Strategy for Survival

The Canadian CAD/CAM Option

A report by the

CAD/CAM Technology Advancement Council*

to

Canadian Industry, Educational Institutions & Government

as a Contribution to Manufacturing Industry

Productivity Improvement and Development

September 1980

Note:

Copies of the CAD/CAM Council 1980 report are available in the following form:

- Executive Summary (approximately 3 pages)
- Condensed Report (as herein)
- Full Report (approximately 190 pages).

* Secretariat
Technology Branch (61)
Department of Industry, Trade & Commerce
235 Sparks Street
Ottawa, Ontario
Canada
K1A 0H5
(613) 593-7861

- Aussi disponible en français.

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Preface

In terms of long term growth and job creation, the manufacturing industries are one of the most important sectors of the total Canadian economy, yet manufacturing industry employment, as a percentage of the total labour force is on a declining trend. Productivity will be especially important to the Canadian manufacturing industries in the 1980's if traditional markets are to be retained and new ones gained in the face of lowered tariff protection and increasing external competition.

In this context, the rapidly emerging use of Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) technology is of special importance.

With the advent of CAD/CAM, it will become increasingly evident in the 1980's that the design of the factory is just as important as the design of the product. Developments will lead increasingly to the marriage of both Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) into highly integrated design and production systems.

In Canada, the Department of Industry, Trade and Commerce established a CAD/CAM Technology Advancement Council in 1978, with members from industry, universities, and government. Objectives of the council include increasing the awareness in industry, and elsewhere, of the importance of this technology, and dissemination of information to encourage and assist CAD/CAM development and application in Canadian industry. The council report, addressed to Canadian industry, educational institutions and government has been prepared to further these objectives, as a contribution to productivity improvement, and to the renewed development of a strong manufacturing industry.

Executive Summary

The council report identifies many issues, discusses each in turn and makes specific recommendations. In summary, however, the council makes three main recommendations, one each to government, industry, and educational institutions.

A - To government, council recommends that a small inter-departmental task force be formed to prepare a formal response to the recommendations involving government contained throughout the report, and to initiate action where appropriate. There is a degree of urgency to this. Priority should be given to establishing the proposed Canadian Centre for CAD/CAM in an effective manner at the earliest date possible, and to those recommendations concerned with awareness, manpower, education and training.

B - Council recommends to industry that virtually every manufacturing company in Canada should designate at least one person in a technical management capacity within the organization to become aware of developments in CAD/CAM technology, if this is not already being done, and to plan the response of the firm to the threats and opportunities that this new technology involves. A second step should be to establish links and mechanisms through development centres and technical societies for the definition and undertaking of projects meeting common needs on a group basis at minimum cost.

C - To educational institutions, particularly, universities and community colleges, council recommends that they examine their course curricula to ensure that CAD/CAM technology, particularly its systems and application nature, is adequately represented. It is further recommended that educational institutions examine opportunities open to them for the education and training of personnel in industry in computer aided design and computer aided manufacturing, with emphasis being given to course material and programs for in-plant training.

The technical and economic factors associated with CAD/CAM systems will cause the technology to be adopted in industry at a rapid rate, particularly in Japan, Germany and the U.S.A. There is therefore a degree of urgency, for competitive reasons, to the recommendations contained in this report. It would appear urgent and essential that the federal government should form an inter-departmental task force at the management and technical level to, first, prepare a formal response to the recommendations of this report and, secondly, to undertake or initiate action as may be appropriate.

The primary recommendation of the report is concerned with the establishment of a Canadian centre for CAD/CAM. The centre's activities would include an information dissemination role, and the contracting out of coordinated research and development projects to other centres, institutions and companies.

I INTRODUCTION AND OVERVIEW

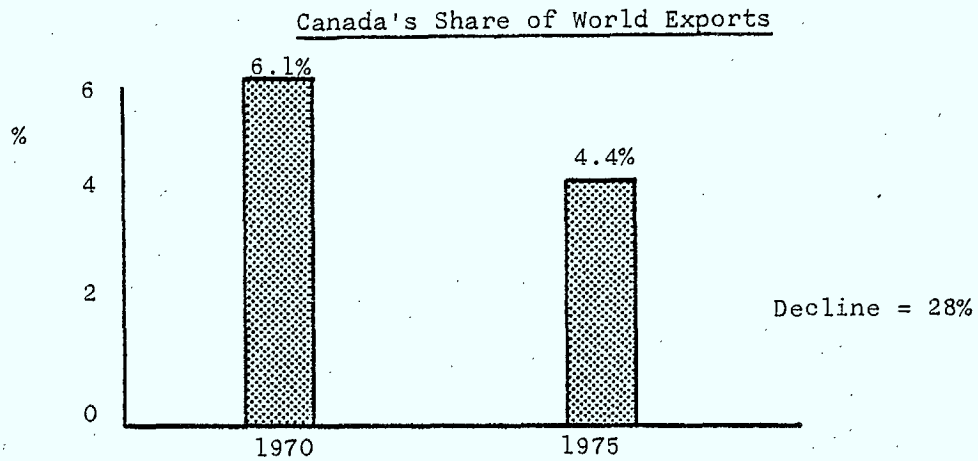
Productivity will be especially important to Canadian manufacturers in the 1980s. During this decade, tariff protection will be lowered, competition from external sources will undoubtedly increase, and inflation will continue at a strong pace. At the same time a new world wide wave of industrial automation, based on a rapidly increasing use of computers in design and manufacturing, is occuring.

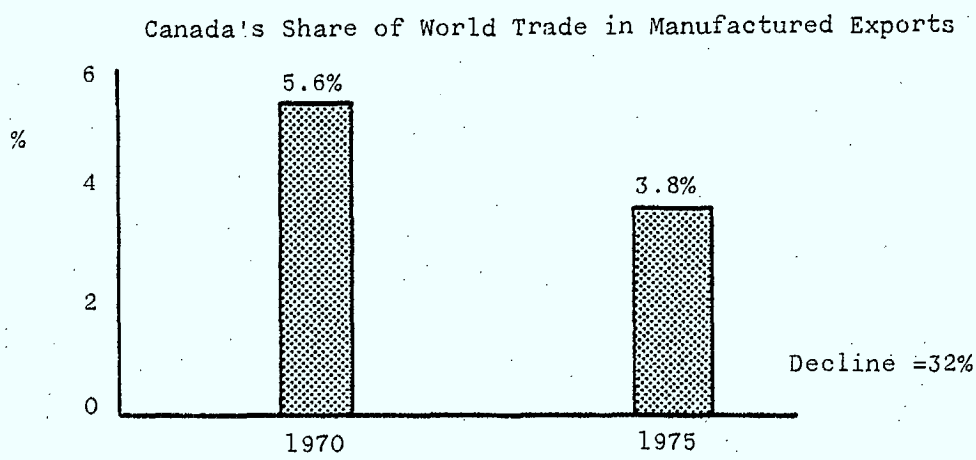
As a result of the latest round of trade negotiations, Canadian industry will face increasing competition from imported products. At the same time, our industry will have better access to foreign markets. However, to compete successfully in this new trading environment, Canadian industry will have to achieve levels of performance, in terms of productivity and technical excellence, equivalent or superior to industry in other countries, whereas Figures 1 and 2 indicate Canada's current declining trend in export performance and productivity improvement in manufacturing relative to other nations.

Although industry is always faced with the challenge of productivity improvement, most advances occur when new technologies are recognized and incorporated into the business of the firm. Three widely accepted key factors and opportunities for raising productivity are: (1)

- employee participation;
- the use of advanced technology; and
- tax legislation for faster amortization of capital investment.

FIG. 1 - TRENDS IN EXPORT PERFORMANCE





Source - Science Council of Canada "Forging the Links - A Technology Policy for Canada" 1979

The use of computer aided design and computer aided manufacturing (CAD/CAM) has been identified by industry leaders and governments in the industrialized countries as a new, rapidly emerging, and key technology, having particular impact on manufacturing industry productivity and competitiveness. Especially in Germany and Japan, and to a lesser degree, in the United Kingdom and the U.S.A., governments and industry are working together in the national interest on the development and rapid application of this technology.

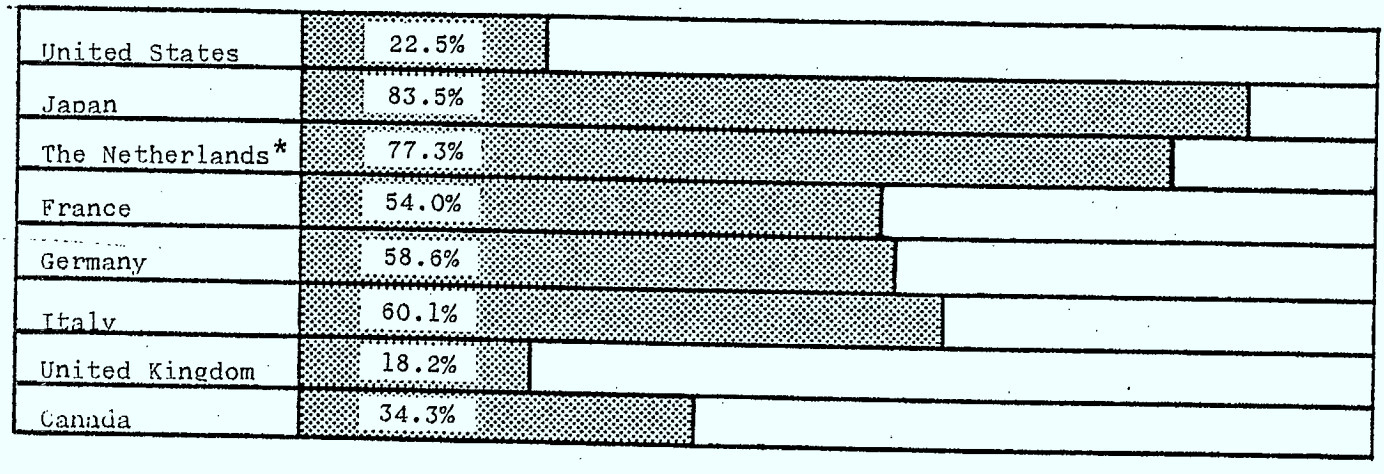
It is important to recognize that the general and widespread revolution in information processing involves at least two main thrusts: firstly, the relatively straightforward processing of large volumes of information, as in service industry and office applications of word processing and communications equipment; secondly, a new wave of factory automation involving computer aided design and computer aided manufacturing. The latter technology, the subject of this report, is of particular importance to the discrete parts manufacturing industry which comprises a very large portion of the manufacturing industry.

The CAD/CAM thrust in the manufacturing sector requires large amounts of user oriented, mechanical, process and systems engineering. With the advent of CAD/CAM, it will become increasingly evident in the 1980s that the design of the factory will be just as important as the design of the product. Development will lead increasingly to the marriage of both CAD and CAM into integrated design and production systems.

What is CAD/CAM Technology?[2]

When the use of computers first began in Canadian industry in the mid 1950s, the emphasis was on engineering computation. In the

FIG. 2 - PRODUCTIVITY INCREASE IN MANUFACTURING 1968-1977



* 68-76

Source - U.S. Department of Labour May 1978

intervening 25 years, the capabilities of electronic computing power have evolved from initial emphasis on computation ability to the inclusion of logical ability, memory and the current great emphasis on graphic display and output.

CAD uses all of these abilities. Of particular note, the advent of graphic displays has enabled the automation of the draftsman's task as well as the engineer's. Due to this enlargement in scope, the name of the activity has been appropriately changed from engineering computation to Computer Aided Design, widely abbreviated as CAD.

Computers have also been employed in manufacturing for many years. However their use is now taking on a new involvement in the more direct control of production equipment and is assuming a more total systems nature.

Most manufacturing companies initial use of computers was not on the factory floor, but indirectly in support of production planning and inventory control. At the same time, the concept of numerical control had been revolutionizing the machine tool industry. Today, NC users employ computers not only for parts programming, but also for local control of machine tools. Increasingly, this is being done with groups of machine tools supervised by a single computer. This principle is being applied not only to metal cutting and removal, but to other manufacturing processes as well. Interconnected computer systems can make the totally automated factory a reality from initial design/conception through to final manufacture, test and shipment.

CHRONOLOGICAL EVOLUTION OF COMPUTER SKILLS

computation ability	-	The ability to perform lengthy calculations at high speed.
logical ability	-	The ability to make pre-programmed decisions; to look through multiple cases and to optimize.
memory	-	The ability to handle large or small files of data swiftly, accurately, and without loss of information.
graphic display	-	The ability to print not only alpha-numeric information, but also graphic information presented as lines, curves and drawings.

All of the sub-systems for fully automated production are available in some form now. These include computer graphics, computer generated parts lists, centralized data bases, computer controlled stacker cranes, computer controlled material handling for delivery of components, direct computer control of machine tools, automatic inspection and test equipment. Their further development and inter-connection into a total manufacturing system is only a matter of time. This will have a dramatic effect on the design and layout not only of modern manufacturing plants, but warehouses as well.

CAD/CAM should not be thought of as being only synonymous with the numerical control of machine tools. It really refers to the entire manufacturing process as summarized in Table I and illustrated in Figure 3. Many significant mechanical, process and systems engineering tasks are included and accomplished in such systems.

Studies have shown that in many shops, the average work piece spends only 5% of its time in the machine, with moving and waiting between operations accounting for most of its production lifetime. Furthermore, studies on cutting machines show that of this 5% in the machine, only 30% of the production time is actually employed in the fundamental task, which is metal removal. In the general machinery industry, these inefficiencies drive up the cost of work in process inventory, a figure of 22% of annual sales being generally reported.

The economic justifications for CAD/CAM include:

- Increased utilization and more efficient use of machine tools and other capital equipment.

- Faster delivery time to the customer.

- Reduced work in progress inventory.
- A more disciplined approach to both design and manufacture
- Greater design creativity through computer graphics use
- Cost reduction through design optimization
- Improved use of materials through family of parts classification and coding
- Reduced scrap material by minimizing fabrication errors
- Improved quality control through NC machining accuracy, repeatability and automated testing
- Improved coordination and information transfer between engineering, production control, manufacturing and accounting
- General productivity improvement of the available workforce
- Automation of one-off parts and short production runs

Advances in Computer Technology[3,4]

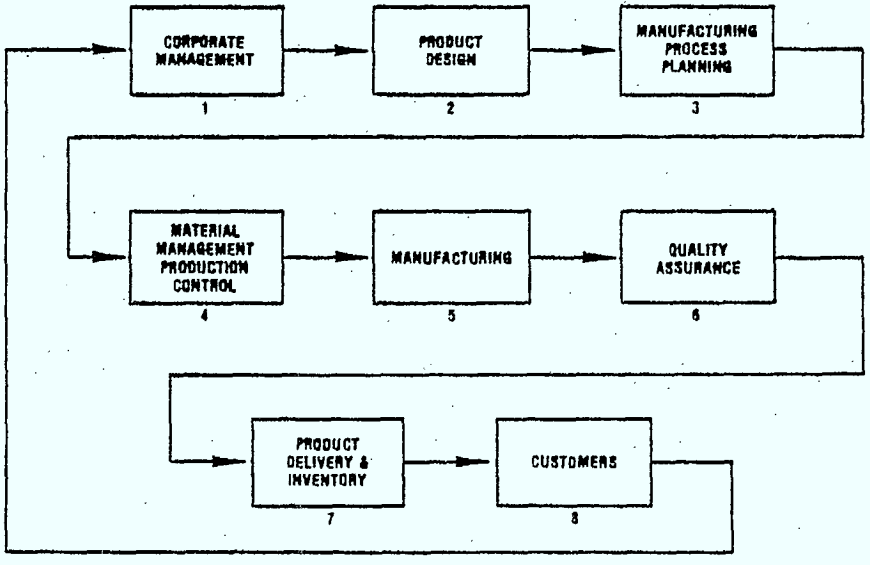
It should be clearly understood that the computer is applied in CAD/CAM systems as an available tool. CAD/CAM technology is of a systems, mechanical and manufacturing engineering nature, and needs to be developed "in-house" by the user. It would be a mistake, therefore, to consider "CAD/CAM" as a product developed and supplied solely, or even primarily, by the electronics industry. Figure 4 illustrates some of the many technologies involved.

It is the continued improvement in the performance/cost ratio of available computers that makes applications like CAD/CAM possible. The improved economics and performance of computers are the result of increasing density of logic and memory devices, embodied today in the term "micro-electronics" and typified by the ubiquitous and pervasive microprocessor.

Comparatively low cost computing power and data storage devices, coupled with an expanding awareness of computers, has made possible a continual supply of new applications. There are many ways of plotting this trend, much of which can be related to advances in micro-electronics technology, very large scale integration (VLSI) and the microcomputer in particular. For example, the number of components per circuit has doubled every year since 1959, resulting in a thousand-fold increase every 10 years.[5] This trend in miniaturization is expected to continue.[6]

At the user level, improvements in the computer price/-performance ratio have improved annually by a factor of about 32% for memory, 23% for logic and 11% for communications.[7] Such improvements of 10 to 1 or better every ten years mean that a

FIG. 3 - FLOW TASKS FOR MANUFACTURING



Source - Proceedings 1978 CAM-I International Spring Seminar

TABLE 1

SUMMARY OF CAD/CAM APPLICATION AREAS

Computer Aided Design	- Production 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 and automated assembly (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. Automated label reading, routing of packages, parcels, baggage in shipping, sorting and distribution centers.

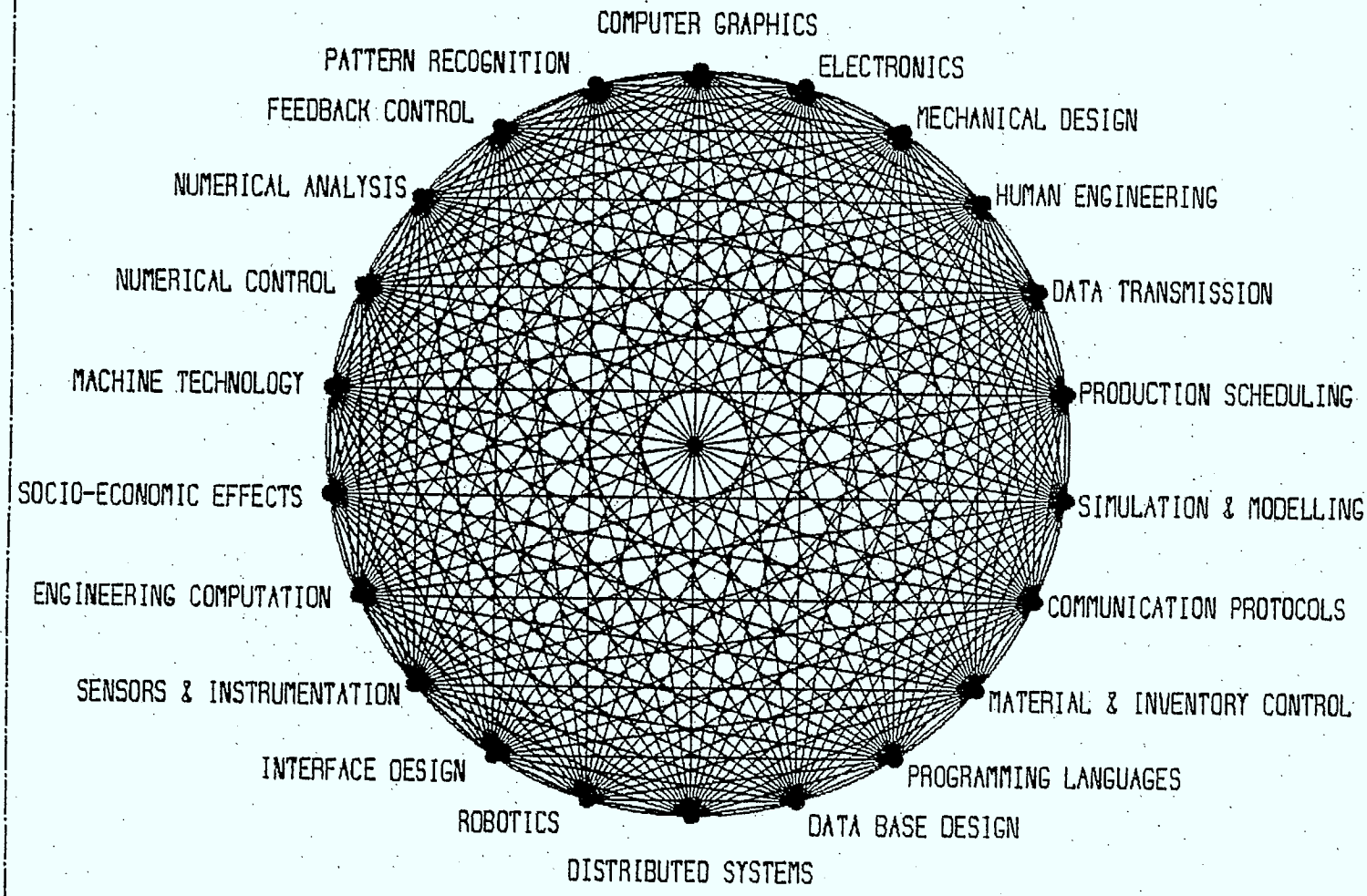
Notes: - CAD/CAM technology will yield its greatest economic and productivity gains when all or most of the above application areas are married or joined together to form an integrated system. Hence there is a strong development trend in this direction.

calculation costing $1000 in the early days of computing would cost only $10 in 1972 and a mere dollar in 1982!

In the light of these trends in manufacturing industry automation, the Federal Department of Industry, Trade & Commerce established a CAD/CAM Technology Advancement Council in 1978. Its membership is drawn from industry, universities and government. Objectives include increasing the awareness in industry, and elsewhere, of the importance of this technology, and dissemination of information to encourage and assist CAD/CAM development and application in Canadian industry.

This report has been prepared by the Council as one of its activities to further these objectives, as a contribution to productivity improvement, and to the renewed development of a strong manufacturing industry. There is a degree of urgency to this in terms of national development as Canada makes the transition to a modern, industrial society.

FIGURE 4 CAD/CAM TECHNOLOGIES & THEIR INTERELATIONSHIPS.



COMPUTER GRAPHICS BY -CADSYS LTD- VANCOUVER

II

A Case for the Timely Exploitation of

CAD/CAM Technology

II A Case for the Timely Exploitation of CAD/CAM Technology

Canadians must realize that CAD/CAM technology is an essential tool in building Canada's economy. It is critical that a national policy be adopted to disseminate information and encourage the development of CAD/CAM technology in support of industry.

It is essential that a domestic infrastructure be established that is fully cognizant of the application as well as the means of economically deploying CAD/CAM technology. Industry cannot rely solely on importation of this advanced technology, as this by itself would not be adequate to ensure a Canadian competitive position.

There are Canadians with demonstrated ability to advance the technology but they are few in number. A national policy to support these existing skills in a structure that addresses the needs of Canadian industry will enable Canada to establish a position as a modern industrial nation. This policy will directly encourage the continued growth of the industrial sector.

There is a need for a major information dissemination and contracting centre in Canada for the cooperative development of user oriented CAD/CAM technology. This is particularly important for smaller businesses which cannot individually support the infrastructure, manpower and high cost of developing software and technology for CAD/CAM applications. Manufacturing firms of virtually all sizes would benefit from coordinated efforts managed by the centre to arrange development of applications of special interest to Canadian industry.

Canadian Research & Development Essential

Research and development in CAD/CAM technology must be actively encouraged and supported in Canada. This effort must be coordinated and distributed in order to develop the best possible structure for transferring advanced technology to industry. Importation of this advanced technology, due to the dynamic nature of its development as demonstrated by U.S., Japanese, German, U.K., and Scandinavian companies, will not in itself be adequate to ensure a Canadian competitive position. It is essential that a domestic infrastructure be established that is fully cognizant of the domain of application as well as the means of economically deploying the technology. Other nations have an established lead in various areas as the result of coordinated effort, both public and private, in research, development and application of CAD/CAM. The development period for CAD/CAM systems can be long, due to the amount of detailed knowledge required, but the interval between development and implementation and subsequent economic advantage can be very short. Consequently the time delays inherent in a reliance on the use of imported technology can negate the apparent advantage of this approach.

The cost of developing CAD/CAM systems is high, and the skills required are sophisticated. For successful timely implementation, it is essential that where possible costs be shared through joint projects and through government assistance. Skills can be developed and employed effectively through a concentration of effort in a few ongoing teams. These development teams would be in technical institutes or universities where long term continuity of effort must be arranged and which might serve any industry desiring their assistance.

In order to keep the R & D work oriented to industrial needs, it is desirable that industry have a direct channel for input in selecting projects for funding and in monitoring the progress of

approved projects. This is best done through a centre devoted to this objective, separate from the institutes and other centres undertaking in-house research and development.

Infrastructure and Educational Support

Educational programs in colleges and universities must be structured to provide the skilled workforce necessary to support an increasingly automated industry. In support of this, seminars and conferences must be organized, and the preparation and development of retraining programs will be required. In-plant training courses and prepared material for self study will be particularly important for personnel in industry.

There is no single strong technical or professional society in Canada concerned with CAD/CAM technology. By its very nature, CAD/CAM tends to fall within the domain of many organizations, none of which have it as a primary endeavour, although some have a stronger or more direct interest than others. (see appendix IV) Technical and professional societies, such as the Society of Manufacturing Engineers (SME) and the Numerical Control Society (NCS) and others based in the U.S.A. maintain local chapters in many Canadian cities as appropriate. While there are many advantages achieved from membership in these large organizations, they do by their very nature make more difficult the establishment of an "East-West" infrastructure, channels of information flow and societies within Canada, which needs therefore to be strengthened.

CAD/CAM technology is itself marketable. While first priority would be on meeting user needs, the establishment of a Canadian Centre for CAD/CAM Technology will, by encouraging structured coherent development, enhance the possibility for sale of Canadian developed CAD/CAM systems and applications knowledge in both domestic and export markets.

A Canadian centre would demonstrate the application of existing technology and would provide technological leadership through the dissemination of reports, and the organization of seminars and CAD/CAM courses. The centre would also be active in funding original work particularly suited to Canadian conditions by the placement of shared cost development projects at other centres and companies. It would enable participating companies to share software and technology and ensure that Canadian industry remains competitive by applying the latest CAD/CAM developments.

Centres serving as focal points for CAD/CAM development already exist in Europe and the U.S.A., and parallel centres are active in certain other industrial sectors. For example, in the electric utility field, R & D is coordinated and funded with government assistance by the Canadian Electrical Association.(8) A Canadian Centre for CAD/CAM Technology would play a similar role in its field in Canada.

III

Opportunities for Development of

CAD/CAM Technology in Canada

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CAD or CAM?

In the allocation of funds and the planning of R & D programs, there is a need to make decisions as to the relative emphasis or allocation of effort on CAD or CAM or CAD/CAM integration. Although CAD and CAM do draw together in integrated systems, they are for the most part two separate fields. They will continue to be regarded by many users as separate activities, requiring different experience and different skills.

CAD projects are of a "soft" engineering nature and are more closely related to the historically predominant activities of most engineering departments or university research. Most CAD projects can be undertaken by individuals without the formation of large teams, although discipline, planning and teamwork are required if larger sets of mutually compatible programs are to result.

Some aspects of CAD development work are homogeneous, such as computer graphics, data base design or numerical analysis. However, many parts are not. Separate teams and centres will tend to develop in such areas as: integrated circuits and VLSI; printed circuit board design and layout; building design in the construction industry; design and stress analysis of mechanical parts etc; and industrial robots.

It will seem tempting and "easy" to rely on imported CAD programs, particularly software developed in the U.S.A. On the other hand, the user never really understands a software package as well as its developer. A near total dependance on the source can develop for changes, extensions, in-depth understanding of the program use and

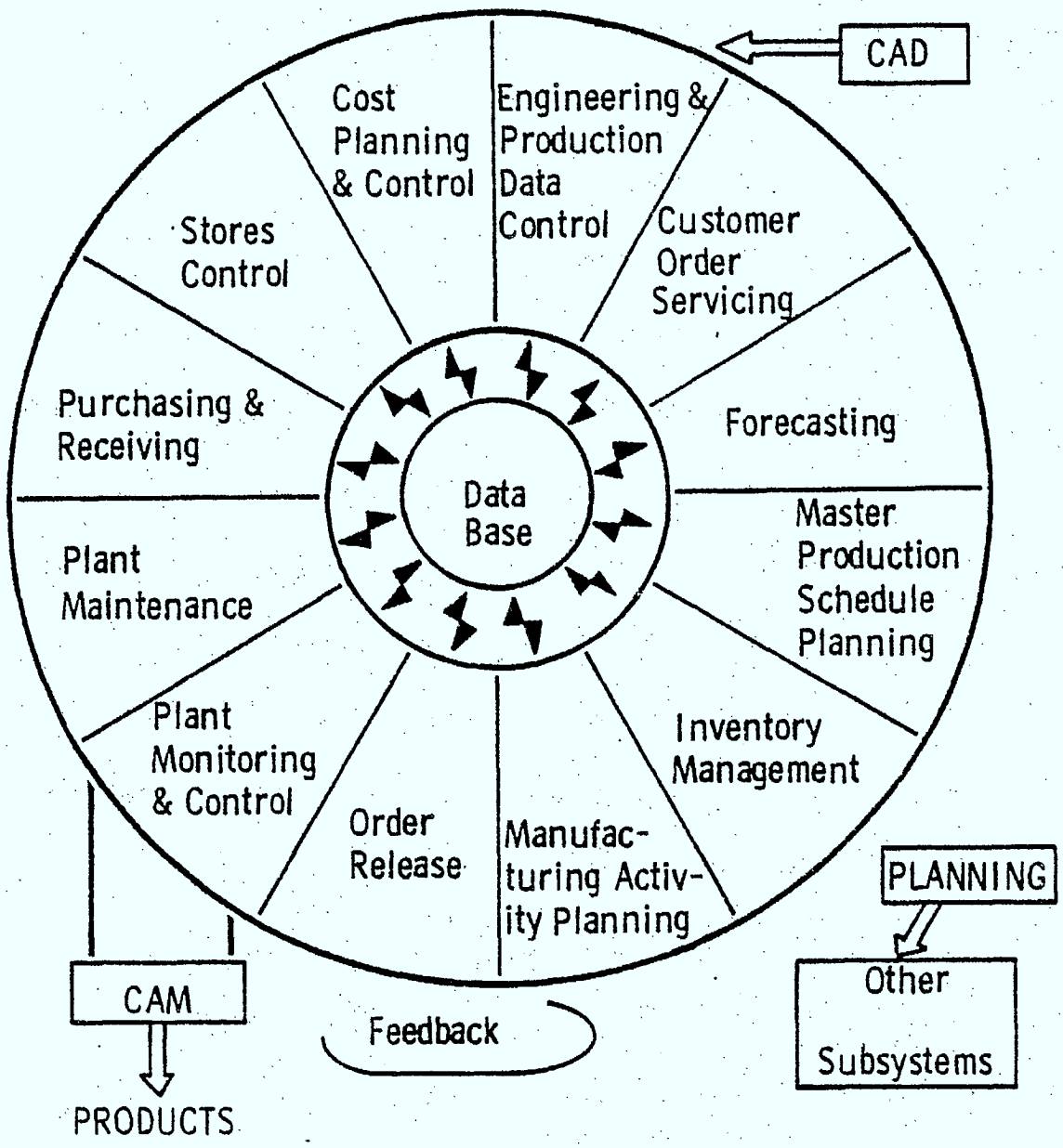
applicability to special conditions. A wide spread use of imported CAD systems, or CAD services imported through remote computing facilities, could result in a near total loss of technological sovereignty for the Canadian manufacturing industry.

The CAM field is probably a more homogeneous field across industry sectors than is the CAD field, particularly in metal cutting. For this reason, it would seem in some ways to be the easier area on which to focus attention. The CAM area is directly related to the potential reductions in manufacturing costs, which for most manufacturing companies are greater than design costs. Furthermore, in the makeup of Canadian industry, while many companies are engaged in manufacturing who do little or no design there are few who design but do not manufacture. These factors would favour early development or emphasis on CAM over CAD.

On the other hand, CAM projects involve "hard" as well as "soft" engineering. There is a greater need in CAM projects for the formulation of teams and teamwork in development. Capital equipment is required in addition to "normal" R & D expenditures and the work is not as closely related to traditional engineering work or university research as usually undertaken in Canada.

In more and more applications, the design and manufacturing applications of computer technology are tending to meld together. This integration is due in part to a greater acceptance of CAD and CAM technologies, but more because the two disciplines can be joined through a central data base, as illustrated in Fig. 5. As CAD/CAM technology develops, especially in mature manufacturing activities, the distinction between the two functions will diminish and eventually become one.

FIG. 5 - CAD AND CAM BECOME INTEGRATED THROUGH THE CENTRAL DATA BASE



Source: Proceedings 1978 CAM-I International Spring Seminar

Technological Change Will Generate Markets

In addition to encouraging the use and application of CAD/CAM systems and equipment throughout Canadian industry, there will be opportunities to develop Canadian sources of supply as new requirements emerge. The user response by Canadian companies to the challenge and opportunities created by this technological change will require substantial investment in new production equipment such as CAD graphic systems, numerically controlled machine tools, industrial robots, other more specialized equipment and in overall systems engineering.

Canadian industry, however, does not have a traditional position of strength in these areas. For example, virtually all the NC machine tools, CAD graphic systems and industrial robots now installed in Canada, have been imported and it can be expected that this trend will continue. However such rapidly changing technology creates the possibility for new suppliers to enter the markets of traditional or established suppliers. Backlogs and long delivery times make it possible for new entrants to gain significant footholds in systems and equipment supply.

Bringing CNC to Workers Unskilled in CAD/CAM Technology

Small metal parts manufacturing companies are often reluctant to introduce CAD/CAM technology. They recognize the real and important mismatch between their skills and those necessary to effectively use NC and CNC techniques. There are a number of ways to provide a better match between these skills. The most obvious, and at present one of the most effective methods, is for the company to use a service bureau or consulting organization as an intermediary. At the present time however there is a substantial use of time sharing computer services involving trans-border data flows for NC parts programming by Canadian manufacturing companies. Alternatives involve encouragement to Canadian based service bureaux and improved design of CNC equipment so that the required skills better match the skills of existing machinists and draftsmen.

Building Design and Construction

The Canadian building design and construction industry makes very little use of CAD/CAM techniques at present. There exists a very real possibility that offshore construction companies using modern technology will capture a significant portion of the Canadian construction market in the near future.

The Department of Public Works has, over the past five years, conducted a program to encourage the wider use of CAD technology to meet their own internal needs and for the benefit of the Canadian construction industry at large. Continuation of the program is currently under consideration, and its future role vis-à-vis the construction industry outside the federal government is under review.

The possible use of CAM techniques, which have not been utilized in building construction to date, may be an additional factor in ensuring that the Canadian construction industry will remain competitive.

Machinery for Low Volume Production

Many sectors of our Canadian manufacturing industry are oriented towards relatively low volume production with small batch sizes. This consequently requires frequent changes in set-up, within established procedures, for material handling, fabrication, assembly and quality control.

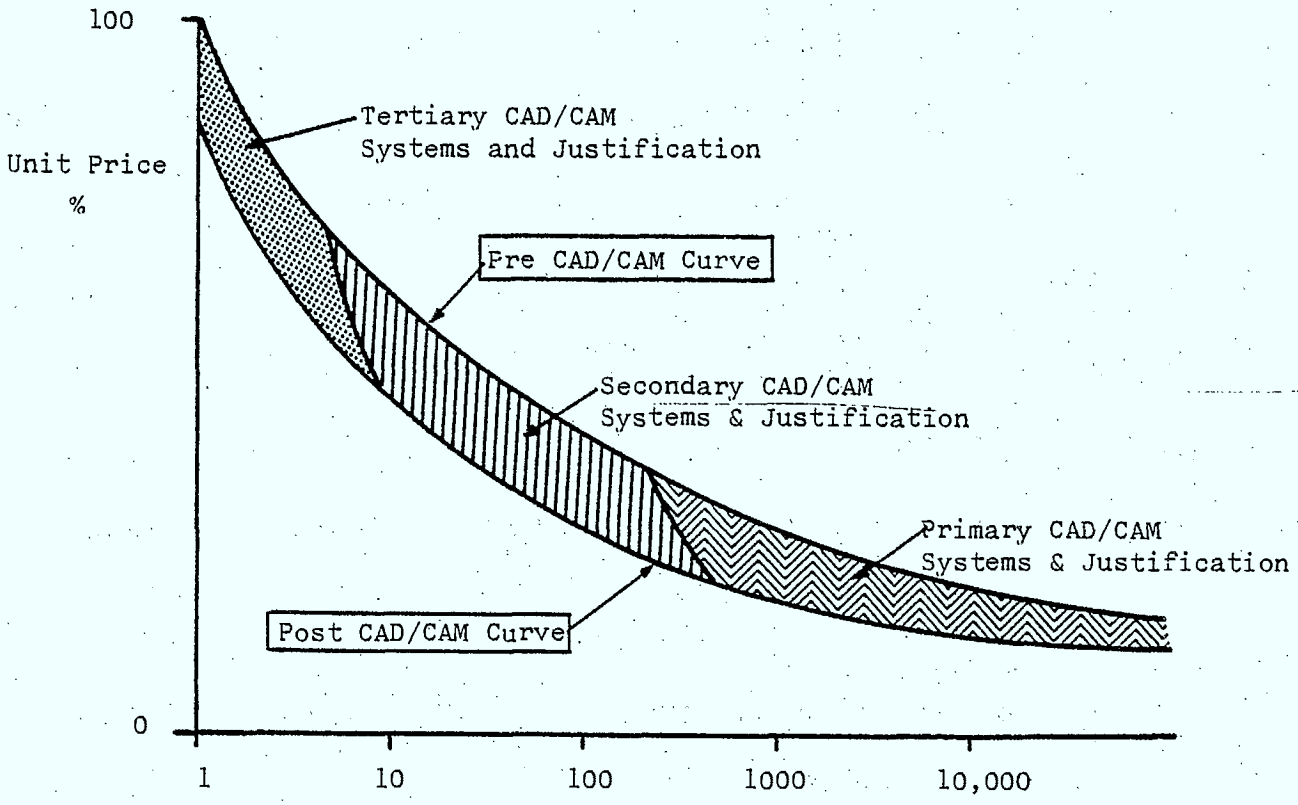
Canadian manufacturers in some fields run the risk of becoming non-competitive because other countries are heavily subsidizing the introduction of automated assembly and production control techniques. There could be a class of industrial robots and flexible manufacturing systems particularly suited to the type of production and the markets available to Canadian industry.

To date, only the largest manufacturing firms have had the in-house systems engineering capability to fully exploit CAD/CAM technology. CAD/CAM systems, particularly those of an integrated systems nature, tend mostly to be employed by only the world's largest corporations; General Motors, Ford, Boeing, Lockheed, McDonnell-Douglas, IBM, Caterpillar. This is currently the primary area of CAD/CAM systems application, as shown in Figure 6. The study by the Canadian Institute of Metalworking (CIM) to identify the attitudes and awareness of Canadian numerical control users to CAD/CAM technology also clearly shows that awareness, knowledge, development and application of CAD/CAM systems tends to be filtering down, over time, from large to medium to smaller sized companies. This leads to primary, secondary and tertiary sequences of economic justification and development as shown in Figure 6.

This will create a great demand for experienced personnel, particularly in small and medium sized companies and others who have tended to deal with manufacturing engineering on an ad-hoc basis, and who do not have designated manufacturing engineering personnel or manufacturing engineering departments.

In addition, some installations report cost reductions from flexible manufacturing systems as high as 75 percent.[14] The secondary or middle section of Figure 10 may therefore have a high degree of economic justification leading to rapid adoption by progressive firms. Having done so, to meet their own present needs and markets, there is then the possibility for such firms to expand downwards into smaller markets and production runs not previously considered economical to them. Should this occur, great pressure could be exerted on small manufacturing firms, due to their lack of expertise and the new economies of scale; a possible situation referred to by some as the small company peril.

FIG. 6 - IMPACT OF CAD/CAM ON PRODUCTION COSTS (CONCEPTUAL RELATIONSHIPS)



Note:
The cost saving and economic justification for CAD/CAM, which is the difference between the Pre and Post CAD/CAM curves, may be greater than indicated. For example, users of flexible manufacturing systems have reported savings of up to 75% in some instances. (14)

Some Product/System Opportunities

There is a need in undertaking CAD/CAM research and development projects to identify specific gaps in technology not only matching Canadian needs but also not likely to be soon available from normal sources of supply. This need for judicious project selection is recognized as a necessary but not easy task in such a rapidly advancing technical field.

Some specific possibilities have been tentatively identified:

- A lost cost microcomputer-based CAD system utilizing geometric modelling concepts and techniques.

- An inexpensive microcomputer based parts programming system.

- Establishment of a uniform or standard parts programming language.

- Establishment of a standard or tentative standard graphics language, possibly based on the GRAPPLE language initially developed in private industry and extended for construction industry CAD by the Department of Public Works.

- Computerized job costing, production planning, machine loading, scheduling and production control, especially for small and medium job shop operations.

- Automatic assembly using intelligent robots.

- Use and evaluation by industry of presently available programs for automatic selection of speeds and feeds.

- Computerized batch ticketing from raw materials to finished product by explosion or implosion of order entry.

- Automatic detail drawing, including automatic tolerancing based on limits and fits for component assembly.

- Advice to potential buyers on the specification, evaluation and selection of automatic drafting and CAD systems.

- Methods for updating NC controllers purchased in the 1970-1975 period, for example by the addition of microcomputers and "behind the tape reader" (BTR) direct numerical control (DNC).

- Research in pattern recognition and robot vision for the sensing and pick-up of fragile parts, determination of the placement of parts and the manipulation of components for assembly.

- Guidelines for justification studies and training programs for NC users, especially for inexperienced or first time users to avoid costly over or under equipment specification, neglect of training needs and neglect in planning for essential parts programming.

- Small scale flexible manufacturing systems, as further discussed in section V item 4.

Monitoring International Developments

CAD/CAM developments are proceeding rapidly in many countries of the world. Due to its size alone, Canada can expect to achieve only a small percentage of new CAD/CAM developments. It is therefore reasonable to expect and recognize that some 90% or more of new developments in CAD/CAM systems and technology will receive their first

development outside of Canada. Development work, aided by strong industry and government infrastructures, are particularly strong in Japan, Germany, U.S.A. and the U.K. For example during the 1976 exchange visit on CAD/CAM and process control to Germany, it was learned that the federal government in Germany had provided funding assistance to a number of industry associations to set up library information storage and retrieval services. In addition, the Government had a central office for contracting, maintaining reports and documentation on CAD/CAM and process control.

In Canada the NRC Technical Information Service (TIS) is virtually the only federal government program which provides technical assistance to small and medium-sized firms. About 90% of Canadian manufacturing firms, which account for approximately 40% of the manufacturing output and 43% of manufacturing employment, are in this category.

There is a need therefore to make improved information storage and retrieval systems more readily available to Canadian industry, particularly small and medium sized companies.

IV

CAD/CAM Technology Development;

Awareness, Manpower, Education and Training

IV CAD/CAM TECHNOLOGY DEVELOPMENT; AWARENESS, MANPOWER, EDUCATION AND TRAINING

The total cost of development work required for the timely adoption of CAD/CAM systems and technology in Canadian industry is very high. It can best, perhaps only, be afforded if there is a minimum of duplication of effort and a maximum of group or shared development projects. Furthermore, the integrated, systems nature of CAD/CAM necessitates team oriented research and development.

Government assistance to industry in the development and implementation of CAD/CAM systems should be primarily directed towards coordination of effort and as an information source, as opposed to a special program for the direct funding of development or implementation. This is in keeping with the fiscal restraint policy of government, the remarkably broad and pervasive nature of CAD/CAM technology, and the belief that direct support programs, if overdone can in the long run be counter productive.

Except for the proposed CAD/CAM information dissemination and contracting centre existing programs should therefore be used wherever possible as listed in Section 5 item 3.

Increasing the Awareness of CAD/CAM

Management of many companies have spent most of their lives using conventional machine tools. Many do not yet fully understand, nor in some cases have even a basic grasp of, the use of computers and numerically controlled machine tools. Fears of the unknown and of making a mistake in equipment selection, cause a reluctance to install CAD/CAM equipment or systems.

The capital cost of NC equipment is very high in comparison to conventional machines. For example a CNC lathe costs $200,000 compared to $30,000 for a conventional lathe of the same size. Similarly, CAD drafting systems typically cost about $200,000. While very high productivity gains can be achieved, equipment from competitive suppliers is difficult to evaluate. Companies therefore hesitate for fear of making a costly mistake.

Company officials need increased knowledge regarding the advantages of CAM equipment. The number of people to be involved is very large. Approximately 20% of the 10 million people in the Canadian labour force are employed in the manufacturing industries. If 10% of this 2 million people require at least an introductory knowledge of CAD/CAM systems technology, as a minimum, the number of people involved is 200,000.

Manpower, Education and Training

From practical applications it has been shown that CAD/CAM techniques can improve productivity significantly. Instances are cited in which flexible manufacturing systems have achieved cost reductions as high as 75% and work in progress inventory reductions of 30%.(9) Case studies and application oriented examples will help to demonstrate productivity gains in similar industries. Training must accompany the justification and application oriented examples in order to make company management cognisant of the composition of CAD/CAM systems.

As a consequence of the general shortage of qualified manpower in computer science and technology, the rate at which the CAD/CAM capability of Canadian industry can grow is constrained. It is desirable that action be taken to support academic institutes in this field. One effective mechanism would be to increase university research grants, and in particular to identify CAD/CAM as a priority area for NSERC strategic grants. A second possibility would be to set up further centres of expertise at universities in CAD/CAM.

V NEEDS AND RECOMMENDATIONS

1 - A CAD/CAM Information Dissemination and Contracting Centre

2 - Awareness and education

3 - Government support of CAD/CAM technology to stimulate the industrial environment

4 - Support of small scale, flexible, manufacturing systems

5 - Identification of technological opportunities

6 - The construction industry CAD centre

7 - Developing Canadian sources of supply

8 - The information infrastructure

9 - International liaison and monitoring

10- The Social Implications of CAD/CAM

V NEEDS AND RECOMMENDATIONS

1. A CAD/CAM Information Dissemination and Contracting Centre

There is a need for a focus for the development of user oriented CAD/CAM technology on a cooperative basis in Canada. This is particularly important for smaller enterprises which cannot adequately support the infrastructure, manpower and high cost attached to the development of the technology but the organization would be of value to manufacturing firms of virtually all sizes, as it would orchestrate the development of applications of CAD/CAM technology of special interest to Canadian industry.

As the single most important conclusion of this report, the CAD/CAM Council recommends the estabishment of a major centre in Canada for the development of user oriented CAD/CAM technology on a cooperative basis.

In order to ensure maximum service to industry, and to make optimum use of existing organizations, it is recommended that the role of the Centre should be primarily devoted to:

- information dissemination to stimulate awareness and improve the knowledge base on CAD/CAM technology in Canada, especially in industry; and

- contracting-out to appropriate development centres and private companies of user-oriented and defined development projects of common interest to Canadian manufacturing companies

The Centre will require funding for its permanent staff, facilities and to finance projects. The base support would be provided by government, with additional funding generated through contract funds paid by project supporters, and from membership in the Centre on a company, institutional and individual basis. The proposed terms of reference for the Centre are in Appendix I.

2. Awareness and Education

There is a need for a substantial increase in general awareness and technical knowledge of CAD/CAM technology by both management and technical personnel in Canadian industry. At this time, there are few technically qualified personnel that understand CAD/CAM systems; there is a shortage of highly qualified manpower in the related fields; and there is a shortage of personnel trained and experienced in NC (numerical controlled) parts programming.

Recommendations

2.1 CAD/CAM seminars and conferences should be held at frequent intervals throughout the year in major centres across Canada. The initiative for these programs would come from the staff of the proposed Canadian Centre for CAD/CAM Technology. Emphasis would be on both managerial and technical considerations with the assistance and participation by knowledgeable individuals from the private sector.

The emphasis, especially at the outset, would be on explaining the fundamental technical principles, economic justification and purchasing decisions, to non-technical management. Representatives from the financial and investment communities would be encouraged to attend in order that they may become informed of the technology so that they could better evaluate the financing of CAD/CAM undertakings.

2.2 Industrial films and documentaries illustrating successful applications of CAD/CAM technology should be encouraged, and if necessary, financed by the federal government and produced by the National Film Board or other appropriate government bodies. These

films could be used as a resource for the general awareness and education program, and made available to public showing at seminars and conferences, on educational television channels and available for loan to industry for in-plant education. A central library for films, other visual aids and papers and reports, should be established in the proposed Canadian Centre for CAD/CAM Technology for circulation to interested parties.

2.3 Funds should be made for a wider distribution of the regular monthly CAD/CAM newsletter to all interested parties. Distribution could be facilitated by the Canadian Manufacturers Association, Provincial Research Organizations, the NRC Technical Information Service, the proposed Canadian Centre for CAD/CAM Technology, or directly by DITC.

2.4 The CAD/CAM Council should define requirements, course outlines and prepare guidelines for government support of education and training of the existing work force.

2.5 CAD/CAM technology should be introduced as part of the regular educational curriculum at the high school, college and university levels. Universities and community colleges should be encouraged to develop and offer short courses on CAD/CAM systems technology and applications. Emphasis should be on course material and media suitable for in-plant training by companies and individuals. Such course material embodying both theory and practice could be a part of the Canada Manpower Industrial Training Program.

2.6 Greater emphasis should be placed on the training of NC programmers at local colleges to meet the future requirements of industry. This would necessitate the acquisition of numerically controlled machines and computers for use by the colleges. Candidates for the college programs should be restricted to high school graduates with high academic standing.

3. Government support of CAD/CAM Technology to stimulate the industrial environment

As stated earlier the total cost of development work required for the timely adoption of CAD/CAM systems and technology in Canadian industry is very high and can be offset through a minimum of duplication of effort and a maximum of group or shared development projects. Furthermore, the integrated systems nature of CAD/CAM necessitates team oriented research and development. This raises the important question as to the role of government in support of CAD/CAM technology.

3.1.1 Maximum use of existing industrial support programs should be made when needed, without creating new or special programs for CAD/CAM unless this is clearly necessary as in the case of the proposed CAD/CAM centre. It is recommended therefore that the following programs, and others where appropriate, be examined for opportunities where even modest changes in policy or administration could improve their efficiency or relevance to manpower training, education, development and implementation of CAD/CAM systems:

- Enterprise Development Program (EDP)
- Machinery Program
- Defence Industry Productivity Program (DIPP)
- Industrial Research Assistance Program (IRAP)
- Canada Manpower Industrial Training Program
- Science Procurement Program of DSS
- Grants and funds available to universities from the Natural Sciences & Engineering Research Council (NSERC)

3.1.2 It should be possible to increase the number of manufacturing technology projects under the Enterprise Development Program, which is administered by DITC. Within the Innovation Assistance component of EDP, CAD/CAM technology projects, particularly those of an integrated or systems nature, could be identified as "process" development. Publication of this interpretation would generate more proposals from the CAD/CAM industry sector.

3.1.3 Similarly, under the Innovation Assistance portion of EDP, elimination of the significant burden criteria for proposals for cooperative development projects would facilitate groups of companies to develop designated key technologies of high priority, such as CAD/CAM.

3.2 Matching funds should be provided to the proposed Canadian Centre for CAD/CAM Technology from existing programs for cooperative or group development projects. Such funding would be essential during the formative years of rapid technological change, and could be maintained for a longer period if merited. The Enterprise Development Program, the program for Centres of Advanced Technology, or some other appropriate mechanism, could, with modification, be used as the means to provide the necessary funding.

3.3 In lieu of a laboratory research and development capability in support of its mission, the Department of Industry, Trade & Commerce should consider contracting out studies to generate publicly available reports on current issues in key technologies such as CAD/CAM. These should occur on a reasonable and regular basis, and deal with the threats, opportunities and state of the art of the technologies. This could be done, for example, through a modification or change in emphasis of the Technological Innovation Studies Program currently administered by the Technology Branch of DITC.

3.4 Further plans should be developed for the coordination of CAD/CAM related research in Canadian universities and other laboratories, particularly with regard to coordination or cooperation on major multi-disciplinarian projects.

3.5 Mechanisms should be developed for the identification and funding of joint projects meeting the collective needs of Canadian CAD/CAM users. These could possibly be through the Canadian Manufacturers Association, the proposed Canadian Centre for CAD/CAM Technology and through Canadian industrial membership in CAM-I.

3.6 The Department of Industry, Trade & Commerce should give priority to establishing more centres of expertise located at Canadian universities in CAD/CAM and related fields, and to the provision of continuing funds where necessary to maintain core research and development at existing centres.

3.7 The Natural Sciences and Engineering Research Council should be strongly encouraged to establish CAD/CAM as a priority area for strategic grants and to create a single committee for the evaluation of grant applications in manufacturing technology, including CAD/CAM.

4. Support of small-scale, flexible manufacturing systems

Many sectors of our Canadian manufacturing industry are oriented towards relatively low volume production with small batch sizes. This, consequently, requires frequent changes in set-up, within established procedures, for material handling, fabrication, assembly and quality control.

Recommendations

4.1 The federal government should support and coordinate the development and implementation of small scale flexible manufacturing systems and industrial robotics technology in Canadian manufacturing.

4.2 The National Research Council should undertake responsibility for funding and coordinating an R&D program for small and medium scale flexible manufacturing systems and industrial robots in Canada. The program should be particularly oriented towards relatively low and medium scale volume production of items where Canadian industry has the greatest need to retain a competitive edge.

5. Identification of technological opportunities

There are opportunities in undertaking CAD/CAM research and development projects to identify specific gaps in the technology that are unlikely to be filled from other sources in the short-term. These gaps would materialize while researchers investigate the application of CAD/CAM technology to unique Canadian requirements.

Recommendations

5.1 These technological gaps should be identified through consultation with Canadian industry, for example, through studies contracted by the proposed CAD/CAM Centre. Canadian institutions active in the CAD/CAM sector would then be more able to advance the technology through exploitation of these opportunities and special development efforts.

5.2 Some specific areas of research opportunities include:

- use of interactive graphics and geometrical parts programming for the preparation of NC tapes or tool path data files;
- design and development of graphics languages which are oriented towards machinist and draftsman skills;
- reduction in the cost of interactive graphics systems;
- improved man/machine interface in CAD systems;
- improved communication, between CAD systems; or
- improved communication and interface between CAD and CAM systems.

5.3 Research and Development should be encouraged in the field of man-machine communications with the objective of developing easier to use methods for NC parts programming and to reduce the machinist skills necessary for the operation of NC and CNC machine tools.

6. The CAD Needs of the Canadian Construction Industry

There is a need to improve the efficiency of the Canadian building design and construction industry through the accelerated development and application of CAD techniques.

Recommendations

6.1 The federal government should continue to encourage the application of CAD/CAM in the construction industry.

6.2 The National Research Council and the Department of Industry, Trade & Commerce should continue to cooperate with the Department of Public Works in the review of the DPW CAD Centre. Recommendations should be made and appropriate support extended for future work in both CAD and CAM in construction.

7. Developing Canadian sources of supply

In addition to encouraging the use and application of CAD/CAM systems and equipment throughout Canadian industry, the emergence of this new technology provides an opportunity to develop Canadian sources of supply for the hardware, software and systems.

At the present time, in addition to a heavy reliance on external sources for CAD/CAM equipment there is also a substantial use of time sharing computer services involving trans-border data flows. Due to the degree of expertise required to provide CAD support, Canadian based computer service bureaux have tended to focus their efforts almost exclusively on financial, accounting, distribution and service industry applications in which they have a better understanding, and to provide relatively little CAD capability.

Recommendations

7.1 Import levels for CAD/CAM systems and equipment should be monitored to identify their impact on balance of payments and to identify opportunities for import replacement.

7.2 Opportunities to encourage and expand viable Canadian sources of supply for CAD/CAM equipment and systems in both domestic and export markets should be supported. This can be done through existing federal government programs.

7.3 The viability of establishing a Canadian capability for the manufacture or supply in areas of expected high demand or great emphasis should be examined, such as:

- numerically controlled machine tools;
- control systems for NC machine tools;
- turnkey CAD graphics systems;
- CAD graphic terminals;
- industrial robots and/or auxilliary equipment; and
- CAD/CAM systems design.

8. The information infrastructure

There is a need to establish a stronger infrastructure with improved channels for information flow and technology transfer within Canada pertaining to CAD/CAM. This greater east-west communication and presence would encourage Canadian development and, at least partially, offset the strong north-south pull between Canada and the U.S.A.

Recommendations

8.1 The CAD/CAM Council, and the proposed Canadian Centre for CAD/CAM Technology, should continue to work with others for the establishment and maintenance of information flow and cooperation within Canada. For guidance, a list of known organizations which currently form the "CAD/CAM Infrastructure" in Canada is contained in Appendix IV.

8.2 Every manufacturing company in Canada should designate at least one person in a technical management capacity to become aware of developments in CAD/CAM technology and to plan the company's response, if this is not already being done.

9. International liaison and monitoring

CAD/CAM developments are proceeding rapidly in many countries of the world. There is a need for awareness and improved knowledge of international activities on a continuing basis.

Recommendations

9.1 Periodic exchange visits, under Canada's Science and Technology Exchange Agreements where appropriate, should be continued where they have already been initiated as with the Federal Republic of Germany. Similar agreements should be established with other countries that are recognized leaders in CAD/CAM development.

9.2 Short-term exchanges of experts between development centres are also appropriate and should be similarly encouraged. There is a need to establish a budget for travel, living and reasonable short-term operating expenses if this is to be accomplished.

9.3 Consideration should be given to strengthening the scientific counsellor positions in selected Canadian embassies in order that they may provide an improved reporting and awareness service on technology development abroad. Attendance at selected technical conferences and the subsequent forwarding of an overview and conference documents (which are often not available except to registrants) to the Canada Institute for Scientific and Technical Information would be of great benefit to industry and policy-makers. CISTI could then make the papers and related publications available through its usual distribution methods.

10. The Social Implications of CAD/CAM

Technology is always a two edged sword. Depending on how it is used it can either be to man's benefit or to his harm. The implementation of advanced information and automation systems such as CAD/CAM is no expection to this general rule, and carries with it significant social implications.

The social implications of CAD/CAM include:

- The man/machine relationship and the effect on workers who operate or use CAD/CAM systems. It should be noted that this includes office workers as well as factory workers. Indications are at hand for example, that large numbers of office workers will soon find that their workplace consists of a keyboard and screen for significant amounts of the day.

- The effect on the international balance of payments of moderately industrialized countries like Canada, and particularly on the prospects of the developing countries for the creation of wealth or employment.

- The general use of computer technology and encouragement of computer applications having high social benefit.

- The possible widespread effects of technology and employment.

A full discussion of the employment implications of technology, emphasizing computer and automation systems is contained in Appendix IV of the CAD/CAM Council's full report to which the reader is therefore referred for further information. While no one can accurately forecast the future, especially for such an involved and dynamic situation, the general consensus is that the

downside risk of doing too little, and losing competitiveness is far greater for the presently industrialized countries than the upside risk of doing too much and causing unnecessary technological displacement.

Recommendations

10.1 While encouraging the application of CAD/CAM in Canada, efforts should also be made in parallel to:

- Establish guidelines and measures to encourage the design of CAD/CAM and computer systems with good man/machine interface design, and which treat the operator or worker in a humane way. In principal, man should be master of the machine wherever possible. Systems in which man becomes the servant or the slave of the machine should be avoided by careful systems design and selection of objectives.

- Computer and production systems, for example, should be designed in a manner which avoids having the operator paced by the machine, especially over long periods of time. The system design, whenever possible, should have the machine paced by the operator, not vice versa.

10.2 Provision should be made for a variable work rate over the work day, selected by the operator and with provision for work breaks etc. as required.

10.3 Applications in which the operator's performance rate is monitored and recorded by the computer should only be implemented with the awareness and understanding by the operator of the methodology and how the information is utilized.

10.4 The widespread application of advanced information and automation systems such as CAD/CAM, creates the possibility that a large part of the industrial activity and economic wealth of the nation may be created by a relatively small fraction of the population so employed. It is important, as this possibility advances and perhaps becomes reality, that equitable mechanisms be established and maintained for the distribution of such wealth, as well as its creation. Unemployment insurance is the principal such mechanism today, but will require modification in order not to further and seriously weaken the work ethic if the number of recipients increases.

10.5 Canada should keep aware of social implications as they are identified in other countries and the means adopted for the amelioration of any undesirable effects. The IFAC Technical Committee on the Social Effects of Automation, and possibly the OECD would appear to be appropriate and useful channels for this.

10.6 In order to maintain balance and extract maximum benefit from computer technology, Canada should give high priority to computer applications having high social benefit, such as applications in health, medicine and bio-medical engineering, in addition to applications such as CAD/CAM which tend to emphasize economic benefits.

10.7 Coincident with the emergence and adoption of new technologies, Canada must develop improved mechanisms for more vigorous technologically based social planning in order to be prepared, to adapt, and to more conveniently accept the changes which will inevitably occur.

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APPENDICES

APPENDIX I

SUGGESTED TERMS OF REFERENCE
FOR
A CANADIAN CAD/CAM TECHNOLOGY CENTRE

Structural Principles for the Centre

There are a number of fundamental structural elements of the proposed Centre that will give it form and purpose. The following considerations constitute the operating criteria:

(1) The Centre should be independent of any vested commercial interest in the development of CAD/CAM technology.

(2) In addition to funds derived from membership fees and project sponsors, the Centre will require government assistance for its operation and project sponsorship, especially in the formative years.

(3) The Centre must remain as a coordinating, information dissemination and contracting group, rather than become an organization for "in-house" CAD/CAM systems development.

(4) The Centre will report to the CAD/CAM Council and be directed by the Council in general policy matters. However, the Centre would be responsible for the maintenance of a knowledge base and awareness of technically capable contractors. It would have the authority to award contracts as directed by Council and as appropriate.

(5) It will be a function of Centre staff to maintain memberships in appropriate technical societies and attend major technical conferences for the purpose of project planning and the maintenance of technical skills.

(6) In the allocation of funds for specific projects, policy similar to that followed by NRC and other agencies may be adopted for the following project types:

- Projects meeting very broad needs across several companies or sectors may be fully funded;
- Projects meeting the needs of groups of companies which would be jointly funded by the project sponsors and available government funds;
- Projects meeting only specific company needs which would be fully funded by the company, although the Centre may assist in coordination, contracting, etc.

(7) While it may not necessarily represent an exact model, the R&D program of the Canadian Electrical Association provides a useful example for a cooperative development centre involving both government and private sector funding.

Starting from approximately equal electric utility and government contributions (provided through the Department of Energy Mines and Resources) of approximately $1 million each in 1977, the electric utility R&D program has been projected to grow to a $7.08 million total expenditure by 1979. It is expected to reach $12.384 million in 1983, with equal contributions by electric utility assessments and EMR providing over 90% of the necessary funds.

To date, 150 liaison engineers have been involved in the program. Over 100 contracts have been awarded for specific projects in electrical energy generation, transmission, distribution, utilization and conservation.(8)

(8) Until such time as the proposed Canadian Centre for CAD/CAM may be established, it is urgently recommended that the council secre-

tariat and industry advisory service function for CAD/CAM information, presently located in the Technology branch of the Department of Industry, Trade & Commerce, be strengthened substantially as an interim measure, or permanently if necessary.

Staffing and Responsibilities of the CAD/CAM Centre

The Centre would employ a staff of professional people knowledgeable in CAD/CAM, with adequate support personnel. The Director of the Centre must be a person with considerable stature in the field.

To encourage technology transfer with industry and other organizations, a combination of permanent and term employment should be used. A partial rotation of personnel with other institutions, such as the provincial research organizations, National Research Council of Canada and CAD/CAM Centres outside of Canada, should be planned and encouraged on a term appointment or sabattical basis.

In addition to the critical function of coordinating all Council projects through liaison with project sponsors and contractors, the Centre would maintain a wide range of support roles. The Centre would:

- coordinate the information flowing to and from the membership;
- draft all project proposals eminating from the membership with supporting documentation for consideration by the Council;
- maintain a library and information retrieval system for use by the Council and membership and, as appropriate, to support its own activities;
- maintain an inventory of skills for direction of specific technical requests for assistance;
- prepare contract proposals for tender;
- prepare and publish the monthly newsletter;

- maintain the CAD/CAM Canada article series;
- by virtue of membership in foreign technical societies, report to Council and associate membership, current matters of interest related to Council activities;
- maintain a directory of educational programs such as extension courses and short courses related to CAD/CAM and available to others, and encourage participation in these;
- represent the Council in the organization and presentation of seminars and technical conferences and the development of standards related to CAD/CAM systems and components;
- maintain awareness of the capability of Canadian agencies, universities and corporations to undertake various aspects of CAD/CAM development; and
- obtain the services as needed of project monitors from the project sponsors or membership on an invited or volunteer basis.

Centre Membership

The CAD/CAM Centre should have a membership consisting of four categories:

- Ordinary members (individuals)
- Institutional members (technical societies etc)
- Corporate members (companies)
- Project sponsors

All members would receive the CAD/CAM newsletter and would be eligible to attend all open meetings and seminars. Sponsors of specific shared cost projects would participate in the planning and review of the sponsored projects and receive one or more complete documentation sets. Corporate members would receive all publications generated by the Centre, including access to the documentation of

sponsored projects. Distribution of the latter documents would be restricted to project sponsors only for the first year following completion of each such project. Documentation on non-proprietary projects will be distributed to all members.

Members would be provided with outlines of proposed activities of the Council and would be invited to augment these proposals with information that would increase the applicability of the results of the Council's activities.

Members would also be invited to submit proposals to the council for investigation. Where these projects require the development or enhancement of the technology beyond the present public domain state, members with similar interests would be asked to establish a project planning group to define the criterion for a council project.

Company members with common areas of interest would be solicited to jointly fund a development or research project directed toward the advancement of CAD/CAM within their sphere of interest. The sponsors for each specific shared cost project would form a steering and review committee for each project, including representation from the Centre, and Council where appropriate.

An appropriate fee for each class of membership would be established, to cover costs associated with maintenance of the membership.

CAD/CAM Council Functions

The establishment of the Centre will involve some changes in the role of the CAD/CAM Technology Advancement Council. To coordinate the activities of the Canada Centre for CAD/CAM Technology Advancement, the Council, in addition to its present activities, would:

- Act as the equivalent to a Board of Directors for the Canada Centre for CAD/CAM Technology Advancement;

- Select those projects to be supported through the Centre;

- Be empowered to direct financial support provided by project sponsors and government to those projects supported by the Council;

- Provide guidance to government granting agencies in the appropriate coordinated project areas; and

- Offer support to cooperating development organizations in the development of integrated CAD/CAM systems and standards.

APPENDIX II

TERMS OF REFERENCE
TECHNOLOGY ADVANCEMENT COUNCIL ON
COMPUTER AIDED DESIGN/COMPUTER AIDED MANUFACTURING
(ADOPTED APRIL 28, 1978)

General

- The Council will be under the general direction of a chairman.

- The Department of Industry, Trade and Commerce will be responsible for the administration of the Council, in deciding the appointment of members, the provision of the secretariat and the financing of operating expenses.

- Continued funding of the Council's operation will be at the discretion of the Department.

Objectives

Within the general field of CAD/CAM technologies:

- 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.

Duties

Within the general field of CAD/CAM technologies:

- To provide a centralized source of timely knowledge about existing technology, including the assessment of technological developments 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.

Membership

- The Council will consist of 12-18 individuals selected from industry, government and universities, who are recognized authorities in the field.

- The term of office will be for a period of three years.

- The chairman will be selected by the Council members with preference to be given to a member from industry.

- ITC will normally provide two or three members, one of whom will serve as the secretary.

Meetings

- The Council will normally meet approximately four times each year. Subcommittees or working groups may meet more frequently.

- Individual members will be expected to serve without remuneration, but shall be reimbursed reasonable travelling expenses incurred in attending Council meetings.

APPENDIX III

MEMBERS OF THE CAD/CAM TECHNOLOGY ADVANCEMENT COUNCIL

Industry

Mr. D.E. Close,
Manager,
Computer Graphics Implementation,
Canadair Limited,
Montreal, Quebec.

Mr. R. Fielding,
Technical Director,
Alcan Canada Products Limited,
Kingston, Ontario.

Mr. H.T. Watt,
President,
Computer Assembly Systems Limited,
Brockville, Ontario.

Mr. John Kershaw,
General Manager,
Chicopee Manufacturing,
Kitchener, Ontario.

Mr. A.M. Lount,
President,
CADSYS Limited,
Vancouver, B.C.

Mr. J.J. Nassr, (Past Chairman)
President,
Canadian Advance Production,
Consultants Limited,
St. Laurent, Quebec.

Mr. C. Archibald
Director of Manufacturing
NCR Canada Ltd.
Waterloo, Ontario

Mr. G.L. Patterson,
Manager, CAD/CAM Systems,
Bell Northern Research,
Ottawa, Ontario.

Mr. J. Davies,
Editor,
Canadian Machinery & Metalworking,
MacLean-Hunter Limited,
Toronto, Ontario.

University

Dr. D. Bonham, (Chairman)
Associate Professor,
Department of Mechanical Engineering,
University of New Brunswick,
Fredericton, New Brunswick.

Mr. J.R. Dickinson,
Director, Systems Analysis,
Control & Design Activity (SACDA),
Faculty of Engineering Science,
University of Western Ontario,
London, Ontario.

Mr. J.E. Crozier, (Past Chairman)
Manager,
Canadian Institute of Metalworking,
McMaster University,
Hamilton, Ontario.

Professor D. French,
Department of Mechanical Engineering,
University of Waterloo,
Waterloo, Ontario.

Government

Mr. J.L. Harrison,
Division Manager,
Transportation Industries Branch, (53),
Department of Industry, Trade and Commerce,
Ottawa, Ontario.

Mr. J. Scrimgeour,
Consultant,
Technology Branch, (61),
Department of Industry, Trade and Commerce,
Ottawa, Ontario.

Mr. J.K. Pulfer,
Executive Director,
Interlaboratory Programs,
National Research Council,
Ottawa, Ontario.

June 1980

APPENDIX IV

ORGANIZATIONS FORMING THE DEVELOPMENT AND TECHNOLOGY TRANSFER INFRASTRUCTURE FOR CAD/CAM IN CANADA

Technical Societies

American Foundry Men's Society	4 chapters
American Institute of Industrial Engineers	7 chapters
American Institute of Plant Engineers	4 chapters
American Society of Mechanical Engineers	3 chapters
The Canadian Society for Civil Engineering	(CSCE)
The Canadian Society for Electrical Engineering	(CSEE)
The Canadian Society for Industrial Engineering	(CSIE)
The Canadian Society for Mechanical Engineering	(CSME)
The Canadian Information Processing Society	(CIPS)
Canadian Association for Production & Inventory Control	6 chapters
Canadian Institute of Mining and Metallurgy	(CIM)
Canadian Operational Research Society	(CORS)
Canadian Welding Society	
Institute of Electrical and Electronic Engineers	(IEEE)
Institute of Textile Science	
Instrument Society of America	(ISA)
Numerical Control Society	
Society of Die Casting Engineers	2 chapters
Society of Manufacturing Engineers	8 chapters
Society of the Plastics Industry of Canada	

Centres of Advanced Technology, Research Association

Canadian Institute of Metalworking	(CIM)
Systems Building Centre	
Systems Analysis Control & Design Activity	(SACDA)
Canadian Food Products Development Centre	
Canadian Welding Development Institute	

Industrial Manufacturing Companies	approx. 8000

Canadian Universities

- Applied Science and Engineering Faculties	(approx. 36)
- Computer Science Departments	(approx. 34)

Industrial Research Institutes

Canadian Welding Development Institute
University of Windsor
Nova Scotia Technical College
McMaster University
University of Waterloo
University of Manitoba
Ecole Polytechnique
McGill University
Université du Québec à Montréal
Pulp and Paper Research Institute of Canada

Provincial Research Organizations

Nova Scotia Research Foundation Corporation
New Brunswick Research and Productivity Council
Centre de recherche industrielle du Québec (CRIQ)
Ontario Research Foundation
Manitoba Research Council
Saskatchewan Research Council
Research Council of Alberta
British Columbia Research Council

National Research Council

Canada Institute for Scientific & Technical Information (CISTI)
Engineering Laboratories
Technical Information Service (TIS)
Associate Committee on Automatic Control (ACAC)
Advisory Committee on Computer Technology Research

Industrial Trade Associations

Air Industries Association of Canada
Apparel Manufacturers' Association of Ontario

Apparel Manufacturers' Institute of Québec
Automotive Parts Manufacturers Association (Canada)
B.C. Fashion and Needle Trades Association
Canadian Textiles Institute
Canadian Advanced Technology Association (CATA)
Canadian Association of Data Processing Service Organizations (CADAPSO)
Canadian Manufacturers Association (CMA)
Canadian Business Equipment Manufacturers Association (CBEMA)
Canadian Institute of Steel Construction
Canadian Machine Builders Association
Canadian Machine Tool Distributors Association
Canadian Nuclear Association
Canadian Pulp & Paper Association (CPPA)
Canadian Ship Building and Ship Repairing Association
Canadian Society for Nondestructive Testing
Canadian Tooling Manufacturers' Association
Canadian Welding Society Inc.
Electrical & Electronic Manufacturers' Association of Canada (EEMAC)
Footware and Leather Institute of Canada (FLIC)
Machinery & Equipment Manufacturers' Assoc. of Canada
Manitoba Fashion Institute
Portland Cement Association

General

Economic Council of Canada
Institute for Research on Public Policy
Science Council of Canada