Technological Innovation Studies Program

Research Report

A STUDY TO IDENTIFY THE ATTITUDES AND AWARENESS OF NUMBERICAL CONTROL USERS TO CAD/CAM TECHNOLOGY
and
THE TECHNOLOGICAL AND ECONOMIC STRENGTHS AND WEAKNESSES OF MACHINE TOOL PART PROGRAMMING

by
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Rapport de recherche

Programme des études sur les innovations techniques

Industry, Trade and Commerce
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ACKNOWLEDGEMENTS

The writer wishes to thank the management of all the companies listed in Appendix I for their sincere efforts in making this survey possible.

In addition, I would also like to thank Dr. Ian Yellowley for his assistance with the analysis, Reg Woodruff for his excellent graphics, members of the CAD/CAM Council, my secretary, Kay Lawrence, and Jennifer Rose for her patience while I completed this report.

CAD/CAM - "SYNERGISM IN THE WORLD OF NUMERICAL CONTROL"

In 1980 the CAD/CAM accronym has become a buzz word that has a different meaning to different industries. The electronics industry views CAD/CAM as the computer, software and periphal hardware that manufacture printed circuit boards, integrated circuit chips and testing equipment. The aluminum extrusion industry views CAD/CAM as the computers, software, and a wide range of other equipment including die shop support tools press control, material handling and robotics.

One may recall statements to the effect "You're only into N.C., why don't you get into CAD/CAM".

From the survey that forms the basis of this report, it is quite apparent that NC users understand more about CAD/CAM than any other single identifiable group of companies. When one attempts to define CAD/CAM, it is impossible to overlook NC technology.

CAD and CAM came into being at the end of World War II. The Parsons Corporation of Traverse City, Michigan, received a contract to produce helicopter rotor blades. Along with the contract came patterns from the helicopter manufacturer for checking the finished work pieces. Utilizing a punch card accounting machine, Mr. Frank Stulen of Parsons was able to generate coordinate tables of the airfoil contours. Using the information, Stulen proceeded to generate two axis airfoil machining path data which was then taken to a manually operated Bridgeport machine. The resultant machined curves were far more accurate than any other method achieved up to that time. Subsequently the Parsons company followed up this achievement by using the data to directly control the first rudimentary machine tool. This development was followed up by the Massachusetts Institute of Technology (MIT) Servomechanism Laboratory through an airforce contract to develop servo-mechanisms for a machine tool. Furthermore, MIT was actively developing the Whirlwind I computer which became the initial data generator for the servo controlled machine tool. Hence the birth of CAD and CAM. The separation of CAD and CAM continued for about two decades until micro electronics provided the economic feasibility for computerized numerical control (CNC). At the same time several other developments were taking place that allowed a remote computer to feed information to NC and CNC machine tools commonly referred to as distributed or direct numerical control (DNC).

In addition to the computer feeding information to the NC system, front end computer devices, such as the Cathode Ray Tube (CRT), were being applied to the computer for interactive communication. This interactive communication is today called Computer Aided Design (CAD). Thus the link between CAD and CAM was completed forming today's accronym of CAM/CAD.

A CAD/CAM system encompasses many technologies and disciplines and can be simple or extremely complex if they include:

<u>Computer Aided Design</u> - The ability to create designs interactively and store the part shapes, and dimensions for later recall. The ability to compile a bill of materials and show the interelationship of part shapes.

<u>Computer Aided Manufacturing Engineering</u> including part classification systems, process planning, methods and routing sheets. Computer Aided parts programming utilizing languages such as APT, COMPACT, GTL, GENESIS, G-TURN. The ability to

compute the cost of a part or an assembly using current production rates and current labour and material costs.

Computer Aided Materials Management including the ability to select vendors automatically and cause the computer to type purchase orders or requests for bids. The ability to maintain inventory control or raw stocks by means of computer records. Instant availability of data from the computer's open order file for receiving and for incoming inspection operations. Computer controlled automatic storage warehouses for raw stock, work in process, fixtures, finished parts or finished products. . Computer managed and computer controlled materials movement.

Computerized Numerical Control including direct control of a group of machines for metalcutting, forming, fabricating, inspecting, assembly and testing. Control of Robotics devices for part handling, welding and assembly.

Computer Scheduling and Production Control including short range schedules and manpower allocation plans corrected and updated immediately after any major change in condition. Preparation and issuance of all priority or sequence lists, move orders and work orders.

Computerized Source Data Collection including instantaneous status reports from all DNC machines and the ability to make changes in source programs at the machine.

Disciplines The disciplines include: computer technology and the ability to program computers in many different languages. Manufacturing Engineering with the ability to describe to the computer the most economical way to manufacture a component or assembly. Mechanical engineering with the ability to design mechanical components and carry out the analysis. Electrical Engineering with the ability to put together modules of hardware and software to form complete systems. Mechanical and Electrical technology and the ability to maintain or repair electronic and mechanical systems.

As one can see from the above list of technologies and disciplines CAD/CAM is an integrated design-manufacturing system that may be in its simplest form, a mini or micro computer being used to generate a drawing and/or data in the form of punched tape to drive an NC machine.

From that simple system the complexity can increase to include the technologies above and extended to technologies that are still in the research stage.

EXECUTIVE SUMMARY

Industry, Trade and Commerce (ITC) through its Technological Innovation Studies Program contracted the Canadian Institute of Metalworking to survey the leading companies in the metalcutting field of CAD/CAM to determine

a) In general, their attitudes and awareness to CAD/CAM technology.

b) In particular, their technological and economic strengths and weaknesses of machine tool part programming.

The study surveyed 105 companies located in Ontario (72%), Quebec (10%), British Columbia (14%), Alberta (2%) and Manitoba (2%) that are current users of NC equipment. The rationale for the report can be justified by stating that, if the current users of NC equipment are the leaders in CAD/CAM technology, particularly the large users with many machines, then other companies just entering the market place, may benefit greatly by knowing the attitudes, awareness, strengths and weaknesses of the current leaders. The study separated companies into large users (4 or more NC machines) and small users (1 to 3 NC machines) and the analysis was completed on this basis. In the large user category there were 18 companies in the 200 to 800 employee range with a combined total of 140 NC machines.

Concerning the impact that computers will have on manufacturing, the majority of users stated that computers will either be essential or important to remain competitive. Newly installed computerized manufacturing equipment is a problem for users as they indicate that start-up takes far too long. However, the majority of users are pleased with the return on investment, the mechanical reliability and the additional advantages the new technology provides.

A majority of users are aware their competitors are using NC and to a lesser extent use the computer for NC part programming and design.

The greatest constraint to increased utilization of CAD/CAM will be the lack of technically qualified personnel along with a lack of understanding by management. Continuing Government support programs for training was suggested as the best way to overcome the above constraint.

Skilled machinists and manufacturing engineers are the most sought after personnel by manufacturing companies. In an effort to rectify the skilled labour problem, users would like Government to continue or increase the amount of support for on-the-job training programs and place more emphasis on industrial training at Universities and Colleges.

The analysis of comparative useage of CAD/CAM technologies now and in five years produced interesting results. The increase and expansion ranged from a minimum of 2.2 times the current level to a maximum of 10 times the current base within 5 years. Technologies providing the major growth include production scheduling from a data base, computer aided design and drafting, NC machining and integrated CAD/CAM systems.

According to present users, the number of machine tools installed will more than double during the next five years. By 1985, there will be in excess of 3,200 installations with the majority of new installations being computerized systems (CNC).

Production time represents 72% of the available hours on an NC machine according to users, with tape proving time being 10%. The remainder of the time is used for maintenance (9%) and the manufacturing of tooling.

Complex part geometry was more of a problem with the small user than the large users. Tape program corrections are mainly due to the machineability of various metals, tooling problems and process planning errors.

The trend in N.C. programming is towards the stand-alone mini-computer system and away from time sharing. Small users are mainly manual programming (58% of those surveyed) but will increase their use of the mini-computer from 6% of those surveyed to 38% during the next five years.

As a user purchases more machine tools, the trend is to separate the process planning activity from programming. Many of the small users do not have a separate programming activity and rely on the shop to carry out the job from print to finished part.

The average job lot size for machining centre work is 6 to 24 parts. However, it is not unusual for companies to machine one part. Batch sizes on the NC lathe are much higher in general with the average being 50 - 100 parts.

The selection of a programming language is mainly the decision of the senior programmer in large users and usually a combined effort through a justification study in the small users. Sales demonstrations were not a major factor for purchasing the system or language according to users.

Average programming costs varied considerably from user to user. Companies utilizing manual programming and companies machining a wide variety of complex components could not be classified as having an average cost per NC tape. However, there were 16 to 20 companies generating between 50 to 1000 programs each per year where a cost per tape "mean line" could be established. In addition all the companies were carrying out simple to medium complexity work and were using computer assisted time sharing.

Programmers have generally come from a machinist background or through a process planning background. The majority of programmers are high school graduates with an apprenticeship or a technical shool diploma.

BACKGROUND TO THE STUDY

The Federal Government spends millions of dollars each year assisting Canadian Industry. Some of this money supports industry directly through various subsidization programs for studies, research and development, manpower training and the purchase of complex machine tools and supporting equipment.

Numerically controlled (NC and CNC) machine tools are of particular interest to the Government for support due to this proven concept for increasing productivity. Within the last few years NC has taken on, or been included within, another dimension due to "the micro processor revolution". This new dimension, called Computer Aided Design and Manufacturing (CAD/CAM), encompasses NC machine tools, programming systems, support software, input-output terminal devices, computer graphics for design and manufacture, classification and coding systems, automated process planning, robotics, material handling, direct numerical control and virtually every other device or package of software whose purpose is to increase the productivity of component manufacturing.

It, therefore, has become increasingly important to Government that industry should be aware of its own strengths and weaknesses in the CAM field and be cognisant of recent advanced trends, constraints, and generally be aware of this rapidly emerging technology. The CAD/CAM Council in its first major report *[1] recommended to industry that virtually every manufacturing company in Canada should designate at least one

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*[1] Strategy for Survival - The Canadian CAD/CAM Option, September, 1980.

person in a technical management capacity to become aware of developments in CAD/CAM technology.

The rationale for the report contained herein, is therefore based on the premise that the leaders in CAD/CAM technology in Canada are today's current users of NC machine tools. These leaders may be broken down into subgroups and classified in various ways. For example, there are the large companies with many NC systems (>50), and large companies with only a few. Small companies with 20 or more systems, and small companies that are just starting out.

Therefore, if the current users of NC are the leaders in CAD/CAM, particularly the companies with many machines, then other companies just entering the market place may benefit greatly by knowing the attitudes, awareness, strengths and weaknesses of the current leaders.

This report is based on the results of the study that clearly show that awareness, knowledge, development and application of CAD/CAM systems tends to filter down over time from the large users to the smaller users.

The Study

The study itself is based on the results obtained through interviews, by means of a questionnaire, and through the experience of working with industrial customers at the Canadian Institute of Metalworking (CIM). The questionnaire was forwarded to 248 users of NC machines resulting in 105 completed questionnaires. Interviews were carried out with firms in British Columbia, Alberta, Manitoba, Ontario and Quebec. Returned questionnaires were categorized firstly into small, medium and large firms. An initial analysis was attempted on this basis but problems of classification were encountered in that some small and medium sized companies are technically very advanced and superior to the large firms with only 1 or 2 NC machines.

The second analysis, which is the one used in the report, separates the companies into small and large users of NC equipment, rather than on the basis of company size.

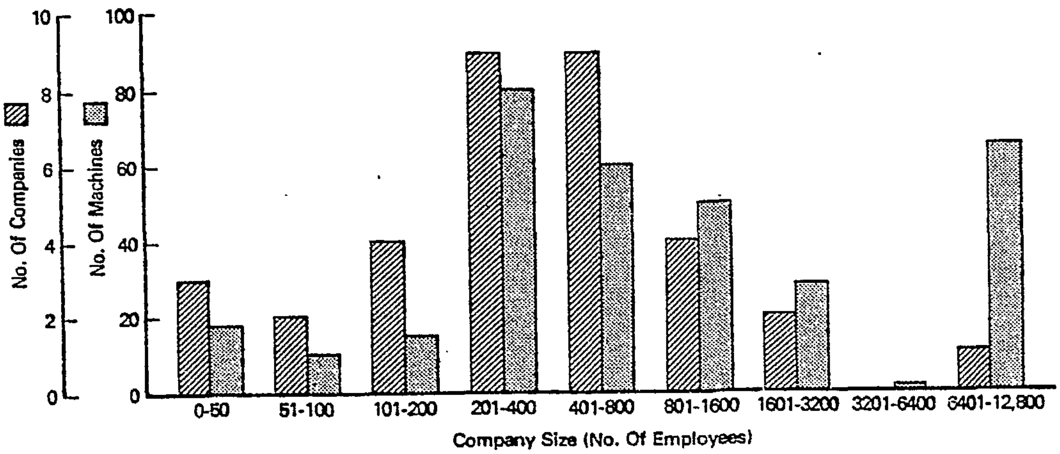
Small Users

The small users referred to, consist of forty-six companies with one to three NC machines. These companies may or may not have plans to purchase more equipment in the future.

Large Users

The large users referred to, consist of thirty-five companies that have a minimum of four NC machines installed with plans to significantly increase the total, in addition to proven experience and enthusiasm.

The following graph relates the company size (number of employees) to the number of companies in the large user category plus the number of machines installed in these companies.



The Survey Questionnaire

The survey questionnaire was divided into several parts. The first part identified the business of the company including its size and product. Secondly, management was asked to relate its present attitude and awareness of CAD/CAM, the degree of CAD/CAM useage by their competitors, what the constraints were to increased utilization of CAD/CAM, what incentives were necessary to overcome the constraints, what category of skilled workers was in greatest demand and how should problems be overcome. In addition, management was asked to select the CAD/CAM technology area which will have the greatest use and application in the company in the next five years, as compared to the present use.

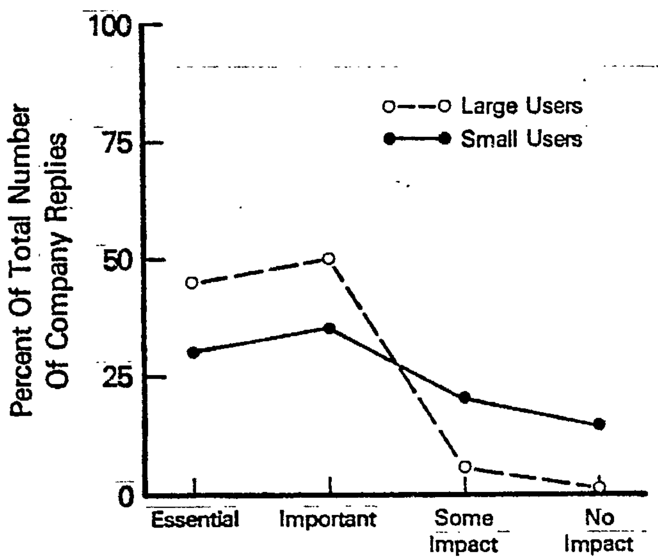
The second half of the questionnaire focussed on the NC activity of CAD/CAM, questionned the growth for various types of machine tools; batch quantities and complexity of work carried out; methods of programming the machines; examined the programming language; questionned the number of programs per year and the cost of programming; summarized the problems encountered in programming; related the production time of machine tools to overhead time; categorized the flow of information to the NC machine tool; and lastly developed a portrait of the NC programmer.

ANALYSIS OF USER OPINIONS TO CAM EQUIPMENT

The Impact of the Computer in Manufacturing

Our study asked the question "How important do you consider the use of computers in the control of manufacturing or design operations in the next 5 years in your company?" NC users responded overwhelmingly that the computer will play an important role in manufacturing productivity. The large users with more than four NC machines stated that computers were essential or at least important to remain competitive. The small users were not so firmly convinced. Present small users with plans to purchase more NC equipment should question their initial reaction on the impact of computers.

UTILIZATION OF COMPUTERS IN THE CONTROL OF MANUFACTURING OR DESIGN OPERATIONS IN THE NEXT FIVE YEARS



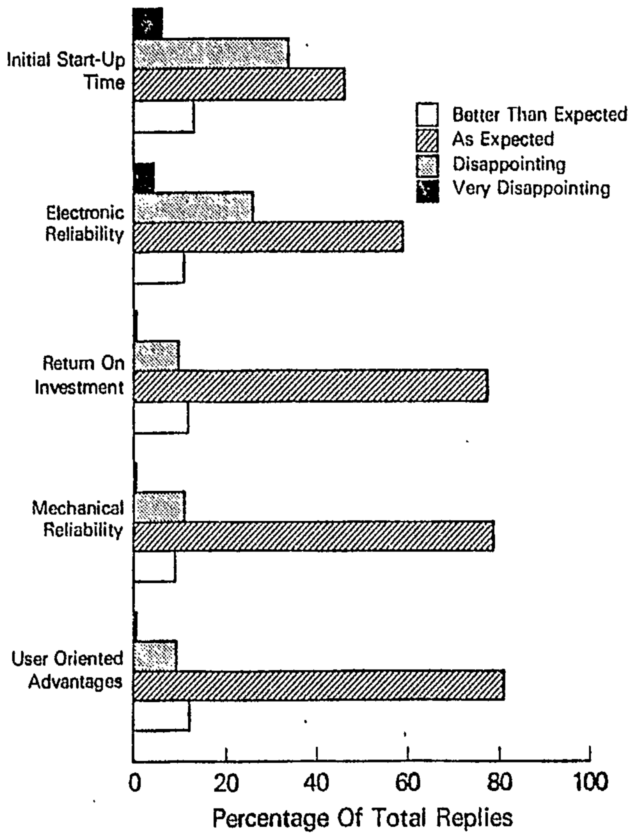
User Satisfaction to CAM

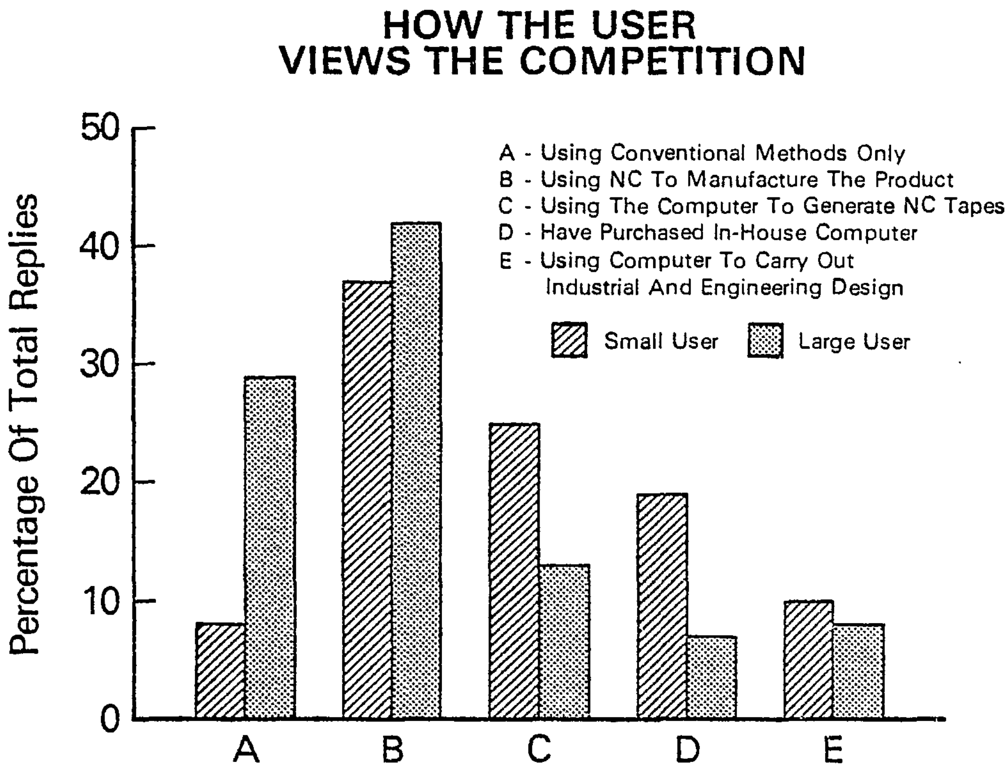
We asked all users to indicate their satisfaction or dissatisfaction with NC machine installations based on the following criteria. Electronic reliability, mechanical reliability, user oriented advantages, return on investment and initial start-up time.

In each category the major response was that the equipment performed as expected with categories of: return on investment, mechanical reliability and user oriented advantages providing users with better than initially expected results. The categories of electronic reliability and equipment start-up time did not meet user expectations. Skilled electronic technicians are difficult to find and if the user does not have such a person on staff the equipment may be inoperative for weeks at a time.

From the results established, it is also quite apparent that a serious area of concern to many users is initial start-up time of equipment. In particular the small users were especially concerned with this category. There is generally a lag in equipment start-up which appears to drag on through in-plant training and equipment failures until the initial shake-down period is over. The problem is also compounded by the reluctance of the users to train their own personnel adequately before the equipment arrives at the user's facility. The results indicate that the larger users (the users with experience) are less susceptible to start-up problems because of their ability to thoroughly investigate equipment in advance of the purchase, their ability to define adequate specifications and their frequent insistence on "bench mark testing" prior to purchase. It appears that the smaller companies without internal R & D support, would do well to hire a consultant for a few days in order to improve system specifications and to provide a smoother transition during start-up.

SATISFACTION WITH EQUIPMENT THAT INCORPORATES SOME COMPUTER CONTROL





How the User Views the Competition

In order to determine the overall view of users towards CAM we asked each user to comment on the technology level of their competitors. The small users of NC equipment expressed the opinion that much of their competition was still using manual equipment although 42% have switched to NC to manufacture their product. It is significant to remind the reader at this time that only NC users were surveyed. If a similar question had been asked of a group of companies only using manual machines, we feel the response would have been quite different.

The large users identified their competition as progressively going into computerized methods for manufacturing with a significant number of users (19%) identified as having their own computer. It also appears that the majority of NC users in a particular market segment agree with each other on the need for advanced technology. For example, the majority of aerospace respondents were presently using computer assisted time sharing and planning to go to the in-house computer with a manufacturing engineering capability.

On the other hand, a large number of the small users and in particular the "jobbers" were quite satisfied with manual programming and viewed the CNC machine as the ultimate step due to the increased capability of shop floor programming.

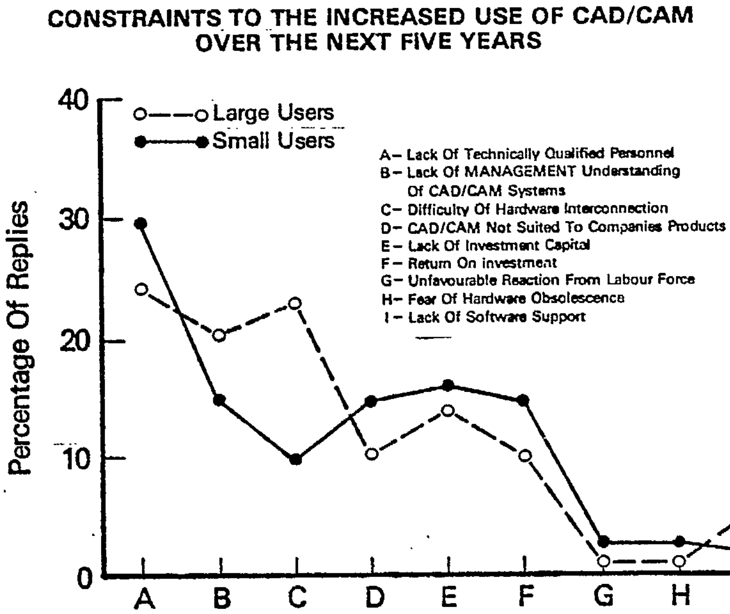
Constraints to Increased Utilization

The greatest constraint to the increased use of CAD/CAM during the next decade in Canada will be the lack of technically qualified personnel. This includes manufacturing engineers, process planners, NC programmers, machinists and NC operators. In addition management was critical of its own capability in understanding CAD/CAM systems. The third most common constraint was the system's capability of connecting hardware into a more complete system. This problem again points to technical personnel problems.

Contrary to a similar survey in the United States, return on investment was not the major concern.

In addition to the constraints listed several users pointed out that the lack of product standardization was a constraint. Other users elaborated on personnel problems and sited the lack of talent in the support staff, the acceptance of the staff to the implementation of CAD/CAM, and the lack of funding to assign people to study the benefits of CAD/CAM.

The small users did not feel that hardware interconnection was a serious problem. If small users have plans to purchase more equipment they should be aware of the opinion of the larger users.



Government Incentives for the User

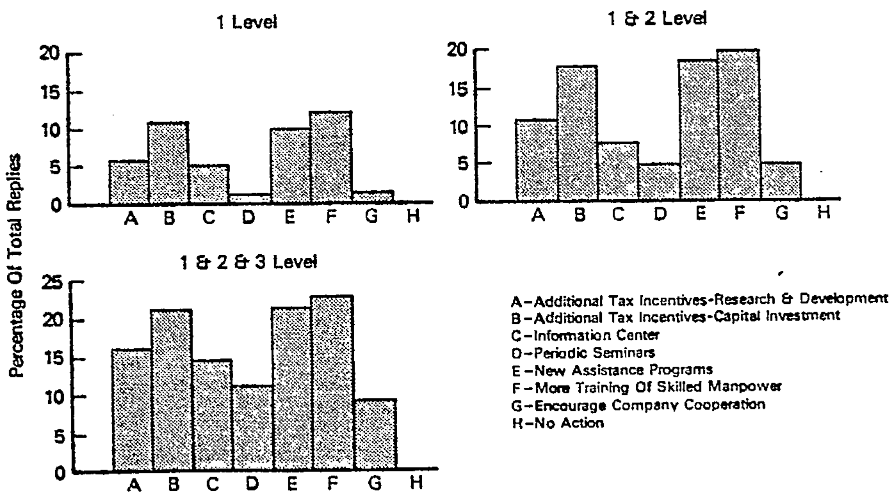
Two questions were asked in the study concerning incentives to overcome the identified constraints, the first being "What help should Government Provide?"

Even though the suggested incentives in the questionnaire placed tax incentives for capital equipment at the top of the list, users responded with their first choice being "place more emphasis on developing skilled manpower". The second overall choice was for additional tax incentives for capital investments which should include CAD/CAM systems where the prime purpose of implementation is design and programming for manufacturing operations. Tax incentives for research and development ranked high with the large users followed by the suggestion that there is a need for information centers on manufacturing technology. Seminar programs and cooperative ventures between companies for the development of new ideas received very little support especially from the large users.

The graphs portray the response at three levels using weighted averages.

1 level - users first choice
2 level - users first plus second choice
3 level - users first plus second plus third choice.

GOVERNMENT HELP REQUIRED IN OVERCOMING CONSTRAINTS

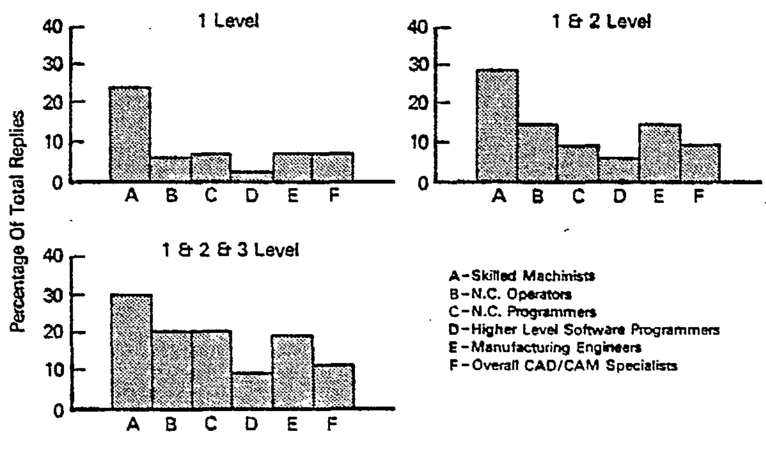


Category of Skilled Workers who are difficult to Hire

As identified, users have overwhelmingly stated that manpower is the greatest constraint to the increased utilization of CAD/CAM. The large users stated that machinists and manufacturing engineers were the most difficult to hire followed by NC operators and NC programmers. The small companies were more adamant that skilled machinists were the most difficult personnel to hire. It is apparant that the need for higher level software programmers in a manufacturing environment is minimal. As more advanced systems are implemented (such as computer graphics for manufacturing), the need for higher level software programmers and overall CAD/CAM specialists will increase.

The graphs indicate the response at three levels using weighted averages.

CATEGORIES OF SKILLED WORKERS WHICH ARE DIFFICULT TO HIRE



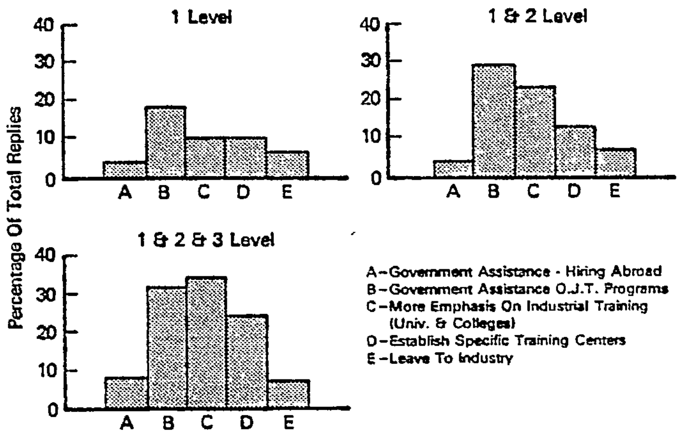
Required Help in Overcoming Recruitment Problems

It has been identified in the study that skilled workers, in particular, machinists, N.C. operators, programmers, and manufacturing engineers are difficult to hire. We asked the question, "What would be the best way for your company to increase the number of these skilled workers?" The majority of companies were in favour of government support programs, and in particular, would like the government to carry on supporting or increase their support for "on-the-job" training programs. In addition, the second most popular request was to assist universities and colleges with manufacturing engineering and technician programs. The third choice overall was the establishment of a centre for specific training in CAD/CAM technology.

The most unpopular way of spending tax payers' money for increasing skilled workers is supporting hiring programs in other countries.

The graphs indicate the response at three levels using weighted averages.

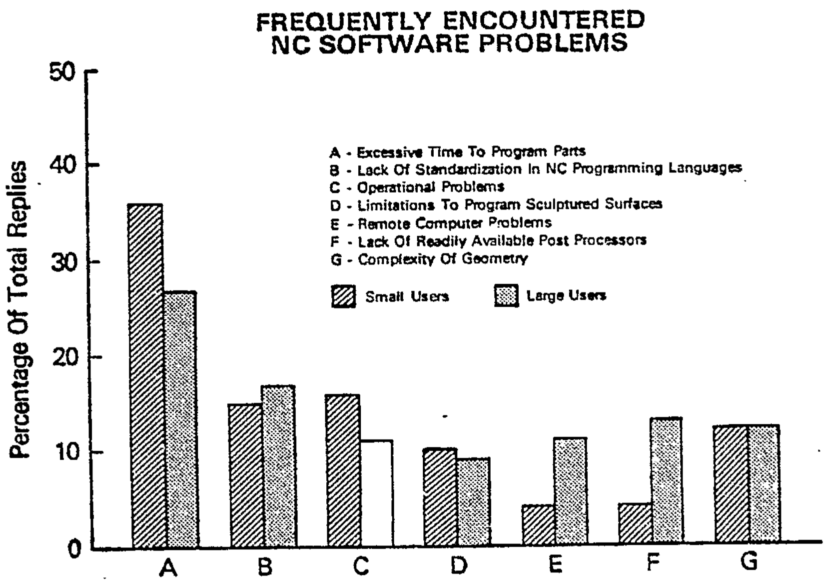
REQUIRED HELP IN OVERCOMING RECRUITMENT PROBLEMS



Frequently Encountered NC Software Problems

This analysis did not go into detail but covered only major areas of complaints as viewed from manufacturing management.

Both large and small users identified management's major complaint as "excessive time to program parts". The small users who are predominantly manual programming were more emphatic on this point. The majority of large users are utilizing the computer in a time sharing mode with local editing capabilities. Many of these companies are planning to switch to an in-house computer over the next few years. It is interesting to note that companies falling close to the "mean line" programming cost (page 41) did not agree with the majority of users identifying the major complaint as excessive time to program parts. Their major complaints were equally split between remote computer problems and the lack of standardization in NC programming languages. As more and more companies switch over to the in-house computer, the "remote computer" complaints will be rectified; however, the problem of standardization will continue to be a problem due to proliferation of languages and systems.



Attitudes Towards Group Funding

Management was asked "Would you be willing to participate in the funding of a group project oriented towards the elimination of the software problems" identified above.

The results from the survey were as follows: Only 11% of the small users were in favour of group funding whereas 44% of the larger companies were in favour. There appeared to be no set pattern to the companies that were in favour. It appears to be related to company policy where the protection of research and development activities provide some companies with a marketing edge.

CURRENT AND FORECASTED USE OF CAD/CAM TECHNOLOGIES

One of the major questions in the survey concerned the forecasted and current utilization of specific CAD/CAM technologies.

Companies were asked to select the CAD/CAM technology which will have the greatest use and application in the company in five years time. In addition, they were asked to indicate where the company stands with regard to the implementation of those technologies at the present time.

The analysis revealed that the majority of companies surveyed were aware of advanced CAD/CAM technologies and portrayed similar expectations for future involvement. As expected the large N.C. users were the most optimistic although the smaller users projected similar future involvement, but scaled down from the larger users. This has not been shown graphically.

In general, engineering computation including design graphics, automated drafting and production and parts scheduling will be major areas for expansion and application in the next five years. *If Canadian industry follows the trend in the United States, then turnkey mechanical design and drafting systems for manufacturing, will make tremendous inroads in Canada. The U.S. market is growing at a rate of 53% per year. It has been estimated that mechanical CAD/CAM systems will represent a one billion dollar segment of a 2.2 billion dollar industry by 1984.

Large users of N.C. equipment stated they will increase the number of N.C. machine tools by at least 100% over the next

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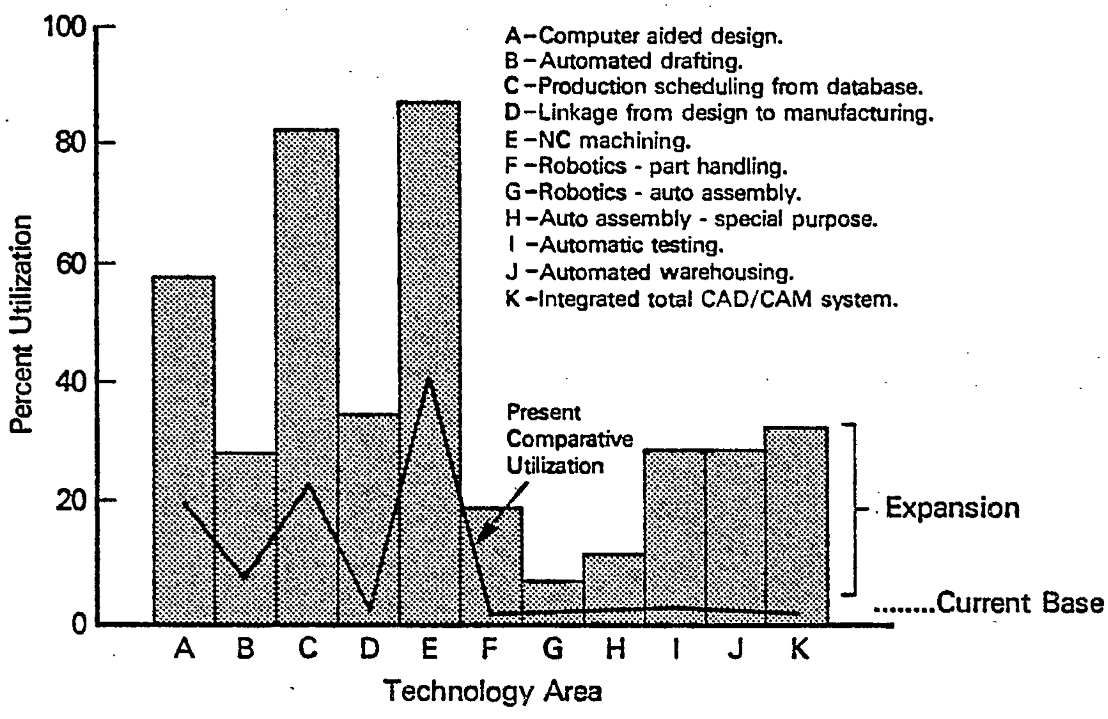
* Source: Merrill Lynch Institutional Report, September 12,1980.

five years and rely increasingly on the computer for production and parts scheduling. Interestingly enough, N.C. users do not have high expectations for robotics and automated assembly. This is probably due to the Canadian scene where the N.C. users are mainly jobbers in manufacturing. In addition, the large assembly, welding, casting and forging plants represent the greatest potential for robotics and are generally not included in the large N.C. user category.

THE EXPECTED COMPARATIVE USEAGES OF VARIOUS TECHNOLOGIES FIVE YEARS FROM NOW



Increase and expansion ranged from a minimum of approximately 2.2 times the current level to a maximum of 10 times the current base within 5 years.

Predicted Growth of NC and CNC Machine Tools

In the small user category approximately eighty nine (89) machine tools were installed in forty-three user locations. The projected total by 1985 for these same users is two hundred and fifty two (252) machines. In the large user category approximately 296 machines are presently installed in 33 user locations with a projected 611 in five years time. This represents a 2.8 times increase for the small users and a 2 times increase for the large users.

*The latest census available of NC machine tools installed in Canada identifies 408 total users with 1396 machine tools installed. By subdividing this group into small and large users as we have done in our survey, we can identify 99 large users. In addition these 99 large users have a total of 810 machines installed which is a ratio of 8:18 machines per user.

Glancing back to our survey, the 33 large users have 252 machines installed which is a ratio of 7:6 machines per user indicating that our survey represents an excellent sample comparing it to the results of the CMM survey.

It is quite simple, therefore, to extend the CMM survey and make a prediction for the number of machines that will be installed at present user locations by 1985. The large users will have 1620 machines and the small users 1640 machines for a total of 3260 NC and CNC macnine tools installed by 1985. This total does not include new users.

It is of special interest to note that Canadian industry appears to be progressive compared to other industrialized countries as indicated by the ratio of N.C. machining centers

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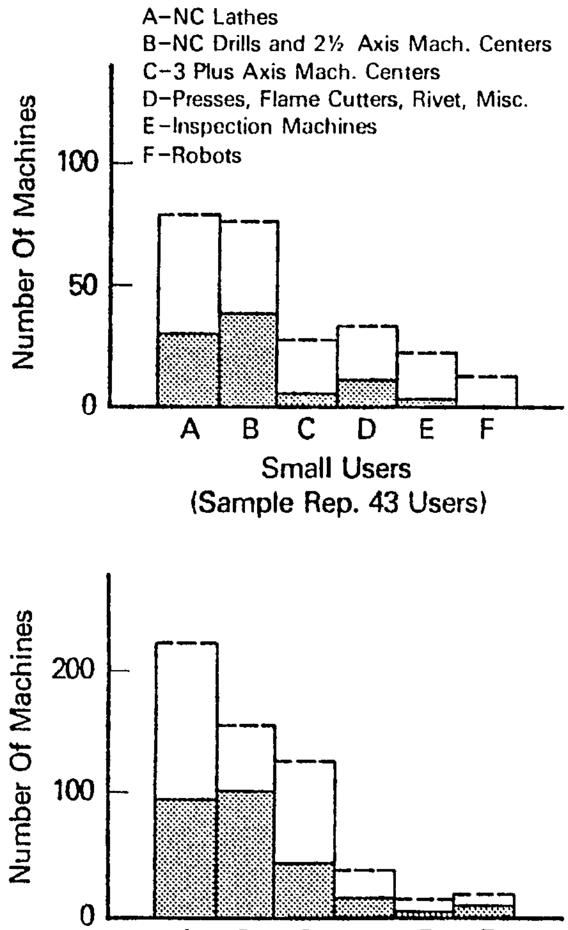
* Canadian Machinery and Metalworking, March, 1980. "1980 Census of Canada's Numerically Controlled Machine Tools".

to N.C. Lathes (3:2). Lathes are more easily programmed and operated and the capital equipment payback period occurs sooner in the majority of cases.

CURRENT AND PREDICTED GROWTH OF NC MACHINE TOOL INSTALLATIONS



Small Users
(Sample Rep. 43 Users)

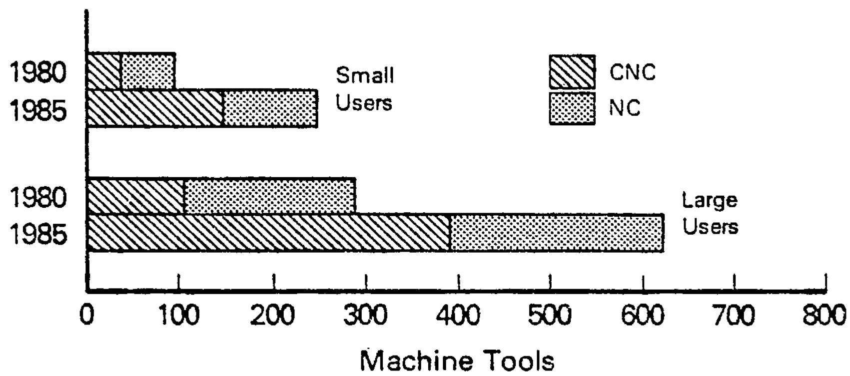
Large Users
(Sample Rep. 37 Users)

Comparative Growth of NC/CNC/DNC

Of the 89 machines installed by small users 37 are CNC systems. Users predicted that by 1985, 168 machines will have CNC systems as compared to 84 standard hardwired systems, an approximate 5:1 increase for CNC.

In the case of the large user there are presently 101 CNC machines in our sample out of a total 296. By 1985 the same users predict that 387 CNC machine tools will be installed out of a total of 611 machines; an approximate 4:1 increase for CNC.

It should also be noted that present users appear to be very knowledgeable on market conditions concerning equipment that will be available from vendors. The majority of control systems vendors have discontinued manufacturing hardwired NC systems in favour of computerized numerical control (CNC). The original CNC architecture has also been changed considerably from systems containing a purchased mini-computer to the present system utilizing distributed micro processor technology.



Direct Numerical Control (DNC)

Present users indicate that Direct or Distributed Numerical Control, where a higher level computer feeds information to a CNC machine tool, will not be used extensively by 1985. Only 21% of the large users signified an intention to install some form of DNC system in the future.

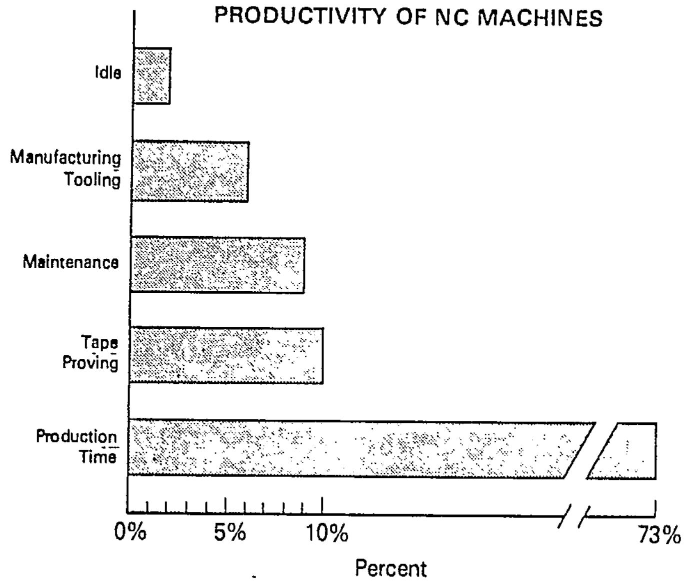
Those in favour of DNC are the manufacurers that continually machine repeat batch quantities of high technology components such as those produced in the aerospace field. One of the major benefits is the ability to carry out source program edit from the shop floor.

Productivity of NC Machines

Very little variation occurred from any of the users when questionned on productivity. Both small and large users were generally within 3 to 5 percentage points of the overall average. Production time represents 73% of the total time available on NC machines, although we did not ask the question on how much of this time was actually cutting metal. Tape proving represents a fairly high portion of the total time available (10% of the time), and represents an area where programming system suppliers should attempt to provide more complete systems to the users in an effort to reduce this valuable lost time. Recent examples that have improved the situation include the use of graphics plotting and the ability to plot the final machine control tape (commonly called "back plotting").

Maintenance represents an average of about 9% of the total time and varies from user to user depending upon whether the user carries out preventative maintenance during the normal working day or after hours.

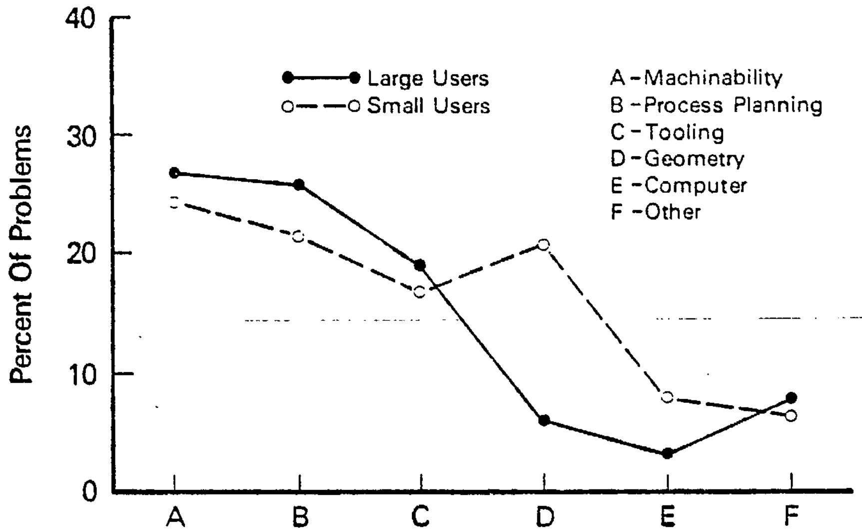
N.C. machines are utilized to manufacture chuck jaws on lathes and holding fixtures on machining centres. This activity represents an average of 6% of the total time.



N.C. Machining Problems

The response regarding programming problems was as expected. With the exception of smaller companies using manual programming who did have geometry problems, most users have few problems or corrections arising from part description or computer useage. The principal problems encountered are due to basic manufacturing procedures. That these problems become more critical on N.C. machines is not surprising, since, in the majority of cases, tools may be expected to be in cut for a considerable proportion of the time, hence the optimization of cutting conditions and tools, becomes much more critical than on manual machines. This problem is amplified by the more structured environment of N.C. machining where a considerable amount of the responsibility has been taken from the shop to the office. As a result of this, problems which would have gone unnoticed, now result in the requirement of tape corrections and become much more visible. It is worth noting that, despite the problems encountered in this area, there is still no noticeable movement towards the adoption of technologically based N.C. programming languages (e.g. EXAPT) nor is there a great deal of interest in computer aided process planning. These trends are somewhat surprising in the light of developments in both the USA and Europe and perhaps reflect a lack of awareness, rather than a lack of concern.

MACHINING PROBLEMS AND CORRECTIONS



Trends in Programming Systems

Due to the sophistication of Computerized Numerical Control (CNC), machine language programming or manual programming has become more attractive to the new user than with the previous type of control system (NC). In the past, computer assisted programming was an absolute necessity in order to calculate complex cutter paths and threading routines. Almost all the new CNC controls are available with decimal point programming, work surface programming, constant surface speed, subroutine programming, etc. These features have greatly decreased the workload of the programmer and reduced the necessity for remote computer assisted methods.

It was interesting, therefore, to obtain the results through analysis on the opinion of small and large users for present and future programming trends. Our survey asked "What percentage of NC tapes are: manually programmed, programmed with the aid of an intelligent terminal, programmed using a computer assisted programming language, programmed with a computer graphics system". In addition, we questionned various methods of computer assisted programming and were able to project the future trend of small and large users.

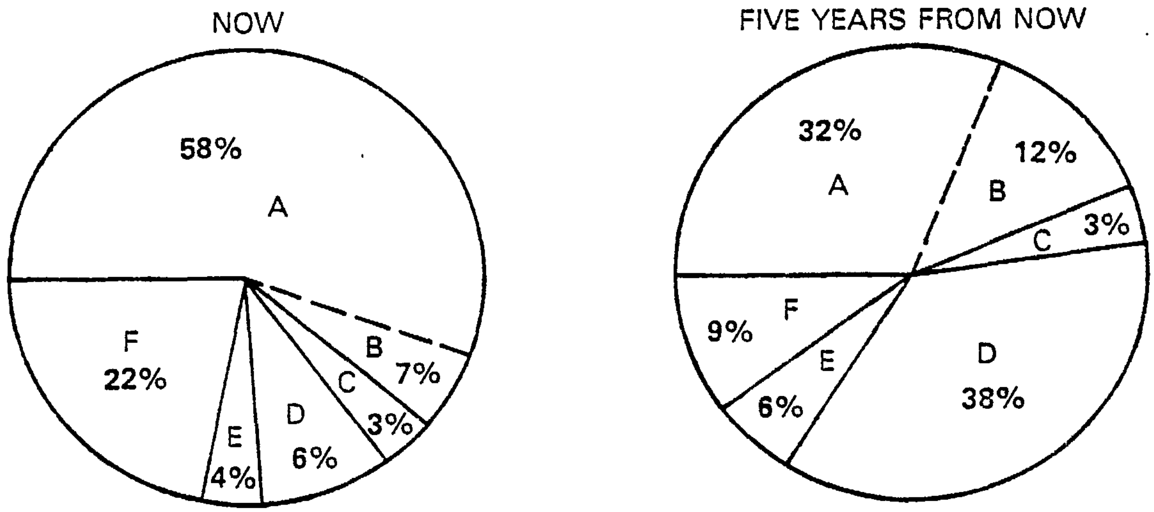
The small users are predominantly utilizing manual programming (70%). The large users make extensive use of computer assisted programming (51%). This percentage takes into account users programming methods that may encompass a variety of programming methods internally. For example, a part may be programmed using computer assisted methods, after plotting or verifying the tool path at the machine, the tape data may be corrected manually at the CNC system or through an off-line terminal or tape preparation system. Many of the large users presently using time sharing services work in this manner.

The most significant trend is the switch from time sharing to stand-alone in-house mini-computer systems. In addition, graphics programming will increase significantly due to NC machining applications that were impossible to justify previous to graphics.

The new small users may jump directly to the "in-house mini" rather than time sharing. This decision will be based on management's awareness of product knowledge along with the influence of present and future suppliers. Since this decision is so important for future productivity, new users would be wise to contract a consultant.

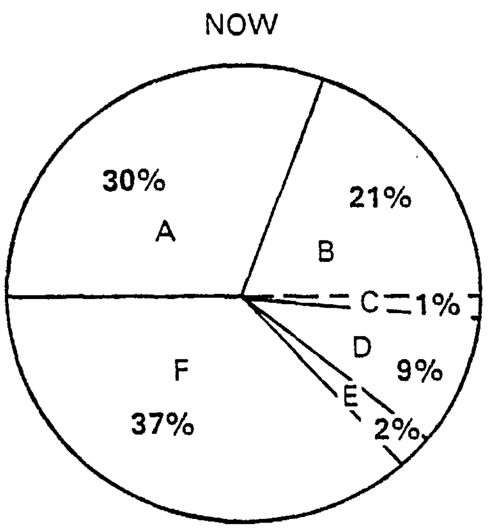
The following graphs indicate the trend of present users over the next five years.

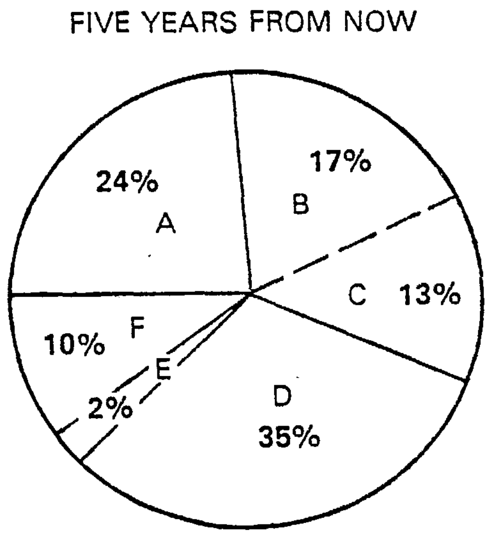
SMALL USERS
(LESS THAN FOUR NC MACHINES)
NC PROGRAMMING METHODS



A - Manual Programming Only
B - Edit Terminal Users
C - Graphic System Users
D - Mini-Computer System Users
E - Large In House System Users
F - Computer Time Sharing Users

LARGE USERS
(FOUR OR MORE NC MACHINES)
NC PROGRAMMING METHODS





A - Manual Programming Only
B - Edit Terminal Users
C - Graphic System Users
D - Mini-Computer System Users
E - Large In House System Users
F - Computer Time Sharing Users

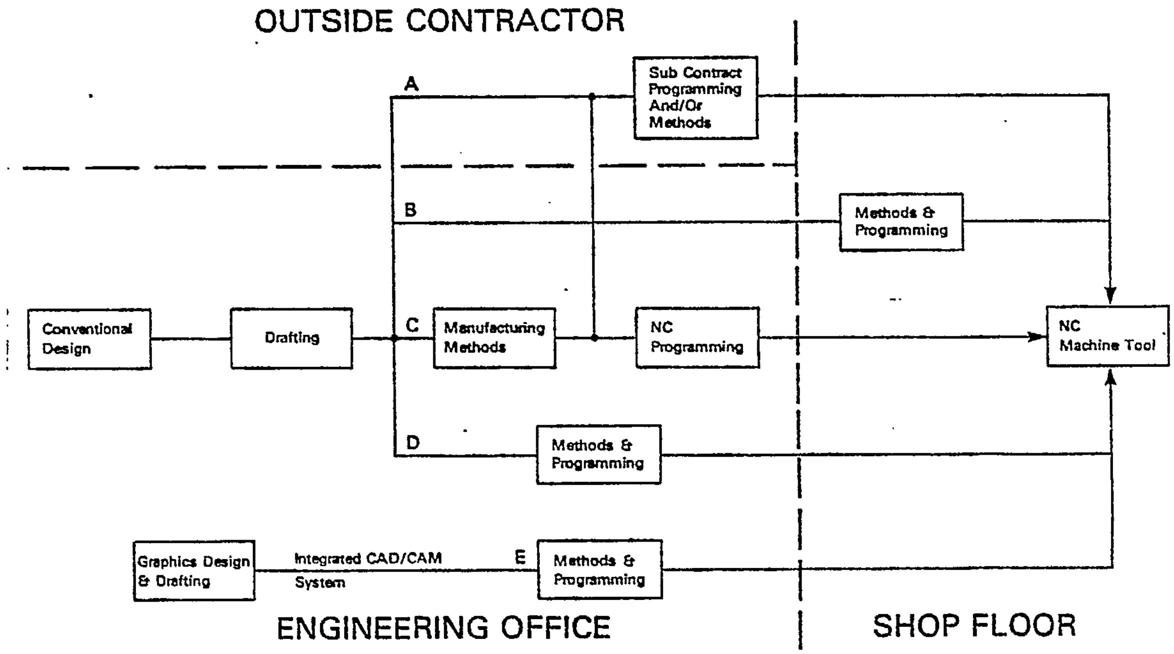
THE PART PROGRAMMING TASK

Flow of Information for Programming

Just how do the majority of users provide programs to the shop floor? The majority of users do not have separate process planning and programming departments and generally rely on one individual to carry out both methods and programming. However, 15% of the small users send the manufacturing drawing directly to the machinist/operator on the shop floor for methods, programming and part manufacture.

As the user increases the number of machine tools, there is a definite trend to separate methods and programming.

Subcontract programming represents only a fraction of the total programming surveyed. However, it is felt that some users are reluctant to state the actual amount of sub-contract programming that is carried out because in some cases, the sub contractor works at the user location and becomes a part of the user programming team. A more recent method for programming is shown by "E". No data is available due to the limited number of installations at this time.



PERCENTAGE OF TOTAL USERS UTILIZING VARIOUS METHODS OF PROGRAMMING

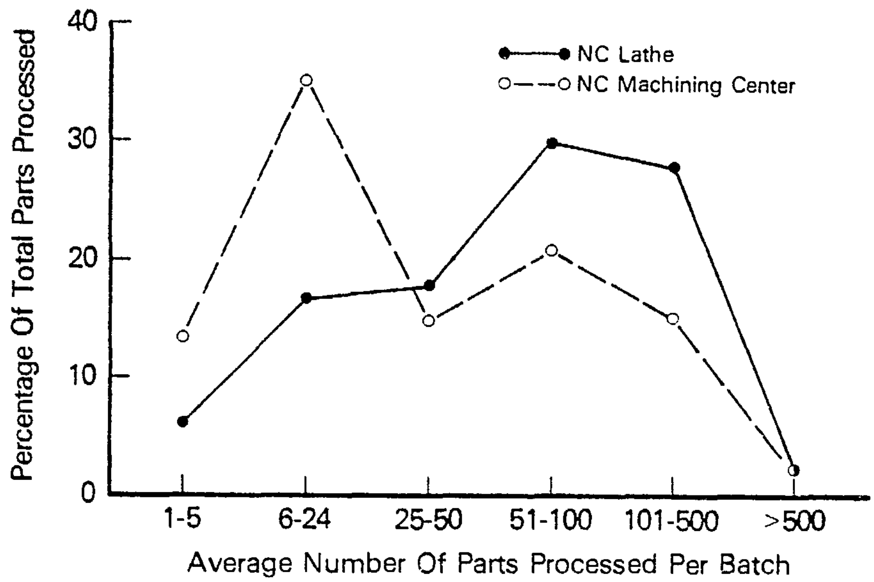
		1980		1985	
		Small Users	Large Users	Small Users	Large Users
Sub Contract Methods & Programming	A	6%	2%	0%	1%
Shop Floor Methods & Programming	B	15%	2%	6%	1%
Separate Function Methods & Programming	C	27%	32%	42%	50%
Same Person Methods & Programming	D	52%	64%	52%	48%
Integrated CAD/CAM	E	No Information Available			

Job Lot Sizes for NC Programming

What batch size of parts is generally machined by users of NC or CNC machine tools? Lathe users stated that 31% of their batch part runs were between 51 - 100 parts and an additional 30% between 101 - 500 parts. Only 2% of those surveyed indicated batch sizes of 500 parts and over.

NC drill and machining center users generally machine low batch quantities. It does not appear to be unusual to machine only one part. Several of the users surveyed were in this category. 35% stated the average lot size was 6 to 24 parts and 13% processed 1 to 5 parts on the average.

When the question was asked "Why did they not process smaller batch quantities (both lathe and MC's)" the major reason appears to be that it is uneconomical due to machine set-up time with the second choice being overall programming costs.



Factors Influencing the Selection of a Programming Language

It is apparent from the survey that selection of a language together with the methods of utilization should be a serious area of concern among first time NC users. The majority of first time users do not understand the benefits or constraints of computer assisted programming and find it difficult to differentiate between computerized numerical control (CNC) and the requirement for an external programming assistance method. In addition, there is very little evidence that users will match the machining requirements, batch quantities, complexity of the part to be machined and throughput, with the language and method required in order to be successful.

Basically, a first time user will purchase his first NC or CNC machine and select the method of programming after the system has been installed. The majority of new users do not consider a "programming language" as one of the fundamental building blocks of a machine tool system. In fact there is much evidence to indicate that first time users have the opinion that CNC totally obviates the need for computer assisted programming. There are still many programming problems that require the use of an external computer assisted programming method. In addition, the argument for programming external to the CNC system should be weighted fairly heavily when one considers the cost of manual programming on a $300,000 CNC machine tool.

When we asked the question "What factors influenced the selection of a programming language" 25% of the small users (1 to 3 machine tools) stated that they used a feasibility study to select the language.

Only 15% of the large users used this approach because they relied on the senior programmer to select the language and method. Presumably the small users would not have had a full time senior NC programmer knowledgeable enough to influence the management.

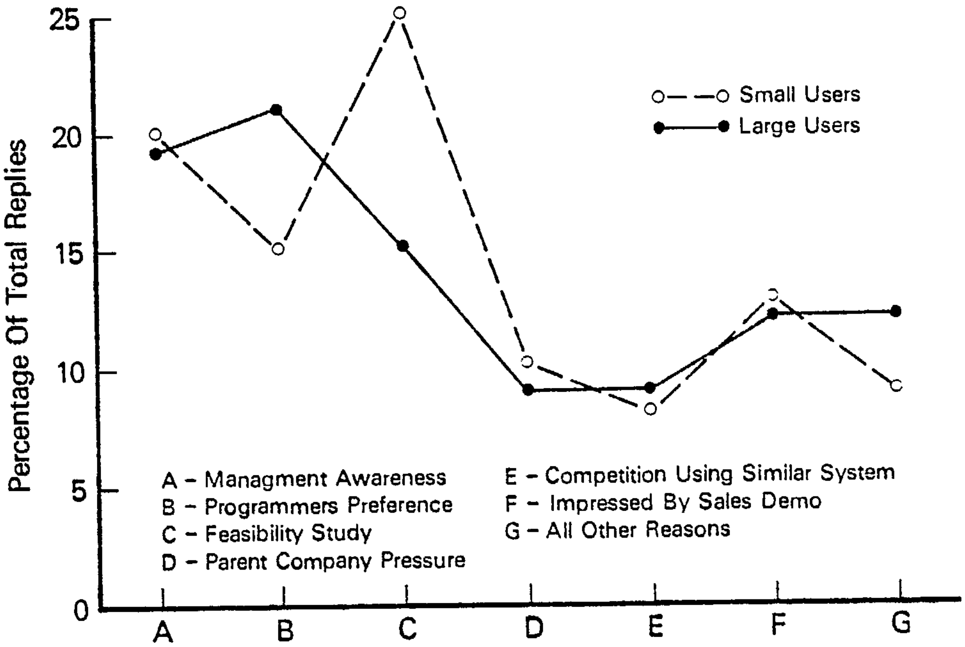
There were many comments from users citing additional reasons for the choice of language. "Back-up support" and "language most used by manufacturing companies" were two reasons cited along with "ease of working with the system" and "complexity of work requirements". Two companies mentioned the "availability of present higher level languages", as being the reason for their choice.

Programming Language Standards

There is no standard computer assisted programming language. APT has become the closest to a standard but there are many versions and subsets of APT. Although the APT family is the standard in the aerospace field, other languages are in wide use in aerospace, jobbing, machinery and electrical companies.

As indicated, many of the small users program manually. They responded to questions by stating that 44% were in favour of a Canadian Standard. The large users who predominantly program through computer assisted methods were less attracted to a Canadian Standard with only 33% in favour. Several users in both groups expressed the opinion that a Universal Standard was preferred over the Canadian Standard.

FACTORS INFLUENCING SELECTION OF
NC PROGRAMMING LANGUAGE



Programming Costs

Of major importance in the study was the attempt to relate NC programming costs to the number of tapes produced or the number of programming jobs carried out.

Several sketches were provided to users that identified parts of varying complexity. They were asked to state the number of new programs prepared during the current year along with their annual cost for programming labour and computer time.

From the analysis, it appears that companies utilizing only manual programming are unaware of their programming costs per part or tape. In addition, companies that are programming complex parts cannot be graphically related because of the variety of work carried out and the length of individual tape programs.

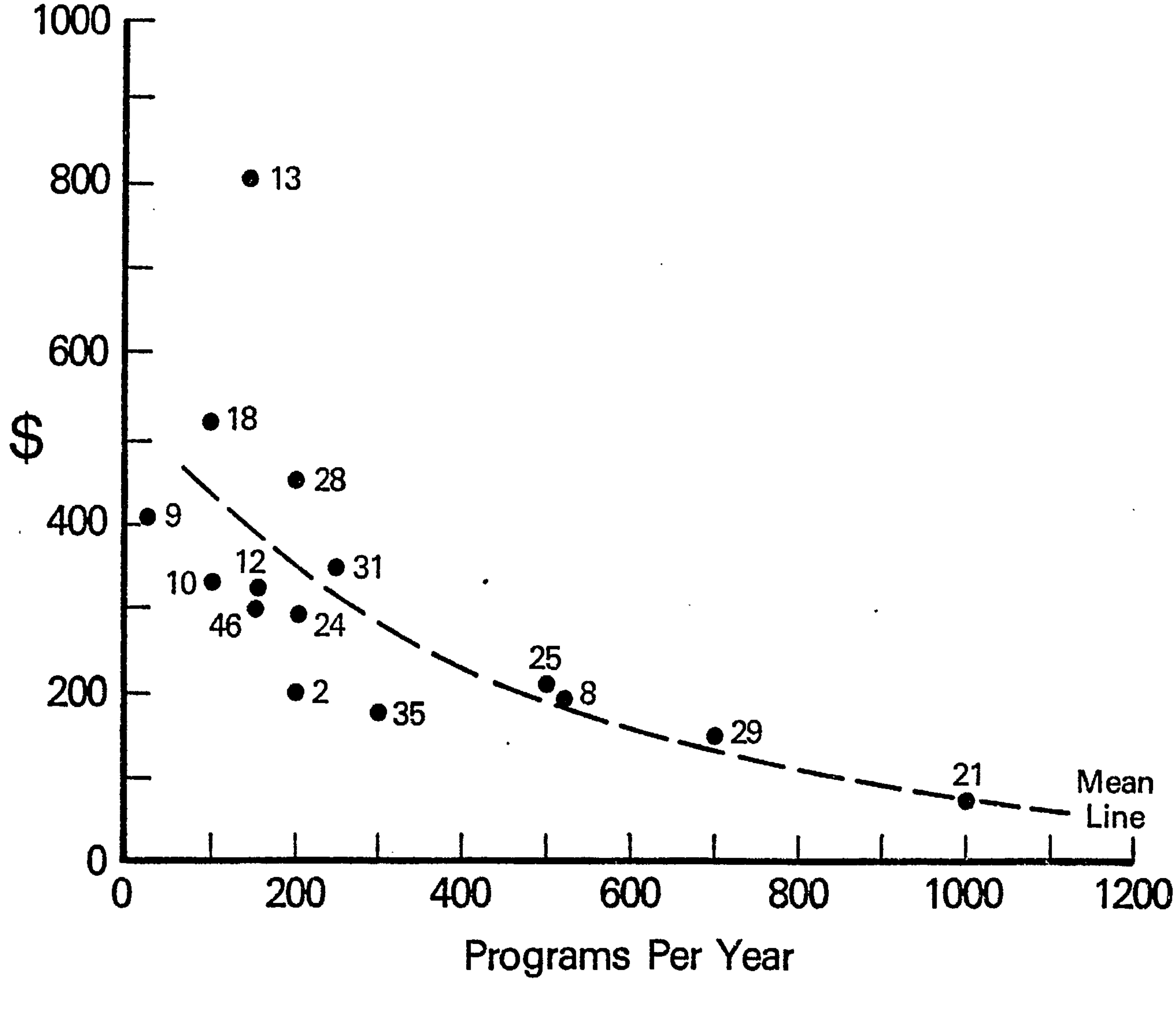
However, sufficient information was provided by both large and small users to enable us to draw a programming cost mean line for work that could be classified as simple to medium complexity. A profile of companies includes jobbing shops, machinery builders, mould and die facilities, aerospace and electrical control manufacturers. The size of the users varies from 60 to 1200 employees.

A mean line for cost per tape was generated by extending a line through a series of individual company costs. This mean line should only be used as a guide to programming costs where the workload is generally routine turning, milling and drilling. However, as the expertise of the user increases (programming-operating) more complex, smaller batch parts may be included in this analysis. As shown by the graph, batch quantities vary considerably.

Another interesting cost figure that resulted from the analysis above was the total average cost of programming per machine. Several of the large users, averaged $8,000 total programming cost per machine.

Companies whose costs are above that figure may wish to examine some of the variables related to the cost of programming. Firstly, is the complexity of work carried out low, medium or high? Secondly, what is the ratio of programmers to the number of machine tools? Thirdly, if computer time sharing is being used, are the costs excessive and if they are, is this the result of the vendor not being competitive or the company's programmers not being fully trained, or some other factor.

AVERAGE COST PER PROGRAM
LABOUR PLUS TIME SHARING



COMPANY PROFILE
COST PER PROGRAM AND COST PER MACHINE

SURVEY NO.	21	29	6	25	35	2	31	24
Industry	Jobbing		Electrical Machinery &	Electrical Control	Mould & Die	Gen. Mach & Fab		
No. Employees	250	1000	800	500	130	650	1200	750
Programmers	3	4	4	3	2	7	4	2
Operators	40	60	25	15	6	17	8	22
Machines								
- Turning	8	8	4	3	1	2	1	3
- Drills	-	4	2	2	1	1	1	
- M/C	11	4	3	3	1	2	2	4
- Other	-	2	3	2	-	1	5	-
Computer Assist	G E.ADAPT	COMPACT II	G - TURN GE - ADAPT	COMPACT II	G - TURN GE - ADAPT	COMPACT II WIED	COMPACT II MANUAL	GE ADAPT
Complexity	2 - 2½ Axis	2 - 2½ Axis	2 - 2½ Axis	2 - 2½ Axis	2 - 2½ Axis	2 - 2½ Axis	2 - 2½ Axis	2 4 Axis
Batch Quantity	25 - 500	25 - 100	6 - 100	1 - 100	1 - 24	51 - 500	51 - 500	6 - 50
Programs per Year	1000	700	500	500	300	200	250	200
Total Cost per program	$80	$150	$194	$210	$175	$190	$335	$280
Program Cost per Machine	$4000	$6000	$8000	$10000	$17500	$6300	$10800	$8000
SURVEY NO.	**48**	**12**	**10**	**28**	**18**	**9**	**13**	**27**
Industry	Aerospace	Valves	Equipment	Machinery	Aerospace		Gen.Jobbing	Electrical Apparatus
No. Employees	120	120	60	500	100	120	260	750
Programmers	1	2	2	2	2	1	4	4
Operators	3	12	2	18	13	4	23	16
Machines								
- Turning	-	4	-	2	2	1	7	2
- Drills	-	2	-	-	-	-	2	
- M/C	1	-	1	4	3	1	8	4
- Other	-	-	-	-	-	-	-	2
Computer Assist	COMPACT II	COMPACT II	MACHINE BUILDERS PROPRIETORY	COMPACT II	IBM - APT G E -ADAPT G - TURN	G E -ADAPT	COMPACT II	G E ADAPT
Complexity	2½ - 3 Axis	2 - 2½ Axis	2½ - 3 Axis	2 - ½ Axis	2 - 3 Axis	2 - 2½ Axis	2 - 2½ Axis	2 2½ Axis
Batch Quantity	6 - 24	6 - 24	25 - 50	1 - 500	51 - 100	1 - 24	6 - 50	6 - 50
Programs per Year	150	160	100	200	100	20	150	50
Total Cost per program	$300	$315	$320	$455	$520	$400	$800	$1500
Program Cost per Machine	$45000	$8600	$32000	$15000	$10000	$4000	$7400	$9250

PROTRAIT OF AN NC PROGRAMMER

The survey attempted to question one of the most important areas of NC machining, namely the function of the NC programmer.

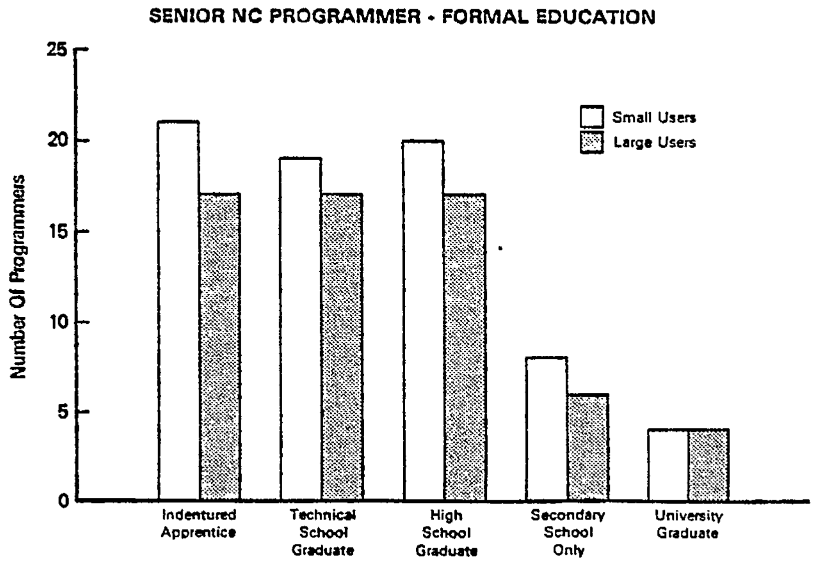
The senior NC programmer, in the case of the small user, was previously a general machinist. Only rarely has the NC operator advanced to the NC programmer's position. The large users indicated that the NC programmer had previously been a process planner or possibly a general machinist. The majority of senior programmers are high school graduates and either completed an apprenticeship or graduated from a technical school.

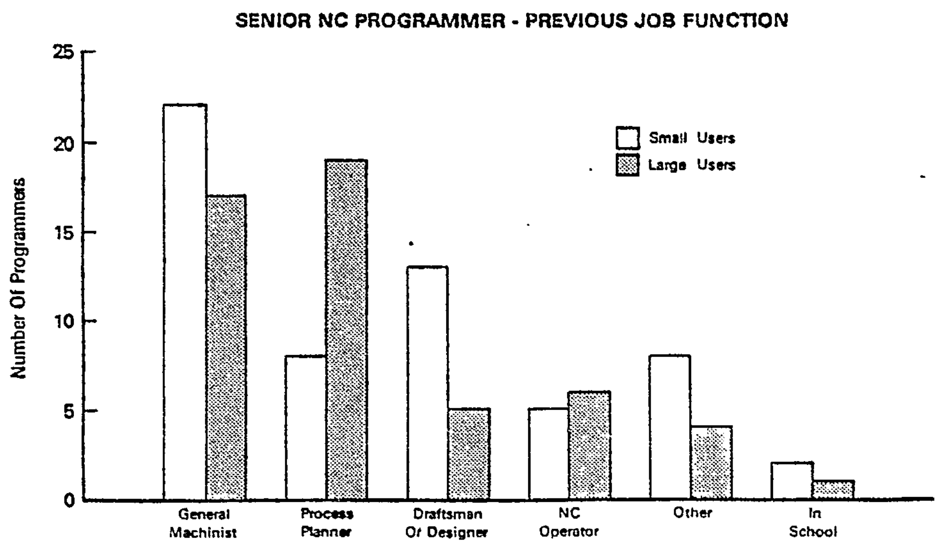
In addition to the normal schooling the majority of programmers attended one or more programming courses at the machine tool or control vendors plant and possibly received additional training at an Institute such as the Canadian Institute of Metalworking.

The value of a programmer increases with their ability to program more complex parts. There is at least a 20% pay differential between a senior programmer programming only 2 - 2 1/2 axis work in comparison to a programmer with a 3 axis and above capability.

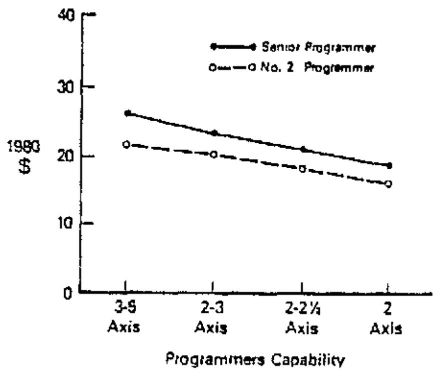
NC machine tool programming is a recent skill. The average time in the job for the senior programmer at a large user's plant is only seven years. The senior programmer generally acts as the NC coordinator in the company. The job requires the ability to design fixturing and tooling, carry out the process planning as well as the part programming. The majority of programmers at large users witness tape proving at the machine tool. The programmer at a small user plant quite often does his own tape proving.

Management places a large amount of responsibility with the programmer and, in the majority of cases, relies on his or her decision in selection of a programming language and system as well as providing serious input in the selection of machine tools.


SENIOR NC PROGRAMMER - FORMAL EDUCATION
Number Of Programmers
25
20
15
10
5
0
Small Users
Large Users
Indentured Apprentice
Technical School Graduate
High School Graduate
Secondary School Only
University Graduate


SENIOR NC PROGRAMMER - PREVIOUS JOB FUNCTION
Number Of Programmers
25
20
15
10
5
0
Small Users
Large Users
General Machinist
Process Planner
Draftsman Of Designer
NC Operator
Other
In School

NC PROGRAMMER - AVERAGE RENUMERATION



	Senior Programmer		No. 2 Programmer	
	Small NC Users	Large NC Users	Small NC Users	Large NC Users
Act As NC Coordinator	87%	65%	31%	26%
Part Programming And Planning	76%	85%	54%	78%
Design And Select Fixtures	78%	76%	42%	57%
Perform Other Computer Related Tasks	24%	26%	0%	11%
Witness NC Machine Tape Proving	89%	96%	85%	100%
Carry Out NC Tape Proving	70%	44%	64%	44%
Have Major "Say" In Selection Of NC Programming System	69%	62%	31%	19%
Have Major "Say" In Selection Of NC Machine Tools	66%	53%	38%	26%
Average Years Experience As Programmer In Present Company	3.5 Yrs.	6.3 Yrs.	2.3 Yrs.	4 Yrs.
Average Years Experience As Programmer All Companies	5.5 Yrs.	6.8 Yrs.	2.5 Yrs.	4 Yrs.

% Indicates, Percentage Of Total Replies

APPENDIX I

CANADIAN INSTITUTE OF METALWORKING

SURVEY TO IDENTIFY THE ATTITUDES AND AWARENESS OF NUMERICAL CONTROL USERS TO CAD/CAM TECHNOLOGY

LIST OF COMPANIES WHO COMPLETED QUESTIONNAIRE

Babcock-Wilcox Can., P.O. Box 310, Coronation Blvd. Cambridge, Ontario, N1R 5V3

Bata Industries Ltd., Batawa, Ontario, KOK 1EO

Bristol Aerospace Limited, P.O. Box 874, Winnipeg, Canada, R3C 3S4

Brown Boggs Foundry Machine Co. Ltd., 275 Sherman Avenue N, Ham. Ontario, L8L 7Y2

Brown Boveri (Canada) Ltd., 160 Boul. St - Joseph Blvd, Lachine, Quebec, H8S 2L5

Burke Machine Works, 341 W. 6th Avenue, Vancouver, B.C. V5Y 1L1

Canada Tool Co. Ltd., 160 Groh Avenue, Hespeler, Ontario

Canadian Aircraft Products Ltd., 2611 Viscount Way, Richmond, B.C., V6A 3P3

Canadian General Electric Co., Ltd., 107 Park Street N, Peterborough, Ontario, K9J 7B5

Canners Machinery Inc. P.O. Box 190, Simcoe, Ontario, N3Y 4L1

C & C Precision Tool Ltd., RR1, Brantford, Ontario, N3T 5L4

Champion Road Machinery Co. Ltd., P.O. Box 10, Goderich, Ontario, N7A 3Y6

Clark Equipment of Canada Ltd., 25 Michigan Boulevard, St. Thomas, Ontario, N5P 1H2

CNC Precision Machining, 712 Copping Street N, N. Vancouver, B.C., V7M 3G6

John Deere Welland Works, Welland, Ontario, L3B 3N3

Deloro Stellite, 471 Dundas Street, Belleville, Ontaril, K8N 5C4

Dominion Engineering Works, 795 1 Ave, Lachine, Quebec, H8S Z5*

Door-Oliver Canada Ltd., 174 West Street South, Orillia, Ontario, L3V 6L4

Ebco Industries Ltd., 7851 Alderbridge Way, Richmond, B.C., V6X 2A5

Embree Industries Ltd., Marketing Division, 151 Birge Street, Hamilton, Ontario, L8L 7V4

Etatech Industries Inc., 58 Morrell Street, Brantford, Ontario, N3T 5N3

Ex-Cell-O Corp. of Canada, 120 Weston Road, London, Ontario, N6A 5L5

Exco Engineering, 220, Torbay Road, Markham, Ontario, L3R 2P3

Foster Wheeler Limited, 81 Eastchester Avenue, P.O. Box 3007, St. Caths,Ont. L2R 7B7

Gearmatic Co. Ltd., 7400 - 132nd St., Surrey, B.C., V3T 4X4

Gorman-Rupp of Canada Ltd., 70 Burwell Road, St. Thomas, Ontario, M5P 3R7

Greening Donald Co. Ltd., 55 Queen St. N, P.O. Box 430, Hamilton, Ontario

Fred Hall & Son Ltd., 35 Glow Avenue, Hamilton, Ontario

Hawker Siddley Canada Ltd., Canadian Car Div. 19433 - 96th Ave., Surrey, B.C.,V6B 4K6

Hawker Siddeley Canada Ltd., Canadian Car Div., P.O. Box 67, Thunder Bay, Ont. P7C 4V6

Hawker Siddeley Canada Ltd., Orenda Division, Box 6001, Toronto AMF, Ont. L5P 1B3

Heroux Limited, 755 Thurber Avenue, Longueuil, Quebec, J4H 3N1

International Harvester Co. of Can Ltd., 208 Hillyard St. Hamilton, Ont. L8N 3S5

International Tools (1973) Ltd., 3805 Malden Road, P.O. Box 7068, Windsor, Ont.N9C 3Y8

ITE Industries Limited, 2401 Dixie Road, Mississauga, Ontario, L4Y 2A3

ITT Industries of Canada Ltd., Four Cannon Court, Whitby, Ontario, L1N 5V8

Jamesbury Canada Ltd., 1282 Algoma Road, Ottawa, Ontario, K1B 3W8

Joly Engineering Ltd., 8960 Park Ave, Montreal, Quebec, H2N 1Y8

Kenroc Tools Limited, 3370 Dundas St. W, Toronto, Ontario, M6S 2S2

Leigh Instruments Ltd., 350 Weber St. N, Waterloo, Ontario, N2J 4E3

S. Madill Ltd., 2560 Bowen Road, Nanaimo, B.C., V9R 5M6

Matte Tool & Machinery Ltd., 172 Toryork Drive, Weston, Ontario, M9L 1X8

McDonnell Douglas Canada Ltd., Toronto, AMF, Ontario, L5P 1B7

Mecon Industries Ltd., 17 Mallory Road, Scarborough, Ontario, M1L 2E4

MIC Manufacturing and Machine Works Ltd., 405 Nyberg St., Kitchener, Ont. N2H 6N2

Moyer Diebel Ltd., P.O. Box 301 Jordon Station, Ontario, L0R 1S0

Nordic International, 1044 Rangeview Road, Mississauga, Ontario, L5E 1H3

Omark Canada Ltd., 505 Edinburgh Road N, Guelph, Ontario, N1H 6L4

Otis Elevator Co., P.O. Box 650, Hamilton, Ontario, L8M 3M1

Pratt & Whitney Aircraft of Canada Ltd., P.O. Box 10, Longueiul, Quebec, J4K 4X9

Pre-Delco Machine & Tool Ltd., 124 Clarke Road, London, Ontario, N5W 5E1

Rapid Tool & Die, 992 Dillingham Road, Pickering, Ontario, LoW 1C6

Rolls Royce Canada Limited, 10210 Pie 1X Blvd, Montreal N, Montreal, Quebec, H1H 3Z2

Sihi Pjmps Ltd., 225 Speedvale Ave W., Guelph, Ontario, N1H 6L8

Singer Valve, 12850 - 87th Avenue, Surrey, B.C. V3T 4W4

Spar Aerospace Products Ltd., 21025 Trans Canada Highway, Ste. Anne de Bellevue, Quebec, H9X 3R2

Sperry Gyroscope Div, Box 390, 3 Hamilton, Ottawa, Ontario, K1N 8P6

Sperry Vickers Div., 280 Attwell Dr., Rexdale, Ontario, M9W 5B6

Standard Modern Tool, 69 Montcalm Avenue, Toronto, Ontario, M6E 4N9

Stelco, Edmonton Fin. Works, P.O. Box 2348, Edmonton, Alberta, T5J 2R3

Stelco, Page Hersey Works, Daine Ave, Welland, Ontario, L8M 3T1

Teledyne Mining Products, P.O. Box 130, Thornbury, Ontario, NOH 2PO

Uniroyal Ltd., 149 Strange Street, Kitchener, Ontario, N2G 1R5

Upper Canada Manufacturing Ltd., 223 Evans Avenue, Toronto, Ontario, M8Z 1J5

Velan Valve Corp, Ave.'C', Grosswold Ind. Park, Williston, Vt 05495

Wagner Engineering Ltd., 40 Gostik Place, N. Vancouver, B.C., V7M 3G2

Wentworth Mould and Die Co. Ltd., 99 Burton Street, Hamilton, Ontario, L8L 3R4

Westinghouse, Motor Division, P.O. Box 510, Hamilton, Ontario, L8N 3K2

There were an additional 26 companies who submitted completed questionnaires but declined permission to release their names.

CANADIAN INSTITUTE OF METALWORKING

SURVEY TO IDENTIFY THE ATTITUDES AND AWARENESS
OF NUMERICAL CONTROL USERS TO CAD/CAM TECHNOLOGY

ADDITIONAL RESPONSES OF NO VALUE IN THE ANALYSIS

Canadian National Railway Moncton Shops, Barker Street Moncton, N.B.	Letter received: Presently installing first N.C. machines. Not enough knowledge and experience to complete questionnaire.
Canadian Timken Ltd. 1055 Talbot Street, St. Thomas, Ontario	Letter received: No NC equipment
Columbus McKinnon Ltd. 580 Wellington Ave., E. St. Catharines, Ontario	Letter received: Ceased manufacturing operations in St. Catharines.
C.P. Rail, 3195 Rachel St. E Montreal, Quebec, H1W 1A3	Letter received: Greatly interested in the survey but are still in the learning process of N.C. Consider their contributions would be of no value
Stackpole Machinery Company 3555 Danforth Ave, Scarborough, Ont.M1L 1E4	Letter received: Company does not derive any benefit from the survey.
The Stanley Works of Canada 367 Victoria Street New Hamburg, Ontario	Letter received: No NC equipment
Thermo Eelctric Can Ltd. 12 Rutherford Road, Brampton Ontario, L6W 3J2	Letter received: No NC equipment
U.D.T. Industries 2125 St. Catherines E Montreal, Quebec, H2K 2H9	Unable to complete questionnaire.
Union Carbide Can 123 Eglinton Ave E Toronto, Ontario M4P 1J2	Letter received: No NC equipment

APPENDIX II

May 1979

CANADIAN INSTITUTE OF METALWORKING
McMaster University
Hamilton, Ontario

A SURVEY TO IDENTIFY THE ATTITUDES AND AWARENESS OF NUMERICAL CONTROL USERS TO CAD/CAM TECHNOLOGY

and

THE TECHNOLOGICAL AND ECONOMIC STRENGTHS AND WEAKNESSES OF MACHINE TOOL PART PROGRAMMING

This questionnaire is designed to identify the attitudes and awareness of numerical control users to CAD/CAM technology and the technological and economic strengths and weaknesses of machine tool part programming.

The findings from this survey will assist potential users in making a choice for the future, help current users to justify their present and future methods and make suppliers more aware of Canadian requirements.

Your response will be held in strict confidence. Conditional with your approval we will acknowledge your participation in the study. You will receive a copy of the final report.

It will take about 30 minutes to complete each section of the questionnaire. Please answer each question factually; there are no right or wrong answers.

Please return your completed questionnaire to me personally addressed as follows:

Confidential

Mr. J.E. Crozier
Canadian Institute of Metalworking
McMaster University
1280 Main Street West, TB13
Hamilton, Ontario
L8S 4K1

Name of Person completing Section A of the Questionnaire ____________________

Position ______________________ Telephone: ______________________________

Name of Person completing Section B of the Questionnaire ____________________

Position ______________________ Telephone: ______________________________

Company Name: ____

Plant Address: ____

____

The report will not identify individual company responses but will use only grouped or unidentified data. It will be assumed that permission is granted to identify the name of the company as a contributor to the data to be contained in the report unless this is declined as indicated below.

Permission declined ☐

SECTION A

SECTION A (QUESTIONS 1 TO 12) HAS BEEN DESIGNED TO IDENTIFY THE ATTITUDES AND AWARENESS OF NUMERICAL CONTROL USERS TO COMPUTER AIDED DESIGN (CAD) AND COMPUTER AIDED MANUFACTURING (CAM) AND SHOULD BE COMPLETED BY THE SENIOR OFFICER OR GENERAL MANAGER OF THE COMPANY.

1. Our company's sales are:
   (Please circle one)
   a. less than $500,000 per year
   b. between $500,000 and $1,000,000 per year
   c. between $1,000,000 and $3,000,000 per year
   d. between $3,000,000 and $10,000,000 per year
   e. between $10,000,000 and $50,000,000 per year
   f. greater than $50,000,000

2. What percentage of the above sales can be attributed to manufacturing in your plant ________%

3. Our main business interests are:

   a. Mould and Die
   b. Aerospace
   c. General Jobbing Machine Shop
   d. Electronics
   e. Other ________________ (please specify product)

4. Number of employees at this plant _________

5. Do you consider the use of computers in the control of manufacturing or design operations in the next 5 years in your company.

   (please circle one)
   a. to be essential to remain competitive
   b. to be important to remain competitive
   c. to have some impact
   d. to have little or no impact

6. How satisfied are you with the manufacturing equipment that you utilize which incorporates some computer control?

	Better than expected	Generally as expected	Dis-appointing	Very dis-appointing
Electronic Reliability				
Mechanical Reliability				
User Oriented Advantages				
Return on Investment				
Initial Start-up time				

7. How extensively have your major competitors implemented the following:

Please circle each letter that describe(s) the technological capability of your major competitor(s)

a. Are using conventional machine tools only to manufacture their product.

b. Use numerical control to manufacture their product.

c. Make use of a computer to generate part programs to manufacture their product.

d. Have purchased an in-house computer to generate part programs, and have or are planning to implement computerized process planning and control techniques.

e. Are using the computer to carry out industrial and engineering design.

8. Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) is a technology that will have a significant impact on productivity during the next decade. Please consider the following possible constraints to the increased use of CAD/CAM technology in your company, and rank them on a scale of 1 to 5, with number 1 representing, in your opinion, the most severe constraint over the next five years, and number 5 representing the least significant constraint.

Difficulty of integration and interconnection of hardware into a more complete system	________
Lack of management understanding of CAD/CAM systems capability	________
Lack of technically qualified personnel	________
Unfavourable reaction from labour force	________
Fear of rapid hardware obsolescence	________
Lack of system software support	________
CAD/CAM techniques not suited to company's products	________
Return on investment too low	________
Lack of investment capital	________
Other (please specify) ______________________	________

9. What government incentives would be useful in overcoming the constraints identified in Question 8? Please rank on a scale of 1 to 5 with number 1 representing, in your opinion, the best incentive to overcome the constraints.

Additional tax incentives for Research and Development	______
Additional tax incentives for capital investments	______
Information center on manufacturing technology	______
Sponsor periodic seminars and discussions	______
Provide new assistance programs or place more emphasis on manufacturing technology under existing programs	______
Place more emphasis on developing skilled manpower	______
Encourage co-operation between companies to establish joint service facilities for development, production or marketing of new products (hardware and software)	______
Take no action	______

10. What categories of skilled workers have you found difficult to hire. Please indicate your most urgent need by numbering from 1 to 6, with 1 being the most urgent need.

______	skilled machinists.
______	N.C. operators
______	N.C. programmers
______	higher level software programmers (e.g. BASIC, FORTRAN)
______	manufacturing engineers
______	overall CAD/CAM specialists

11. What would be the best way for your company to increase the number of these skilled workers. Please number from 1 to 5 with 1 being the best way.

_________ Government assistance in hiring abroad.

_________ Increased government emphasis for "on the job" training programs.

_________ More emphasis on industrial training for students at universities and colleges.

_________ Establishment of centres for specific training in CAD/CAM technology.

_________ Let industry take care of the training of skilled workers without government incentives.

12. Which of the following are N.C. programming problems that you frequently encounter using your present programming method.

(Please circle each one that is applicable in your case)

a. Technical limitations in solving complex geometry.

b. Excessive time required to program parts.

c. Operational problems of the system utilized.

d. Line interference due to the remoteness of the computer system utilized.

e. Lack of readily available post processors for new machines.

f. Limitations of our present system to program sculptured surfaces and other complex shapes

g. Lack of Standardization in N.C. Programming Languages.

h. Other (Please specify) ______________________________

____

13. Would you be willing to participate in the funding of a group project oriented towards the elimination of the problems identified above assuming that this appeared technically feasibile.

Yes ____________ No ______________

14. The chart below will enable you to indicate in bar graph form the areas of emphasis of the current use and application of CAD/CAM technology in your company or firm.

First select the technology area which you expect will have the greatest use and application in your company five years from now. Mark this with an x at the 100 units value of the relative scale 0-100. On approximately the same scale, indicate with another x at 10, 20 ---- 80, 90, etc. the expected use and application of the other CAD/CAM technologies

Secondly, in the same relative scale, use a y to indicate where your company stands with regard to implementation at the present time (e.g. if x = 60% and y = 40% this indicates that you have already implemented 2/3 of what is expected 5 years from now).

	0	10	20	30	40	50	60	70	80	90	100
Engineering computation by computer											
Automated drafting											
Production and parts scheduling from the data base.											
Direct (wired) linkage from CAD to manufacturing processes and machine tools.											
N.C. Machine Tools - Drilling											
- Turning											
- Milling											
Robotic units for parts handling											
Automated assembly by robots											
Automated assembly by special purpose equipment											
Automatic testing											
Automated warehousing, work in progress parts movement and finished goods											
Integrated Total Systems CAD/CAM											

SECTION B

SECTION B HAS BEEN DESIGNED TO IDENTIFY THE TECHNOLOGICAL STRENGTHS AND WEAKNESSES OF NUMERICAL CONTROL PART PROGRAMMING IN YOUR PLANT AND SHOULD BE COMPLETED BY THE MANUFACTURING ENGINEER, N.C. COORDINATOR OR SENIOR PROGRAMMER RESPONSIBLE FOR THE N.C. PROGRAMMING ACTIVITY IN YOUR PLANT.

QUESTIONS 15 TO 21 WILL ESTABLISH THE SIZE OF THE N.C. ACTIVITY IN RELATION TO THE SIZE OF THE COMPANY AS WELL AS THE COMPLEXITY OF MACHINE TOOLS BEING UTILIZED AND PROGRAMMED.

15. How many people are directly involved with the N.C. activity in your company.

.... in Canada ________
.... at your plant ________

16. How many N.C. machine operators do you currently employ at your plant ________

17. How many N.C. programmers do you currently employ at your plant ________

18. How many indirect personnel are involved in the N.C. activity at your plant

a.	toolsetters	________	d.	tool designers	________
b.	inspectors	________	e.	foreman	________
c.	trainers	________	f.	planners	________

19. How long is a shift on your N.C. machine in hours ________

20. How many shifts does the N.C. portion of your plant work per week ________

e.g. 5 shifts = 5 eight hour work periods per week.

21. How many N.C. and C.N.C. machine tools do you currently have and expect to acquire over the next five (5) years.

NOTE:

NC - Numerical Control (Hardwired)

CNC -Computerized Numerical Control (Internal Computer)

	A		B	
	NOW CURRENTLY INSTALLED		TOTAL EXPECTED 5 YEARS FROM NOW	
	NC	CNC	NC	CNC
a. 2 axis lathes				
b. 3 axis lathes				
c. 4 axis lathes				
d. N.C. drill				
e. 3 axis machining centre with 2 axis contouring ...				
f. 3 axis machining centre with full 3 axis contouring				
g. 4 axis machining centre including a 360° rotary table				
h. 5 axis machining centre				
i. electro discharge machines				
j. punch presses				
k. flame cutting				
l. welding machine				
m. inspection machine.......				
n. industrial robot for machine loading and unloading				
o. other ______________ (please explain)				

21A. Do you expect that any of the above machines will be directly controlled from a central computer in 5 years time. NO. ____ YES ____

If your answer is YES please indicate by circling your answers in column B.

QUESTIONS 22 to 33 HAVE BEEN DESIGNED TO INVESTIGATE PROGRAMMING METHODOLOGY, STRENGTHS AND WEAKNESSES. THE SURVEY RESULTS WILL BE AN INTERESTING GUIDE FOR PRESENT AND NEW USERS THAT PLAN ON IMPLEMENTING MORE ADVANCED N.C. EQUIPMENT

22. Please check in each square the average job lot size processed on your N.C. equipment.

	1 to 5 parts	6 to 24 parts	25 to 50 parts	51 to 100 parts	101 to 500 parts	over 500 parts
N.C. Lathe(s)						
N.C. Drill(s)						
N.C. Mill(s)						
N.C. Machining Centre(s)						
Other						

23. Concerning your answers to question 22 above, please number from 1 to 5 the reasons (1 being the most serious) why lower job lot sizes than the above are usually not N.C. machined.

a. _______ There is no requirement to machine lower quantities.
b. _______ Uneconomical due to machine set-up time.
c. _______ Uneconomical due to programming time.
d. _______ Uneconomical due to overall programming costs.
e. _______ Uneconomical due to tape prove out time on machine.
f. _______ Other (Please explain) ____________________

24. What percentage of N.C. tapes are:

a. Manually programmed without any form of computer assist _______%
b. Manually programmed with the aid of an intelligent terminal for duplicating, edit, and merging _______%
c. Programmed using a computer assisted programming language _______%
d. Programmed through a computer graphics system _______%
e. Other (please specify) ____________________
____________________ _______%

100 %

25. Which of the following computer assisted programming languages are currently being utilized in your plant and which method (and language) do you expect to employ 5 years from now.

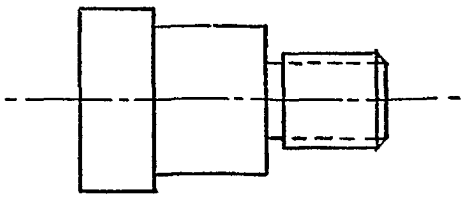
	REMOTE ACCESS TO EXTERNAL COMPUTER E.G. (TIME SHARE)		INPLANT COMPUTER	
	NOW	5 YEARS FROM NOW	NOW	5 YEARS FROM NOW
a. COMPACT II				
b. UNI-APT				
c. G-TURN				
d. G.E. ADAPT				
e. I.I.T.R.I. - APT III				
f. I.B.M. APT - A.C.				
g. I.B.M. APT - I.C.				
h. GRAPHICS PROGRAMMING				
i. Machine builders proprietory language				
j. Other (please explain) ______________				

25A. Do you feel there is a need for a Canadian standard N.C. Programming Language?

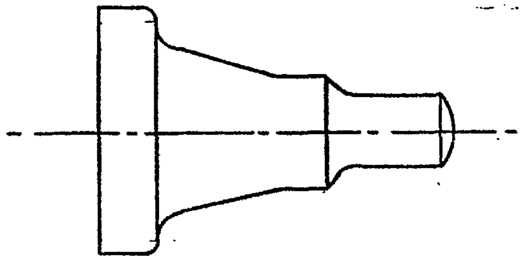
Yes ____________ No ____________

26. Please indicate using a scale of 1 to 5, (1 being the most significant) the factors that had the most influence in your selection of a computer assisted programming language.

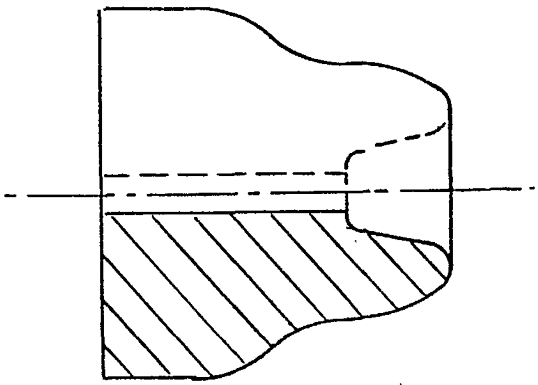
a. ______ Management awareness and selection
b. ______ Programmer's background and preference
c. ______ Parent company selection
d. ______ Through a feasibility study
e. ______ Our competitors using similar system
f. ______ Impressed by sales demonstration
g. ______ Other, Please explain ______________________



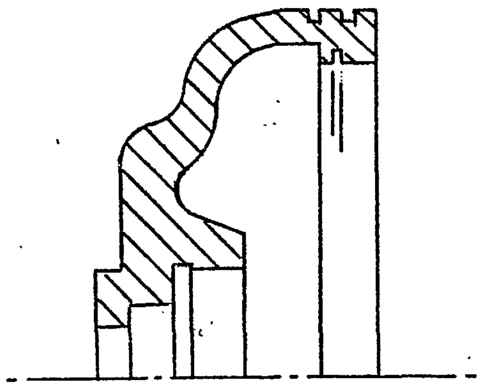
A. PARALLEL TURNING



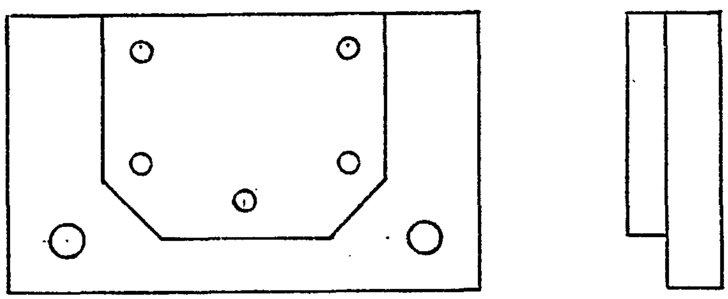
B. TAPER & RADII TURNING



C. CONTOUR TURNING

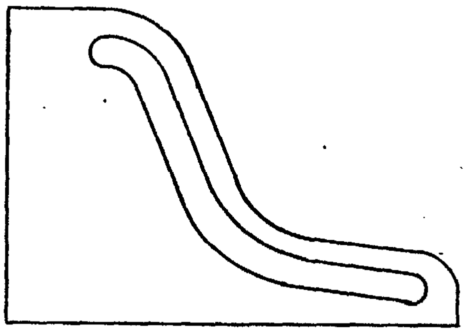


D. BLENDING & UNDER-CUTTING

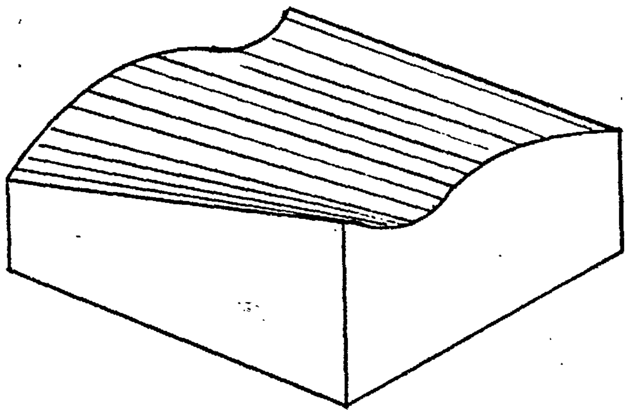


E. POINT TO POINT MILLING AND DRILLING

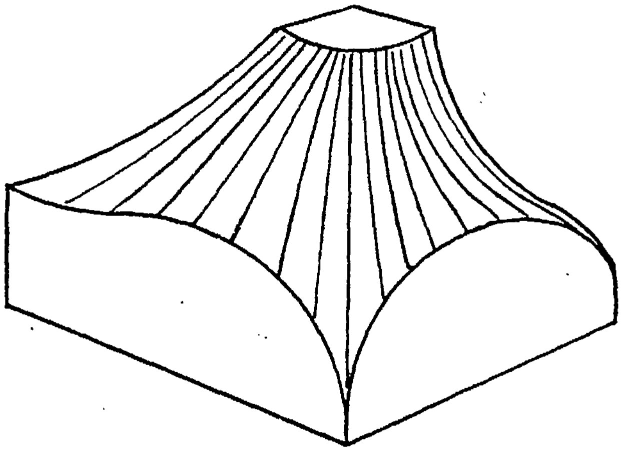
NOTE: These sketches are related to question 27 on page 13



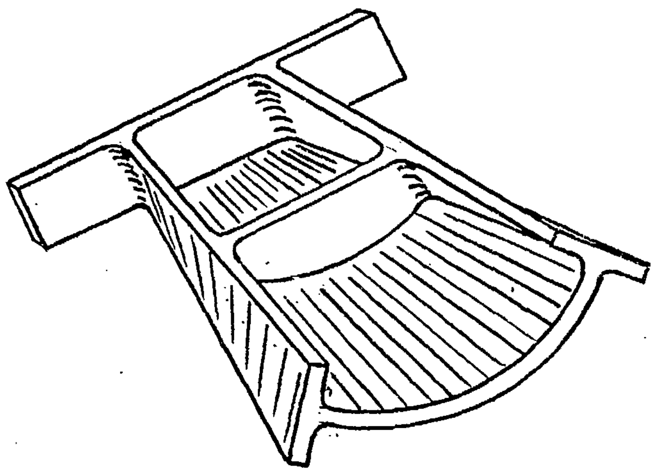
F. 2-AXIS CONTOURING



G. 3-AXIS STRAIGHT LINE INTERPLOATION



H. 3-AXIS CONTOURING



I. 5-AXIS SIMULTANEOUS CONTOURING WITH SWARF CUTS

NOTE: These sketches are related to question 27 on page 13.

27. The sketches, A, B, C, D, E, F, G, H and I represent definitions of N.C. programming complexity and are not intended to represent actual part drawings.

What percentage of your N.C. Programming workload is represented by the definitions according to drawings A to I, and what is your estimate 5 years from now

	Now	Five Years From Now
A		
B		
C		
D		
E		
F		
G		
H		
I		
Total	100%	100%

28. How many new N.C. programs will you prepare during your present fiscal year? No. ________

29. How many new N.C. programs do you expect to prepare in your fiscal year 5 years from now? No. ________

30. What is your current annual cost for N.C. programming?

Labour Cost $ ________

Computer Cost $ ________

Miscellaneous $ ________

31. As a user of a computer assisted programming system, has the system generally met your expectations? (Please circle one)

a. very disappointing
b. disappointing
c. generally as expected
d. better than expected
e. exceptional, couldn't get along without it.

32. What percentage of your tape corrections or modifications are due to:

A		process planning problems
B		geometry problems
C		machinability problems
D		tooling problems
E		computer problems
F		other ______ (please specify)
Total	100%	

33. The productivity of N.C. machines varies from industry to industry. on a percentage scale of -0 - 100 (100 being 100% of production time), please indicate the percentage of time your N.C. machines are performing the following function:

A		production
B		manufacturing tooling (fixtures)
C		tape proving
D		idle waiting for tapes
E		maintenance
F		other ______ (please specify)
Total	100%	

PROGRAMMER EDUCATION, EXPERIENCE AND RESPONSIBILITY

QUESTIONS 34 to 46 INVESTIGATE THE EDUCATION, TRAINING AND OVERALL RESPONSIBILITY OF THE PROGRAMMER OR PROGRAMMERS. ANALYSIS FROM THE SECTION SHOULD BE EXTREMELY IMPORTANT TO COMPANIES THAT ANTICIPATE ENTERING THIS MARKET AND ALSO TO COMPANIES THAT ARE ALREADY A MAJOR N.C. USER.

Please check appropriate box	SENIOR PROGRAMMER	NO.2. PROGRAMMER
34. Formal Education		
Secondary School		
High School Grad		
Technical College (Grad (2-3 years)		
Indentured Apprentice Grad (4-5 yrs)		
University Grad. (4 years)		
35. Previous to becoming a programmer the incumbent's function was:		
N.C. operator		
General Machinist		
Process Planner		
In School		
Draftsman or Designer		
Other ____________________		
36. How many years experience in programming:		
This company		
All Companies		

		SENIOR PROGRAMMER	NO.2. PROGRAMMER
37.	Where did this person receive training in programming.		
	Vendors School		
	On-the-job		
	CIM		
	Other (please specify)		
	______________________________		
38.	Approximate annual remuneration.......		
	Does the programmer perform the following functions: Please answer Yes or No.		
39.	- Act as N.C. coordinator		
40.	- Carry out part processing and planning		
41.	- Design and select fixtures		
42.	- Perform computer related tasks other than part programming		
43.	- Witness N.C. machine tape proving		
44.	- Carry out N.C. machine tape proving		
45.	- Have a major "say" in the selection of the N.C. Programming System required		
46.	- Have a major "say in the selection of N.C. machine tools		

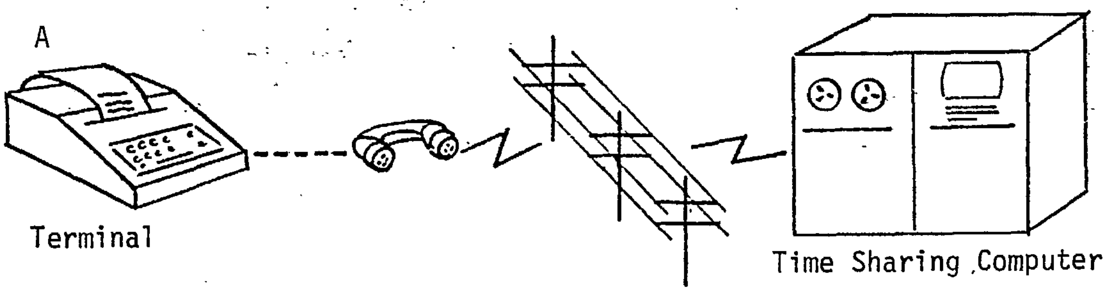
47. Concerning your present and future N.C. Programming workload, which system below most closely represents your present system and the system that you expect to utilize 5 years from now. Please express as a percentage if more than one system is utilized.

47a. If your answer includes "A" below, do you know where the computer is located.

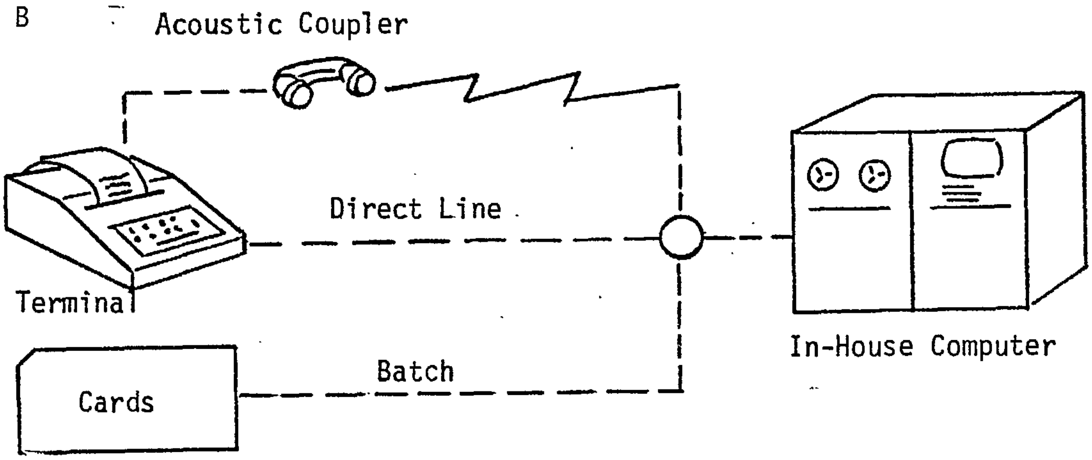
	Now	5 years from now
A		
B		
C		
D		
Total	100%	100%

Country ________________

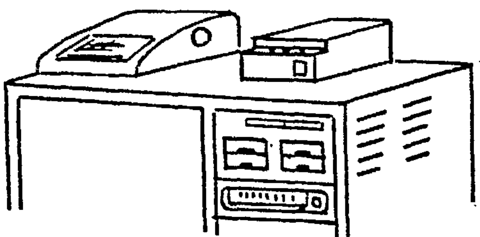
A



B

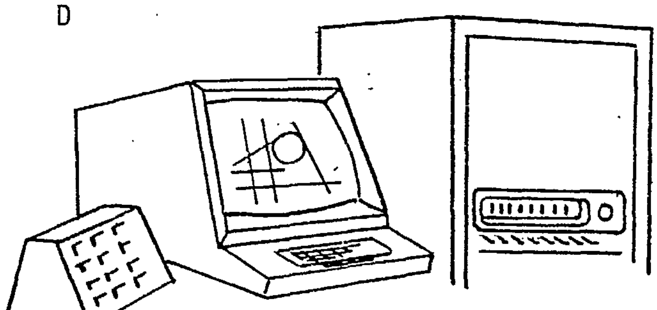


C



Mini Computer with Tape Storage/reader/punch

D

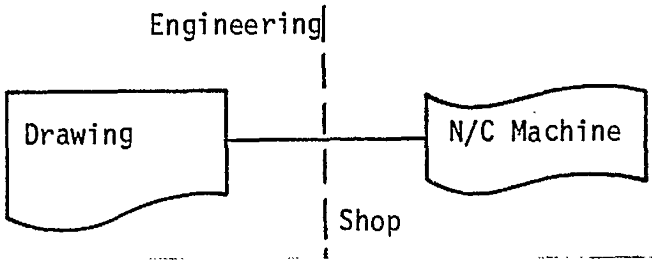


Graphics

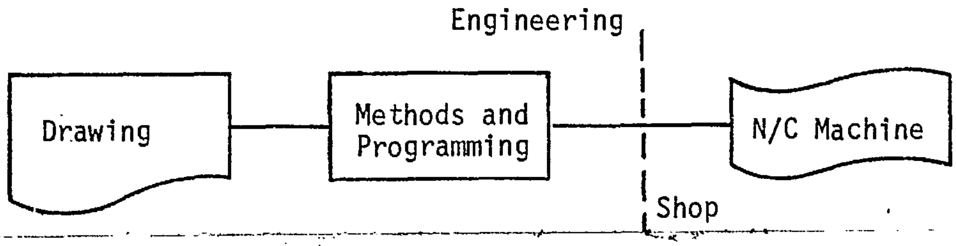
48. Concerning the flow of information for N.C. programming which method most closely represents your present method and the one you expect to utilize 5 years from now. Please express as a percentage if more than one system is utilized.

	Now	5 years from now
A		
B		
C		
D		
E		
Total	100%	100%

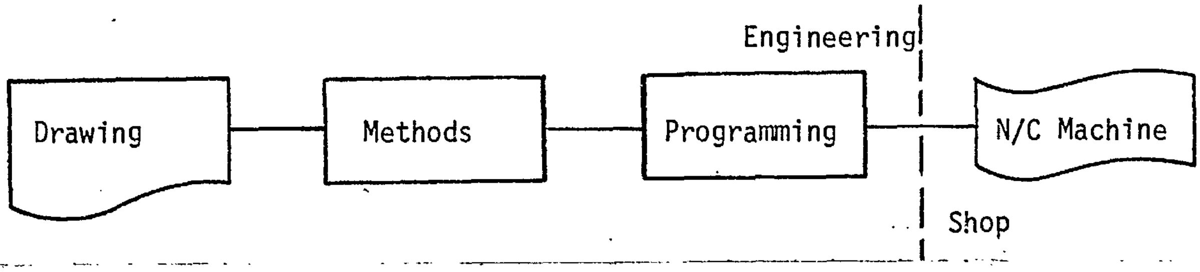
A



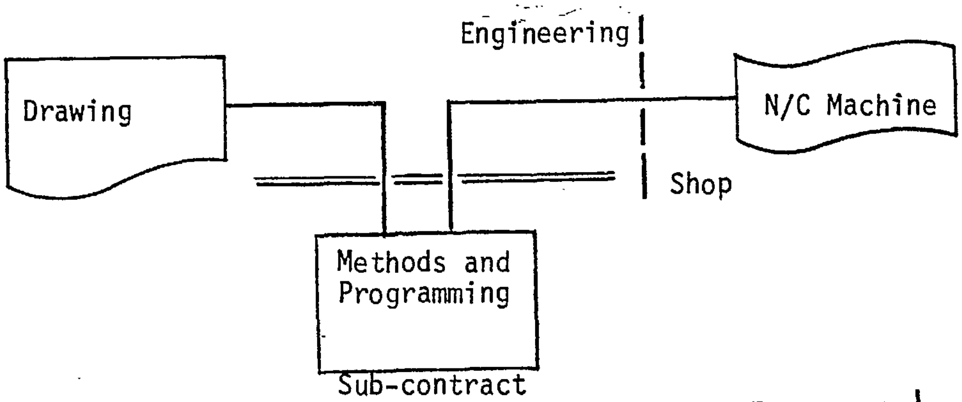
B



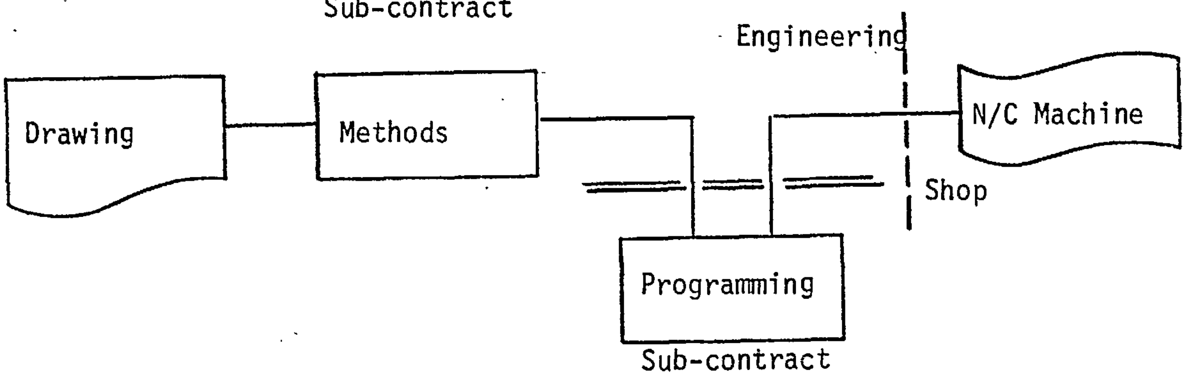
C



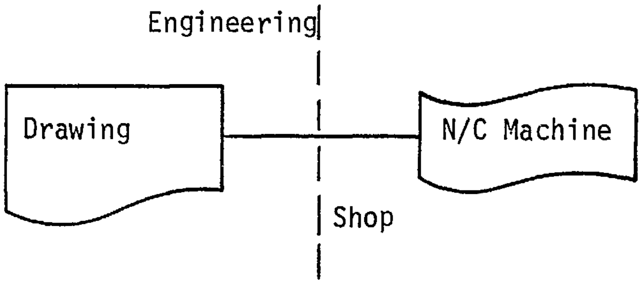
D



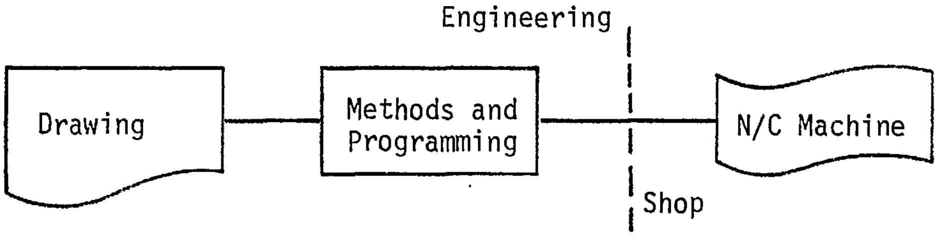
E



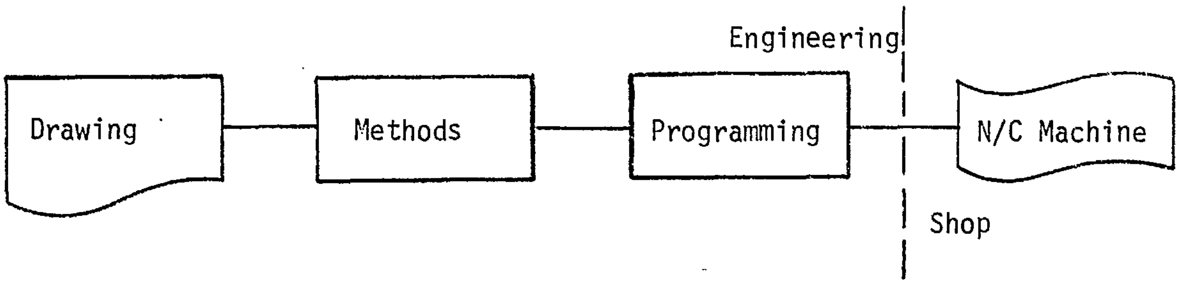
A


Engineering
Drawing
N/C Machine
Shop

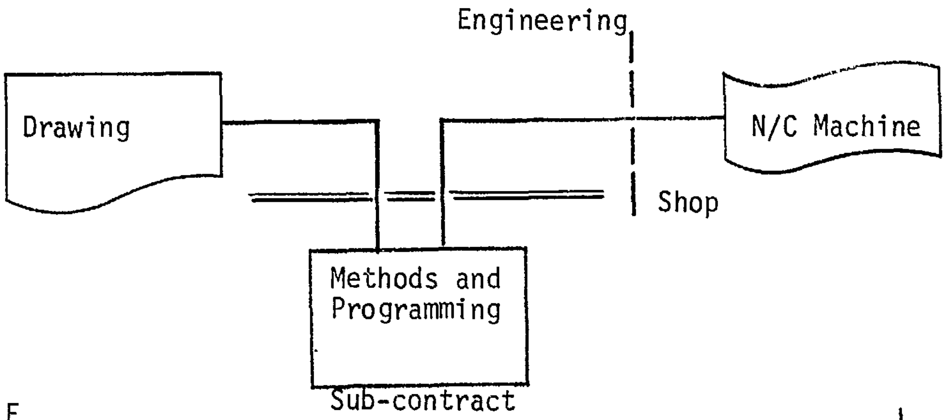
B


Engineering
Drawing
Methods and Programming
N/C Machine
Shop

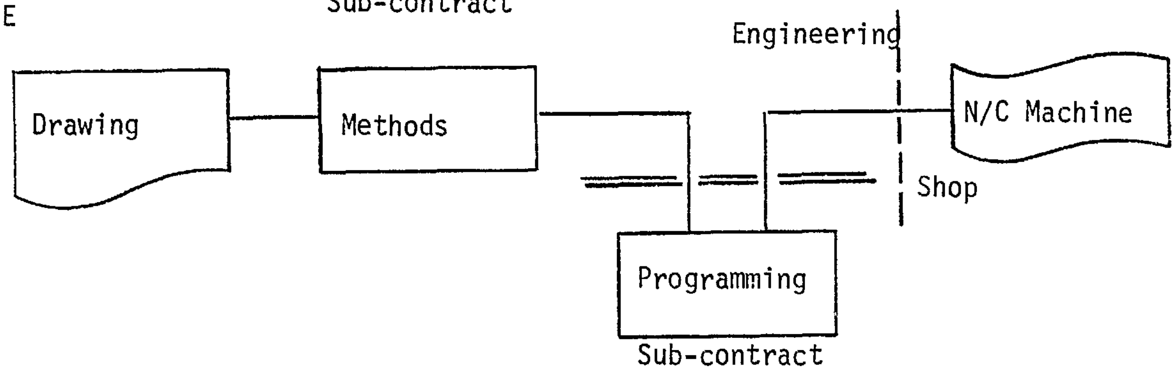
C


Engineering
Drawing
Methods
Programming
N/C Machine
Shop

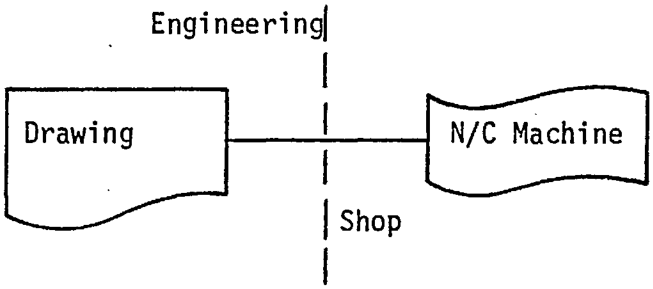
D


Engineering
Drawing
N/C Machine
Shop
Methods and Programming
Sub-contract

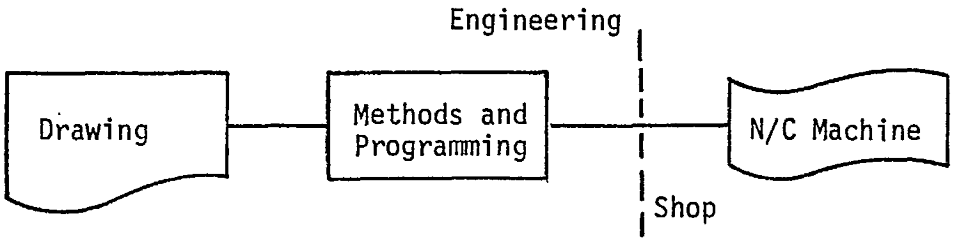
E


Engineering
Drawing
Methods
N/C Machine
Shop
Programming
Sub-contract

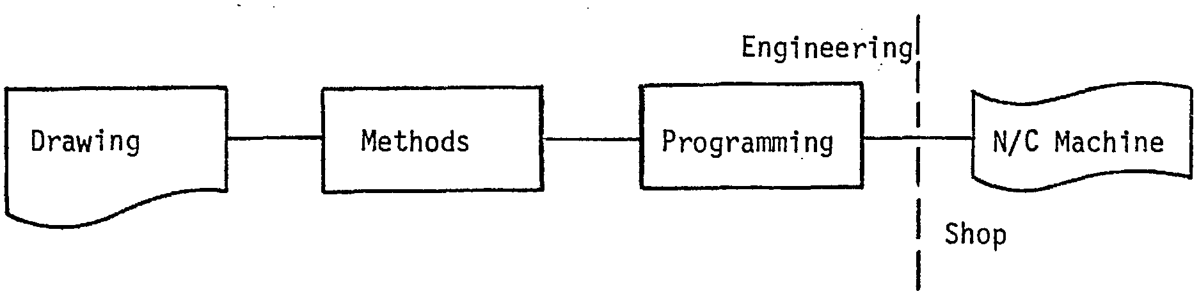
A


Engineering
Drawing
N/C Machine
Shop

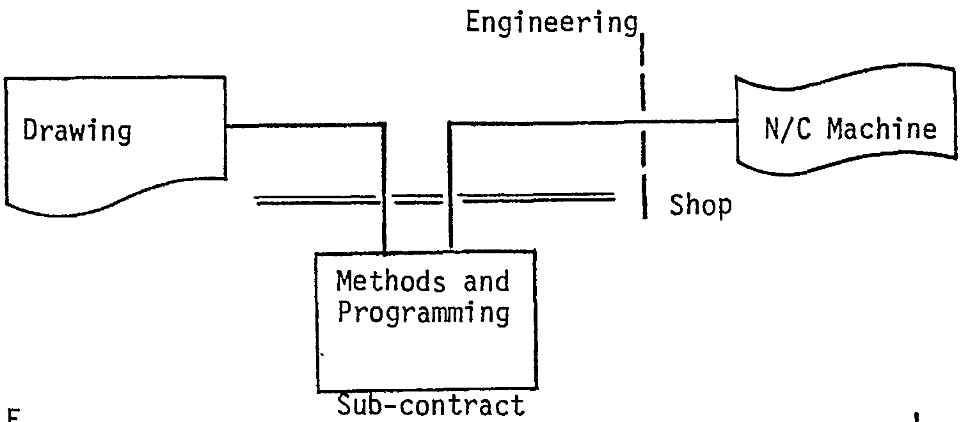
B


Engineering
Drawing
Methods and Programming
N/C Machine
Shop

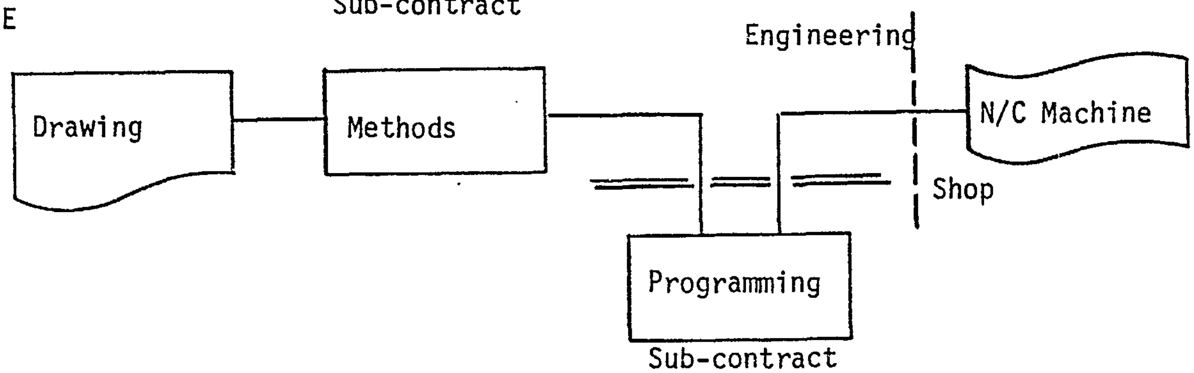
C


Engineering
Drawing
Methods
Programming
N/C Machine
Shop

D


Engineering
Drawing
N/C Machine
Shop
Methods and Programming
Sub-contract

E


Engineering
Drawing
Methods
N/C Machine
Shop
Programming
Sub-contract

TECHNOLOGICAL INNOVATION STUDIES PROGRAM

PROGRAMME DES ÉTUDES SUR LES INNOVATIONS TECHNIQUES

REPORTS/RAPPORTS

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