Past Is Merely Prologue. . .

Computers Advancing World Manufacturing Technology

Although the digital electronic computer was developed in the United States, its potential as a powerful tool to increase manufacturing efficiency and productivity is recognized around the world. Many nations are giving top priority to the development of computer-aided design and manufacturing systems. They definitely will be part of the future.

KEN GETTLEMAN, Associate Editor, interviews
Dr. M. EUGENE MERCHANT, Director of Research Planning
Cincinnati Milacron Inc.
Cincinnati, Ohio

Dr. Merchant, you have participated in many studies that are assessing world-wide trends in manufacturing. Among these are Delphi-type technological forecasts of the future of production engineering. Are there any trends that stand out?

Yes, there is one overall trend that stands out above all others as the major expected technological development in manufacturing between now and the year 2000. And that is the expectation that the computer-integrated automatic factory will be a full-blown reality before the end of this century.

Will this suddenly emerge in the year 2000 or will it take place in steps?

The general consensus from leading world experts gives the following timetable of major developments:

- By 1980, a computer software system for full automation and optimization of all steps in the manufacturing of a workpiece will be developed and in wide use.
- By 1985, full on-line automation and optimization of complete manufacturing plants, controlled by a central computer, will be a reality.
- By 1990, more than 50 percent of the machine tools produced will no longer "stand alone." They will be part of a versatile manufacturing system, featuring automatic part handling between stations, and will be controlled from a central process computer.

The experts who formed the consensus leading to the above conclusions were members of CIRP (International Institution for Production Engineering Research), a prestigious international organization of leading manufacturing researchers from around the world. Have any other studies arrived at the same or similar conclusions?

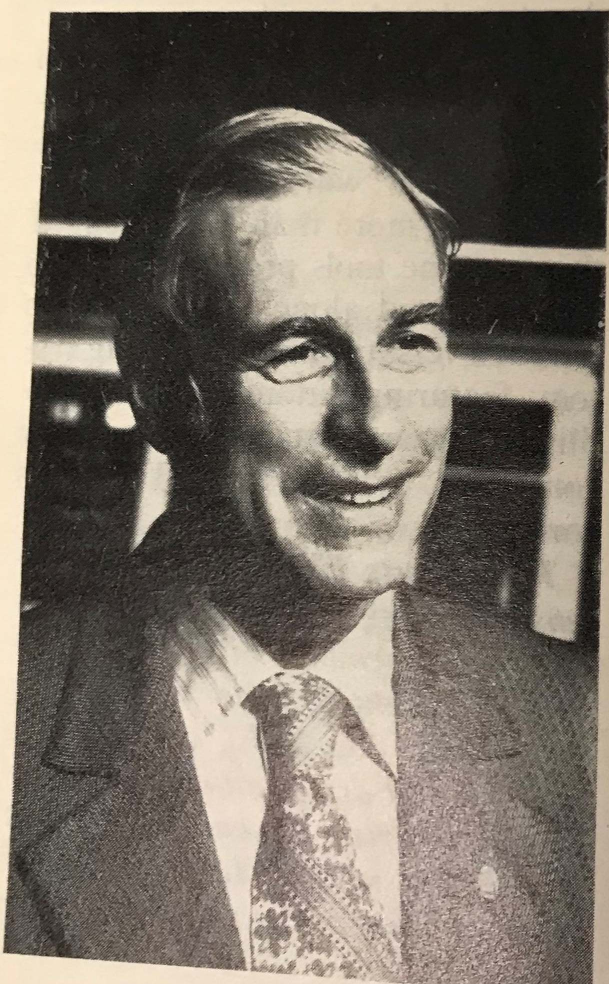
Yes, the University of Michigan and the Society of Manufacturing Engineers conducted a similar study and the conclusions closely parallel those of the earlier CIRP findings.

What do you see as the underlying forces and incentives at work to bring about the development of the computer-integrated automatic factory?

The most obvious technological fact is the reality of the powerful, efficient, and relatively inexpensive digital electronic computer. But there are also very strong economic incentives and social forces at work around the world leading to the computer-aided design and manufacturing developments.

How would you characterize the economic incentives?

Manufacturing contributes approximately 30 percent of the gross national product of modern industrialized countries. Yet, in spite of that, manufacturing is not the highly productive and efficient activity it is normally thought to be. This is clearly true of batch-type metalworking manufacturing, which accounts for about 40 percent of total manufacturing employment. The mass production type of manufacturing systems, such as automotive transfer lines, account for less than 25 percent of metalworking parts manufactured. In fact, 75 percent of



Dr. M. Eugene Merchant joined Cincinnati Milacron in 1936 as a Cooperative Research Fellow at the University of Cincinnati and assumed his present position as Director of Research Planning in 1969. His research activities have included basic and applied research on manufacturing processes, equipment and systems, and the future of manufacturing technology. He has presented numerous papers on these subjects.

Dr. Merchant is a Member of the National Academy of Engineering. He is a Senior Member of the Society of Manufacturing Engineers (President 1976-77), and an Honorary Member of the American Society of Mechanical Engineers (Vice President 1973-75). He served as President of the Federation of Materials Societies in 1974. He is a Member of the International Institution for Production Engineering Research (President 1968-69), and a Life Member of the Engineering Society of Cincinnati (President 1961-62). He is a fellow of the American such parts are manufactured in lots consisting of less than 50 workpieces. When the life of the average workpiece in batch-type metal-cutting production shops is analyzed, only about five percent of its time is actually spent on machine tools. Of that five percent, only about 30 percent (1½ percent of the overall time) is actually spent as productive time in removing metal. This result is illustrated graphically in Figure 1. This situation can hardly be called economic or productive. Further, it truly pinpoints the two main areas where the greatest improvement can be made in economic and productive metalworking manufacturing.

Society of Lubrication Engineers (President 1952-53), and of the American Society for Metals, the Ohio Academy of Science and the Institute for Advancement of Engineering. He is a registered Professional Engineer in the State of Ohio, a registered Manufacturing Engineer in the State of California, and a Certified Manufacturing Engineer.

Dr. Merchant was awarded the Distinguished Contributions Award of the San Fernando Valley Engineers' Council in 1975, the Medal of the Polish Institute of Metal Cutting in 1971, the Distinguished Alumnus Award of the University of Cincinnati in 1969, the Research Medal of the Society of Manufacturing Engineers in 1968, the Richards Memorial Award of the American Society of Mechanical Engineers in 1959 and the National Award of the American Society of Lubrication Engineers in 1959. In 1955 he was chosen as Cincinnati's "Engineer of the Year" by the Technical and Scientific Societies Council of Cincinnati.

What two areas offer the greatest potential productivity improvement?

The first area is to reduce the time workpieces spend in-process in the shop. This will reduce the high and costly inventory of unfinished parts on the shop floor and of finished parts waiting for others in-process so that assembly of the product can proceed. It is evident from Figure 1 that this inventory could be reduced by up to 90 percent. Resulting reduction of indirect capital and labor costs and improvement of productivity could be enormous. Here, indeed, is a major incentive to develop and implement a computer-integrated automatic factory.

What is the second potential area of productivity improvement?

Vastly improved machine tool utilization. The 30 percent machine utilization indicated in Figure 1 must be combined with the fact that the average conventional machine tool spends approximately 50 percent of its time waiting for workpieces (because of the 95 percent time-in-transit shown in Figure 1). As a result, the average machine tool in a batch-type shop is being utilized productively (actually cutting metal) only about 15 percent of the time. Thus, it is evident that this utilization potentially could be increased by 600 percent or more. Resulting reduction of direct labor and overhead costs, and increase of productivity could be very substantial. Obviously, this provides another major incentive to develop and implement a computer-integrated automatic factory before the year 2000.

How about the continued rise of labor costs?

As Figure 2 shows, the real cost for labor around the world has been going up ever since 1965. The compensation per man-hour has increased faster than the output per man-hour. This situation has become even more uneconomic in the past five years due to the rapid rise of wages in the current inflationary world economy. This is coupled with failure of manufacturing productivity to increase at a comparable rate. This situation can only be reversed by improving the rate of increase of manufacturing productivity and decreasing the degree of labor intensiveness, or both. These benefits can be accomplished by developing and implementing the computer-integrated automatic factory in the near future.

It is obvious that there are major economic incentives. What about social forces?

There are three: the attitudes of the workers themselves, their employers, and our government. They are also impelling us toward the computer-aided manufacturing concept for tomorrow's factories.

What is happening in workers attitudes toward manufacturing?

There is an ever-growing reluctance of workers to expose themselves to the manufacturing environment coupled with an ever-growing trend toward the service industries. The same thing is happening in manufacturing that happened in agriculture. In 1790, some 90 percent of all workers in this country were engaged in agriculture. Today, it is less than four percent. As agriculture employment went down, manufacturing employment went up. We are now seeing a decrease in manufacturing employment as the trend moves toward the service industries.

What is the expected manufacturing employment by the year 2000?

Some researchers estimate that manufacturing will only require two percent of the workforce by the year 2000. A more realistic view seems to be around 10 percent, as opposed to some 23 percent today.

How about employers?

In all industrialized nations employers are wrestling with the problem of workers attitudes that show a significant degree of employee dissatisfaction. Thus, they are searching for more meaningful jobs. While the number of manufacturing jobs will go down in the future, the computer-aided concept will be a positive force in making the remaining jobs more meaningful.

How will this be done?

The use of the computer offers opportunities for participation in decision-making through interactive software programs and similar features. It will also make manufacturing jobs cleaner and safer.

Is there a similarity of government attitudes within the industrialized countries?

Yes, the governments of most industrialized nations have moved away from a passive policy of requiring that industries adopt the latest technology to assure worker health and safety to one of requiring the development of new technology for health and safety. For example, in the United States we have a strong push toward part handling and feeding mechanisms so that a worker never need put his hands or any part of his body in a hazardous area, such as a press opening. There is also a pressure to reduce noise levels to 90 or even 85 dbA. OSHA is now directing attention to the dangers of close association with certain chemical compounds. Other nations are putting pressure on their industries for similar work environment improvements. This has provided an additional incentive for computer automation of factories.

Have you found a general world-wide awareness of the economic and

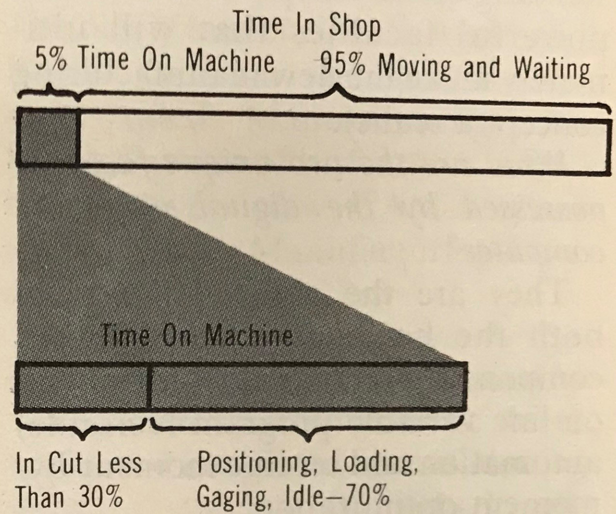
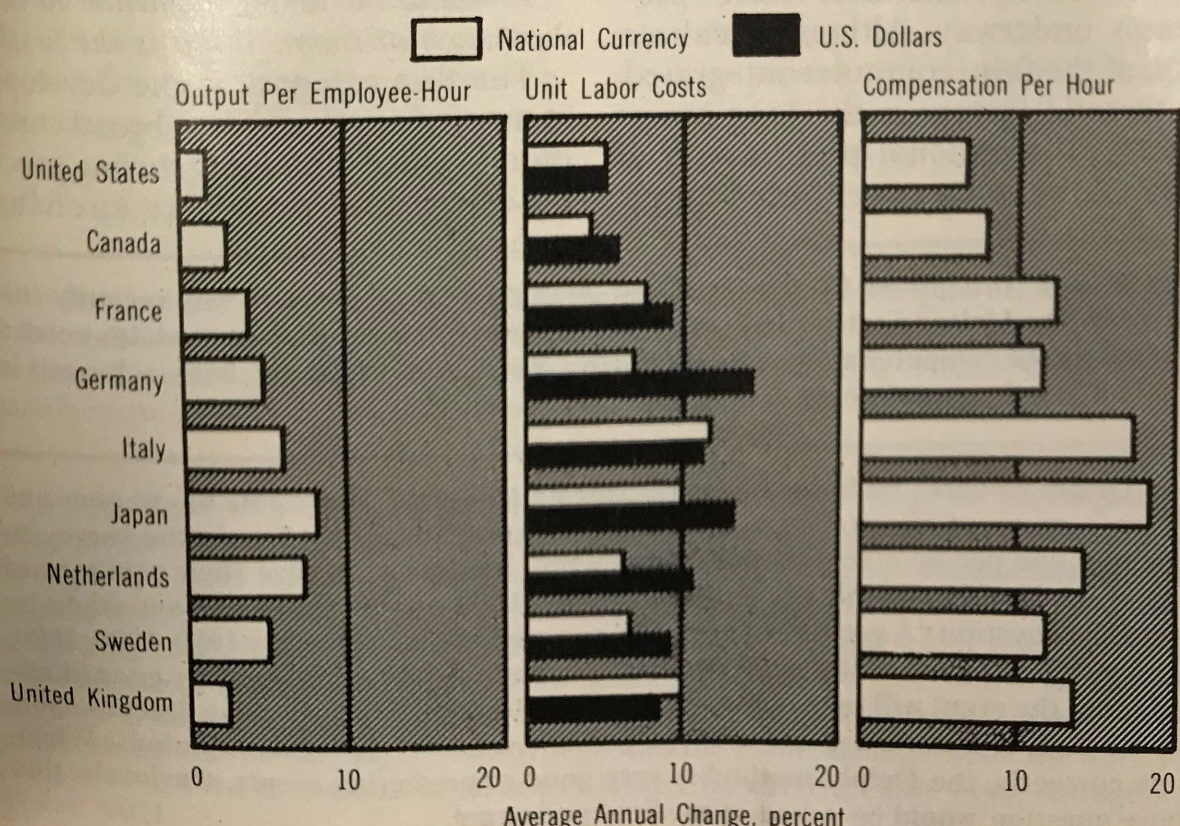


Fig. 1–Life of the average workpiece in the average batch-type production shop.

Fig. 2–Output per employee-hour and labor costs in manufacturing, 1967-'75. Source: Bureau of Labor Statistics Bulletin 1926.



social forces pushing toward the computer-integrated automatic factory?

Yes, there is both an awareness of the forces and a general understanding of the computer and its two powerful faculties that will ultimately make the new manufacturing concept a reality.

What are the two unique faculties possessed by the digital electronic computer?

They are the ability to provide both the hardware and software components of manufacturing with on-line variable program (versatile) automation and on-line moment-by-moment optimization.

Are there many research projects throughout the world to develop the ability of the computer to so function in the manufacturing environment?

Yes, many countries have programs underway. Although realization of the fully computer-integrated automatic factory is the long-range goal of the national programs, it is well realized that to get from today's industrial methods, know-how and installed equipment to that goal requires an evolutionary, rather than a revolutionary, process. The strategy being followed, therefore, is to develop and implement a series of viable, economic steps in the form of short-range programs of research and development, each having two essential characteristics:

1. Potential for sufficient economic return to justify it and to generate enough capital to develop and implement succeeding steps.
2. Compatibility with eventual implementation of the computer-integrated automatic factory.

Are these programs all unique or can they be categorized?

They tend to fall into one of five definable categories.

It would be very worthwhile to review each of them. What is the first?

The first category is the development and application of broad computer control of manufacturing processes and equipment such as

The ICAM (Integrated Computer Aided Manufacturing) project was recently initiated by the United States Air Force to develop new basic software modules needed for integrated computer aided manufacturing. Softech of Waltham, Massachusetts is the ICAM prime contractor.

The Delphi research technique involves stating a number of possible likelihoods and asking a group of experts, all of whom are unknown to each other in the survey to preclude one person's answer from influencing another's, to give their estimate of when such likelihoods will occur. For example, 100 knowledgeable persons might be asked the question "A vaccine to prevent cancer will be developed by 1980, 1990, 2000, later, never?" If most of the replies center on a certain date, there is a very good likelihood that the event will take place very close to the date. The technique depends upon the wording of the statements and the persons asked to give their opinions. When done correctly, the Delphi method is very good at predicting events. Obviously, the above question would be asked of medical personnel.

computer numerical control (CNC), direct numerical control (DNC) and hierarchical computer systems. Such work is proceeding most rapidly in Japan, the United States and West Germany.

How about group technology, which is now gaining more widespread interest?

This is the second important category. It is the development and application of group technology (variations of the concept are also known as family of parts, cellular, or in-line manufacturing) as a required base for application of hierarchical computer systems and the evolution of multistation manufacturing systems. In other words, the inherent capability of group technology to reduce work-in-process time will be further refined with a system of computers that can not only optimize the particular machine tool group but also the functioning of the group with the rest of the manufacturing facility. Such work is proceeding most rapdily in the Netherlands, Japan, West Germany, Norway, and the COMECON countries (U.S.S.R., Poland, Hungary, Romania, Czechoslovakia, East Germany, and Yugoslavia). The newly launched U.S. Air Force's ICAM program (Integrated Computer-Aided Manufacturing) also has this as one of its features as does the relatively new CAM-I (Computer Aided Manufacturing-International) program.

Is anything being done in the systems and computer software areas?

Yes, there is activity in the development of integrated manufacturing software systems. Individual software modules are being developed which can, in the long run, be readily interfaced with each other to build up full software systems that will be appropriate for various types of manufacturing applications. Such work is proceeding most rapidly in the COMECON countries as well as in West Germany, Norway and Japan. The U.S. Air Force's ICAM

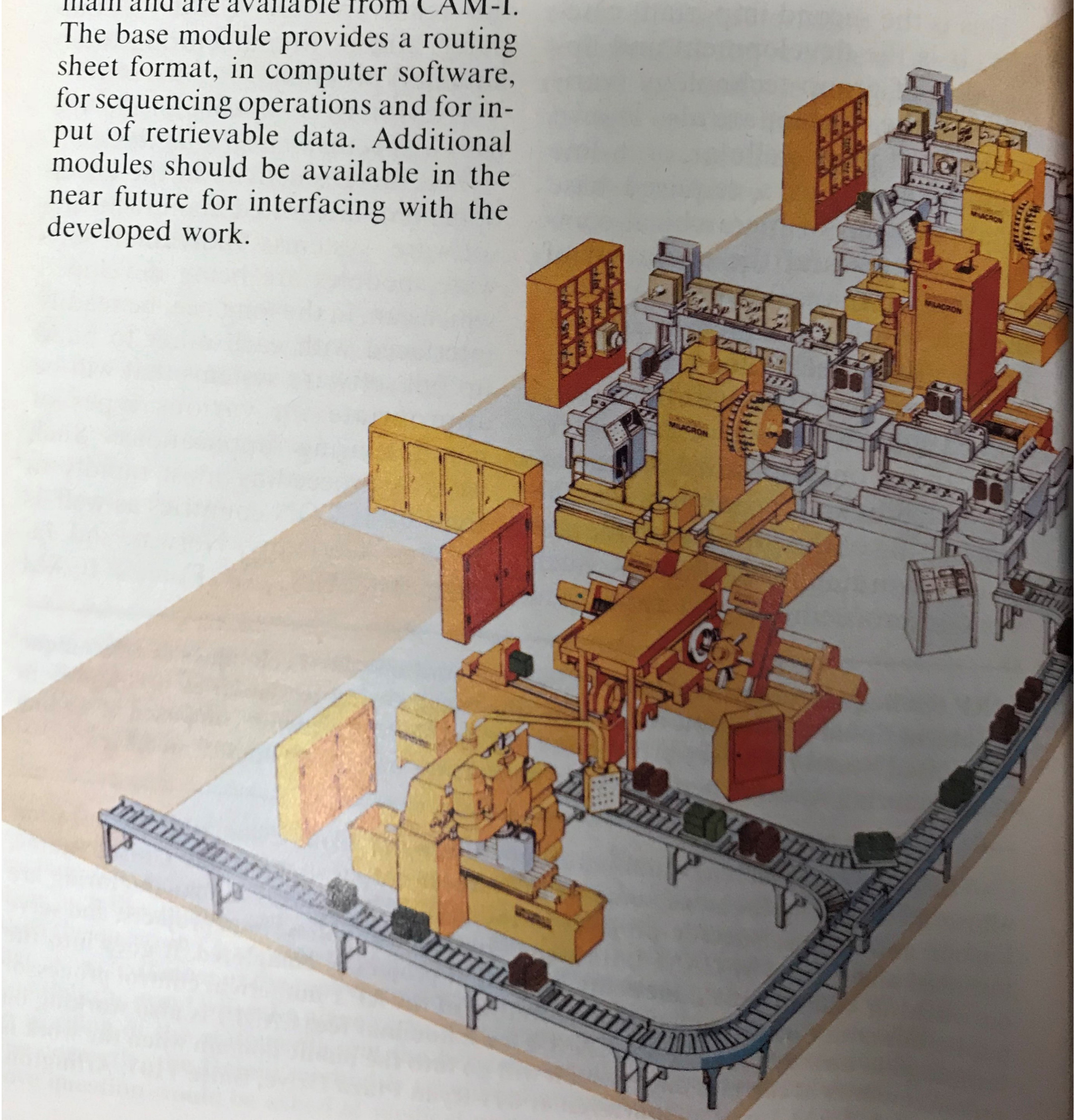
CIRP (College International pour l'Etude Scientifique des Techniques de Mecanique or International Institution for Production Engineering Research as it is known in the United States) is a very prestigious world-wide organization composed of leading manufacturing research personnel. No nation may have more than 15 members.

CAM-I (Computer Aided Manufacturing–International) is a nonprofit organization whose membership includes some of the largest corporations in the United States, Europe and Japan. Specific projects in the area of computers in manufacturing are initiated and funded by CAM-I. Its members establish policy, fund projects, and serve on working committees. Once any individual project is completed, it goes into the public domain. For example, documentation of the APT numerical control processor language is now available from CAM-I for a nominal fee. CAM-I is also working on enhancements of the language, which will go into the public domain when the work is completed. CAM-I is headquartered at 611 Ryan Plaza Drive, Suite 1107, Arlington, Texas 76011.

program is engaged in a similar activity and the CAM-I organization has underway a program for continuing development of an integrated software system for process planning of machined parts. It is called CAPP (Computer Aided Process Planning). Two prototype versions of a CAPP base module are in the public domain and are available from CAM-I. The base module provides a routing sheet format, in computer software, for sequencing operations and for input of retrievable data. Additional modules should be available in the near future for interfacing with the developed work.

What is the fourth class of research programs?

This is the development of prototype computer-controlled multistation manufacturing systems which are, in effect, rather fully automated group technology cells. Such work is proceeding most rapidly in



Japan, East Germany, West Germany, Norway and, more recently, in the United States.

Is the ultimate the totally automatic factory?

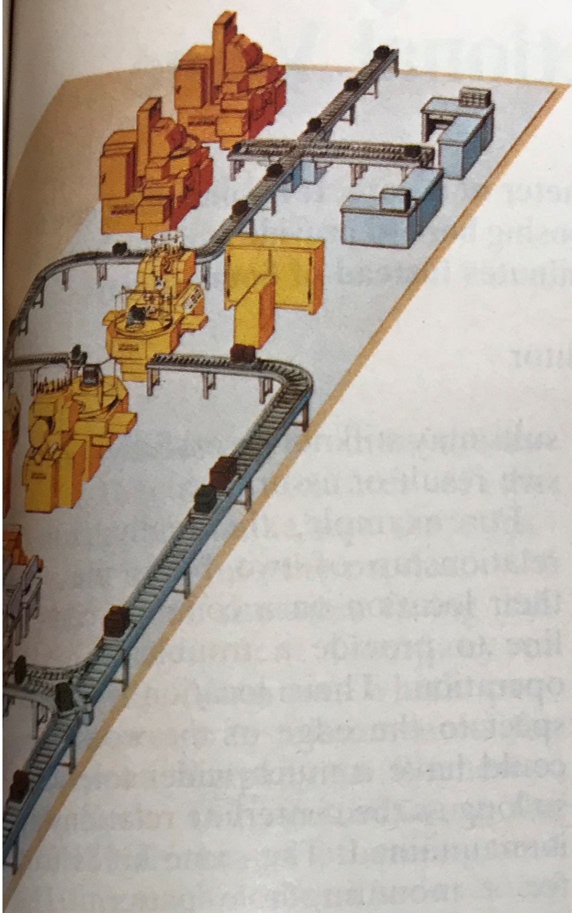
Yes, Japan is proceeding most rapidly with the planning and development of prototype computer-integrated automatic factories. Their government has undertaken a major national planning effort on "methodology for unmanned manufacturing" or MUM as it has become known. However, such planning is also underway to a lesser degree in West Germany.

It is quite clear that most industrialized nations have significant programs underway. Are they organized and funded within the private sector or are they national programs underwritten by respective governments?

Most of them have government backing and financing for the sake of a national productivity effort, while the ICAM in the United States comes through the Air Force in the name of national defense. Our CAM-I programs are private efforts.

As part of the CIRP Delphi study, was the question of social, economic, and environmental impact raised?

Yes, and the general consensus was that the more economical and efficient manufacturing with the aid of the computer will be beneficial economically, environmentally, and socially. It was recognized that there will be a long-term change in the amount and nature of the manufacturing work force, but this can be handled well if we recognize that a change is taking place. MMS



Artist's rendering of a manufacturing cell comprised of ten different machines, of which seven are under CNC. Two different families of workpieces can be handled by the system with each workpiece going to the particular machine tools needed to complete the machining operations. The workpiece is entered at the beginning of the line and comes out completely machined at the end. Computer integration is optional with this type of system. Such systems are being designed and installed in this country and around the world.