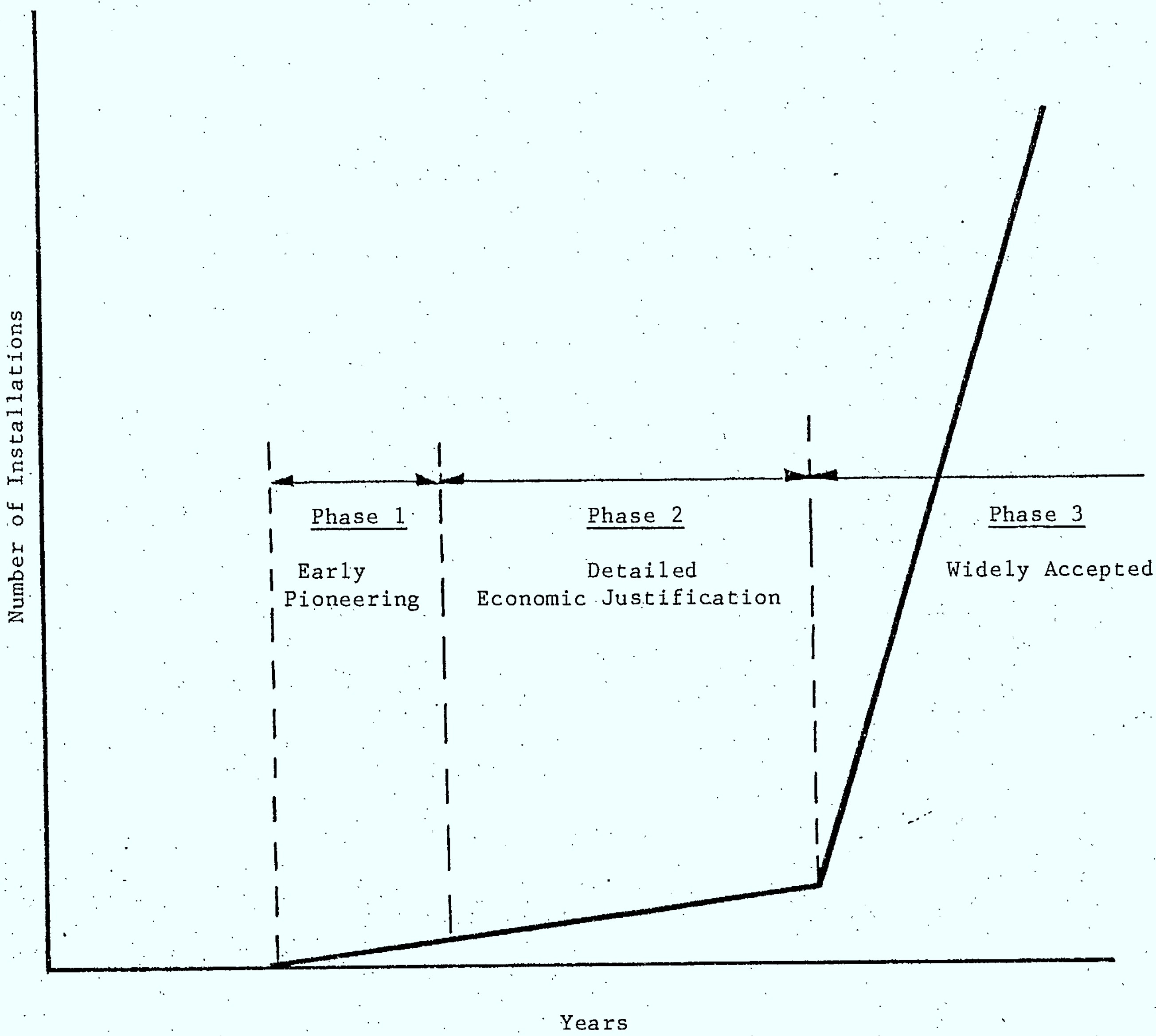
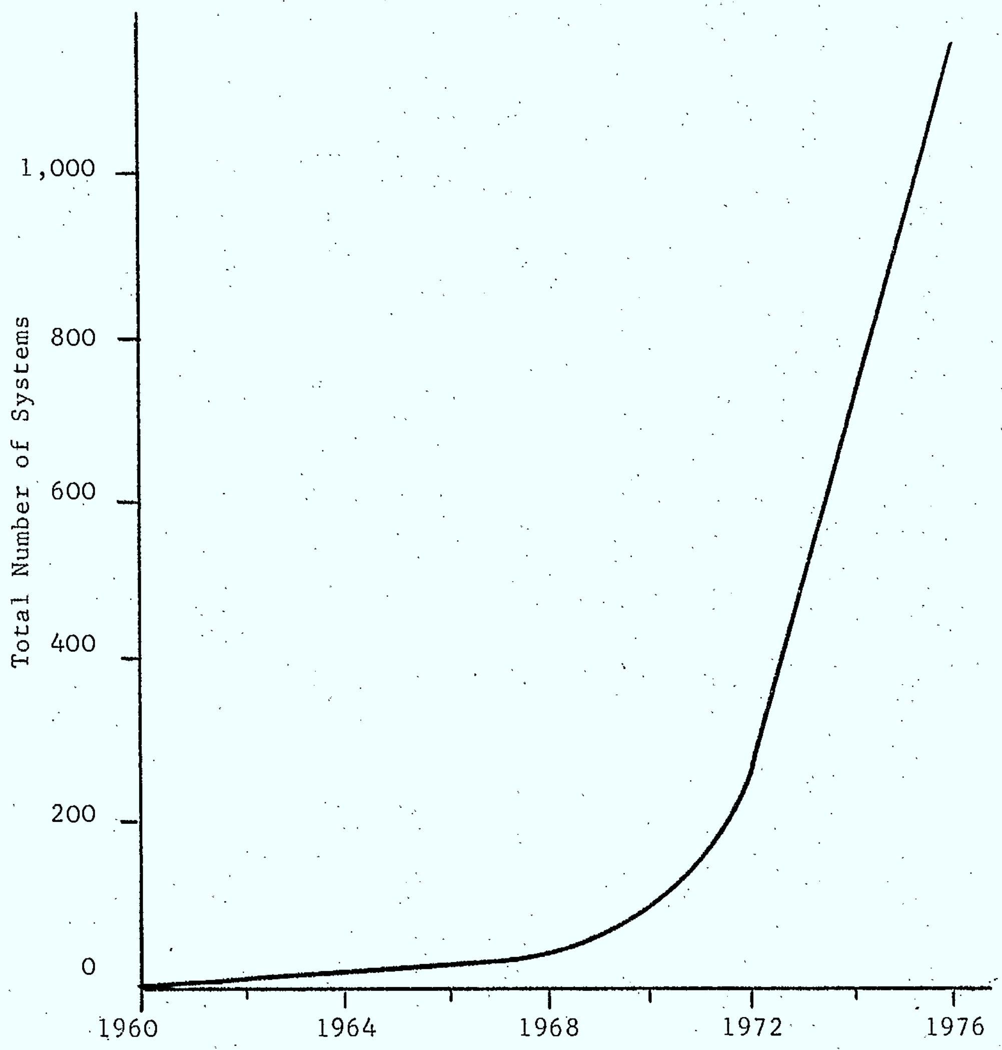


Fig. 4 - Growth of Computer Applications in the Pulp and Paper Industry



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