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Computer Aided Manufacturing

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1.1 Introduction to CAM

Computer-aided manufacturing (CAM) is an application technology that uses computer software and machinery to facilitate and automate manufacturing processes. CAM is the successor of computer-aided engineering (CAE) and is often used in tandem with computer-aided design (CAD).

Computer-aided manufacturing (CAM) is the use of software to control machine tools and related ones in the manufacturing of work-pieces. CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation, and storage.

Its primary purpose is to create a faster production process and components and tooling with more precise dimensions and material consistency, which in some cases, uses only the required amount of raw material (thus minimizing waste), while simultaneously reducing energy consumption.

CAM is now a system used in schools and for lower educational purposes. CAM is a subsequent computer-aided process after computer-aided design (CAD) and sometimes computer-aided engineering (CAE), as the model generated in CAD and verified in CAE can be input into CAM software, which then controls the machine tool.

1.2 Objectives of CAM

A CAM system is highly efficient because it can control the production house through different automated techniques. Any factory can be made highly automated by deploying real-time systems and robotics.

The purpose of CAM is to ensure that the error rate is decreased, uniformity of products is high and precision in the processes can be achieved. CAM operations are part of now almost all industries.

It helps in removing errors from the primary manufacturing processes and can also keep track of further orders and material to be used.

The automated plants have provided hygiene and a clean environment to various processes which cannot be achieved fully by manual processes. For example, the packaging of meat and related products is fully done by automated plants from the slaughter of the animal to the final product.

This has also reduced the labor cost and other operating overheads. The processes are now fully automated that they can replace the tools and switch to the successive processes on their own.

1.3 Scope of CAM

Integrated CAD/CAM/CAE Software like Creo, I-DEAS & CATIA help manufacturers optimize product concepts early in the design process, enabling them to significantly improve product quality while reducing product development time and cost.

Moreover, people having 3D CAD/CAM/CAE knowledge have better chances of growth, immediate employability after completion of the course, graduation, and chances of jobs abroad.

As the market economy opens more and more it has become extremely competitive and with this state of the economy, skilled people play the most important role in the organization. Hence it becomes imperative on the part of top Tool Room Training centers and engineering.

Colleges especially look for new initiatives towards improving the skills and knowledge of students. An emerging trend of engineering. Education in the Tool Room and the world is the rapid incrementation of CAD/CAM/CAE software as an essential part of the curriculum.

1.4 Types of Manufacturing Systems

Manufacturing entails so many processes and operations that comprehending them requires some type of categorization. Manufacturing operations can be categorized in several ways depending on the purpose of grouping, for example, national versus international or product types.

For most purposes, classifications reflect the following six criteria:

1. Continuous or discrete
2. Variety and volume
3. Raw material to the final product
4. To order or to stock
5. Size
6. Machinery used

1.4.1 Continuous or Discrete Manufacturing

Manufacturing operations fall into two very broad groups: (a) continuous-flow or process type and (b) discrete-parts manufacturing (also known as discrete manufacturing).

Continuous-flow operations typify the chemical and mining industries and oil refineries, which produce large amounts of bulk material. Products in these groups are usually measured in units of volume or weight, the batch size is large, and product variety is low. Since batches are large, designing and building special machines for their production makes sense.

Such machines are usually expensive, but their cost is distributed over a large volume, contributing only marginally to the unit cost. Since processes are specialized, they are difficult to modify or salvage, if for some reason the customer no longer requires the product.

Continuous-flow operations, used to manufacture "mature" products in large volumes, are relatively easier to control and operate since production uses dedicated machines. These operations are usually fully automated, with operators minding the machines.

From an integration point of view, the production task is simpler, since processing requirements (one sequentially following the other) are such that integration is built in at the equipment design stage itself. The need for flexibility is just not there.

As technology improves, newer machines with built-in automation replace the old ones. Thus, while the term CIM may be new to process industries, integrated manufacturing based on the CIM concept certainly is not.

The term ***discrete-parts manufacturing*** denotes operations involving products that can be counted. The output of process-type industries is also counted eventually: for example, sugar in terms of the number of sacks or tons.

What distinguishes discrete manufacturing from process industries is the potential flexibility of its output. When demand falls in process industries, operations are simply phased out. Discrete-type operations, on the other hand, are cost-effective to modify for other products needed by the market.

A special feature of discrete manufacturing is that the end product, generally made of several components, can be disassembled and reassembled; an example is a bicycle.

It is not essential for the end product to comprise several components. For example, a discrete manufacturing facility that machines only connecting rods of different shapes and sizes for automobile manufacturers produces a single-part end product.

Whether single or multiple-part, a product must be designed, raw materials procured, machines set up, tools sharpened, operators trained, and a host of other steps taken before actual production can begin. All this is, in essence, preparation for production.

The preparation-for-production cost is normally the same whether one unit or hundreds of units are produced. Since it is independent of the number of units produced, this cost is fixed. The burden of the fixed cost on each unit grows as batch size (the number of units in the batch) declines.

In mass production, where the batch size is large, the fixed cost per unit is low. At the other extreme, in job shops with a batch size of one or two, the fixed cost per unit is relatively high.

1.4.2 Variety and Volume

Another way to look at manufacturing facilities is according to variety and volume. A low-variety, high-volume operation is easier to manage since dedicated automation is possible. A high-variety, low-volume operation, on the other hand, is more difficult to operate and manage.

Based on volume and variety, discrete manufacturing is of three types:

1. Mass production
2. Batch production
3. Job shop

Mass Production: In mass production of discrete parts or assemblies-for example, bolts or ballpoint pens-the production volume is high. Therefore, special purpose, dedicated equipment can be employed.

Machines are considered dedicated when they are tailored to specific products. Examples of mass-produced goods include bicycles, washing machines, and video games.

A mass-production facility is termed a transfer line when products are assembled while conveyor systems transfer them from one end of the plant to the other. A good example of a transfer line is an automobile-production facility.

Batch Production: In batch production of parts or assemblies, the volume is lower, and the variety higher, than in mass production. When the end item is an assembled product, the producer may make some parts in house and buy others from vendors.

Batch production is sometimes referred to as a mid-volume, mid-variety operation. The limited volume does not justify very specialized production machines; general-purpose machines are used instead. This does not, however, alter the shop-floor goal of keeping the machines running and the operators busy.

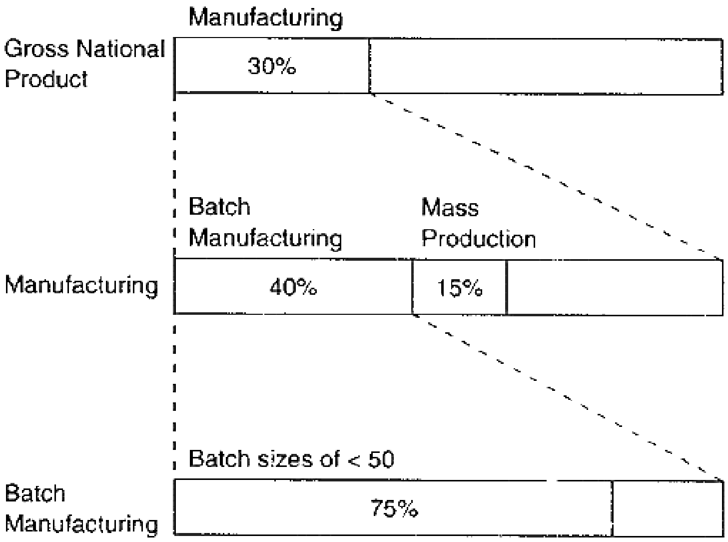

Fig.1.1 - Importance of batch production and small batch sizes to GNP

An enormous amount of coordination among various production functions is essential to optimize the use of the resources. In this type of application, CIM technologies such as cellular manufacturing or robotics hold promise to deliver the economies of mass production while still coping with variety.

Batch production, and to some extent mass production, of discrete products, provides all the challenges under CIM. In batch production, goods are manufactured in batches that may be repeated as required.

Manufacturing directly contributes 30% to the GNP in industrialized economies. Batch production accounts for 40% of this or 12% of the GNP. Also, note that three-quarters of batch production involves batch sizes of 50 or less. Thus, a typical manufacturing facility produces small batches.

Job Shop Production: The job shop represents the most versatile production facility. Within the limitations of the machines and the operators, it can manufacture almost any product. With a low production volume, sometimes as low as 1 to 10 units, the cost of product design and set up is relatively high.

Production facilities for aircraft, ships, or special machine tools are examples of job shops. NC and CNC technologies can significantly improve the productivity of job shops.

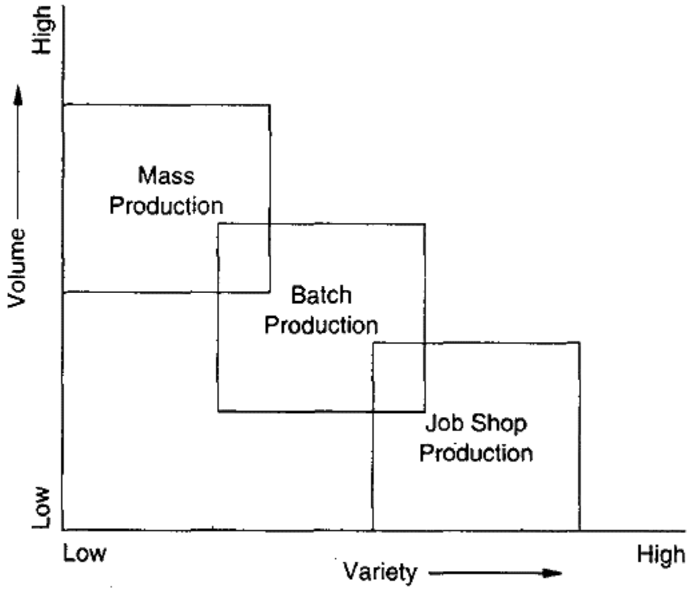

Fig.1.2 - Volume and variety by production type

Which of the three discrete-manufacturing facilities is suitable for a product depends on two factors: variety and volume.

How many different products (including their models, if significantly different) are to be produced? How many of each product (i.e., of each variety) is to be produced during a given period? Note that the term volume means the quantity-the number of units.

Based on volume and variety, the three types of manufacturing facilities just discussed can be represented graphically as shown in the figure. The overlaps emphasize the fact that their boundaries are not rigid. The actual values on the volume and variety axes depend on the complexity of the product.

1.4.3 Raw Material to Final Product

Based on the relationship between raw material and the end product, manufacturing follows one of four different patterns: **disjunctive, sequential locational, or combinative**.

Disjunctive: In the disjunctive pattern, a single raw material is progressively processed into its various components as end products. Examples of disjunctive facilities are slaughterhouses, lumber mills, and oil refineries.

Sequential: In sequential facilities, too, there is only one raw material as input. But, unlike disjunctive operations, which separate the raw material into components, it is progressively modified to become the end product. An example is a supplier's production facility that machines castings for the automobile manufacturer.

Locational: Locational patterns involve buying, storing, and eventually distributing manufactured goods without any substantial physical modification in the product. An example is a company that buys a product in large quantities and distributes it in small packets under its brand name. This pattern suits bulk materials, such as sugar or rice.

Combinative: The combinative type is discrete manufacturing in which components-some produced in-house and some bought from suppliers-are assembled, inspected, packaged, and shipped as end products. A good example is an automobile factory.

From a production viewpoint, the combinative pattern is the most, complex. CIM is targeted primarily at this pattern, although CIM concepts apply to the other three as well.

1.4.4 To Order or To Stock

Based on the immediate destination of the end products, manufacturing may be of two types.

In the first, products are shipped directly to consumers, wholesalers, or retailers. Such companies are said to produce "***to order***." Since they do not store the end products, for finished-goods inventory is unnecessary. Capital is therefore released and profit realized immediately following production. Job shops usually operate in this mode.

In the second type, products are stocked in finished-goods inventory; marketing distributes them to retailers or consumers as needed. This type of operation is said to produce "***to stock***." Such facilities usually produce in batch sizes that minimize the unit cost. In this type, capital is tied up until the end products can be sold.

CIM can offer significant benefits for both types of operations. To-order companies can respond rapidly to meet the needs of consumers, while to-stock companies can produce economically in smaller batch sizes, thus lowering the capital investment in finished-goods inventory.

1.4.5 Size

It is sometimes convenient to classify manufacturing companies based on size, with criteria such as the number of employees, annual sales turnover, net worth, and so forth.

Whether a company is small or large is often determined by the number of employees. While there is no standard cut-off number, the following categorization is usually practiced: small, below 100; medium, 100 to 499; large, 500 or more.

Contrary to the general perception that only large companies can afford modern facilities, the level of modernization and the sophistication of the technology used are independent of the company size.

1.4.6 Machinery Used

A variety of machine tools, equipment, and processes are used in an average plant.

They fall into the following functional groupings: Metal forming, Metal cutting, Assembly, Material Handling, Inspection, Testing, and Gauging. Others, such as casting, welding, riveting, brazing, heat treatment, washing stations, plastic molding, etc.

1.5 Role of Management in CAM

In the modern world, rapid changes and global expansion results in the changing of a business organizational trend.

Business transactions that had been done traditionally are no longer sufficient, so a new method has to be introduced to meet the consumers' to cope with current market demands, therefore Business Process Reengineering (BPR) that has been introduced since the 1990s are used worldwide nowadays, with the addition of information system and technology.

IT can help to improve main business processes in terms of communication, inventory management, data management, management information systems, customer relationship management (CRM), computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE).

This study explained the role of IT in a business's process within the area of CRM, communication, information management, and inventory management to boost the efficiency and effectiveness of BPR adoptions.

1.6 Concepts of Computer Integrated Manufacturing (CIM)

CIM means exactly what it says: computer-integrated manufacturing. It describes the integrated applications of computers in manufacturing. Several observers have attempted to refine its meaning:

"CIM is not applying computers to the design of the products of the company. That is computer-aided design (CAD)! It is not using them as tools for part and assembly analysis. That is computer-aided engineering (CAE)! It is not using computers to aid in the development of part programs to drive machine tools. That is computer-aided manufacturing (CAM)! It is not materials requirement planning (MRP) or just-in-time (JIT) or any other method for developing the production schedule. It is not an automated identification, data collection, or data acquisition. It is not a simulation or modeling of any materials handling or robots or anything else like that. Taken by themselves, they are the application of computer technology to the process of manufacturing. But taken by themselves they only create the islands of automation." - Leo Roth Klein, Manufacturing Control Systems, Inc.

One needs to think of CIM as a computer system in which the peripherals, instead of being printers, plotters, terminals, and memory disks, are robots, machine tools, and other processing equipment. It is a little noisier and a little messier, but it's a computer system.

- Joel Goldhar, Dean, Illinois Institute of Technology

An attempt to define CIM is analogous to a group of blind persons trying to describe an elephant by touching it; each has a different description depending upon the body part touched. Nevertheless, several definitions of CIM have been attempted.

The one put forward by Shrensker (1990) for the Computer and Automated Systems Association of the Society of Manufacturing Engineers (CASA/SME) is perhaps the most appropriate. According to him, "CIM is the integration of the total manufacturing enterprise through the use of integrated systems and data communications coupled with new managerial philosophies that improve organizational and personnel efficiency."

The term CIM comprises three words-computers, integrated, and manufacturing. Though all three words are equally significant, the first two are secondary-merely adjectives modifying the last one (manufacturing).

CIM is thus the application of computers in manufacturing in an integrated way. All types of computers, from personal computers (PCs) to mainframes, may be used in CIM.

The middle term, integrated, in CIM, is very appropriate. It brings home the point that integration of all the resources-capital, human, technology, and equipment-is vital to success in manufacturing. Implicitly, CIM discourages any haphazard application of computers, and other technologies, that results in isolated islands of automation.

Integration is achieved through timely and effective communication, which CIM relies on heavily. Since the computer is the basis of integration, communication within the context of CIM is strongly computer-oriented.

Although computers and computer communications have been with us since the 1950s; CIM is relatively new. It began to draw attention only in the 1980s. Why this late? For two reasons.

First, until recently computers had been too expensive to be cost-effective in manufacturing. Only business functions, such as accounting and payroll, and to some extent inventory management, could justify the high costs. The low cost and improved capabilities of today's computer systems have changed that.

The second reason for the delayed "birth" of CIM and its slow progress is the sheer complexity of integration, arising from the large number of tasks that interact in discrete manufacturing in today's sophisticated market.

Integrated manufacturing by itself is not a new concept. But CIM-which orchestrates the factors of production and its management-is.

CIM is an umbrella term under which all functions of manufacturing and associated acronyms, such as computer-aided design and computer-aided manufacturing (CAD/CAM), flexible manufacturing system (FMS), and computer-aided process planning (CAPP) find a place.

In general, CIM benefits can be grouped into tangible and intangible categories, as listed below.

Table 1.1 - Benefits of CIM

Tangible Benefits	Intangible Benefits
Higher profits	Higher employee morale
Less direct labor	Safer working environment
Increased machine use	Improved customer image
Reduced scrap and rework	Greater scheduling flexibility
Increased factory capacity	Greater ease in recruiting new employees
Reduced inventory	Increased job security
Shortened new product development time	More opportunities for upgrading skills

1.7 CIM Wheel

CASA/SME has suggested a framework, the CIM wheel, to elucidate the meaning of CIM. Formed by SME in 1975, CASA is an interest group of manufacturing professionals. The CIM wheel, developed by CASA/SME's Technical Council, is shown in the figure.

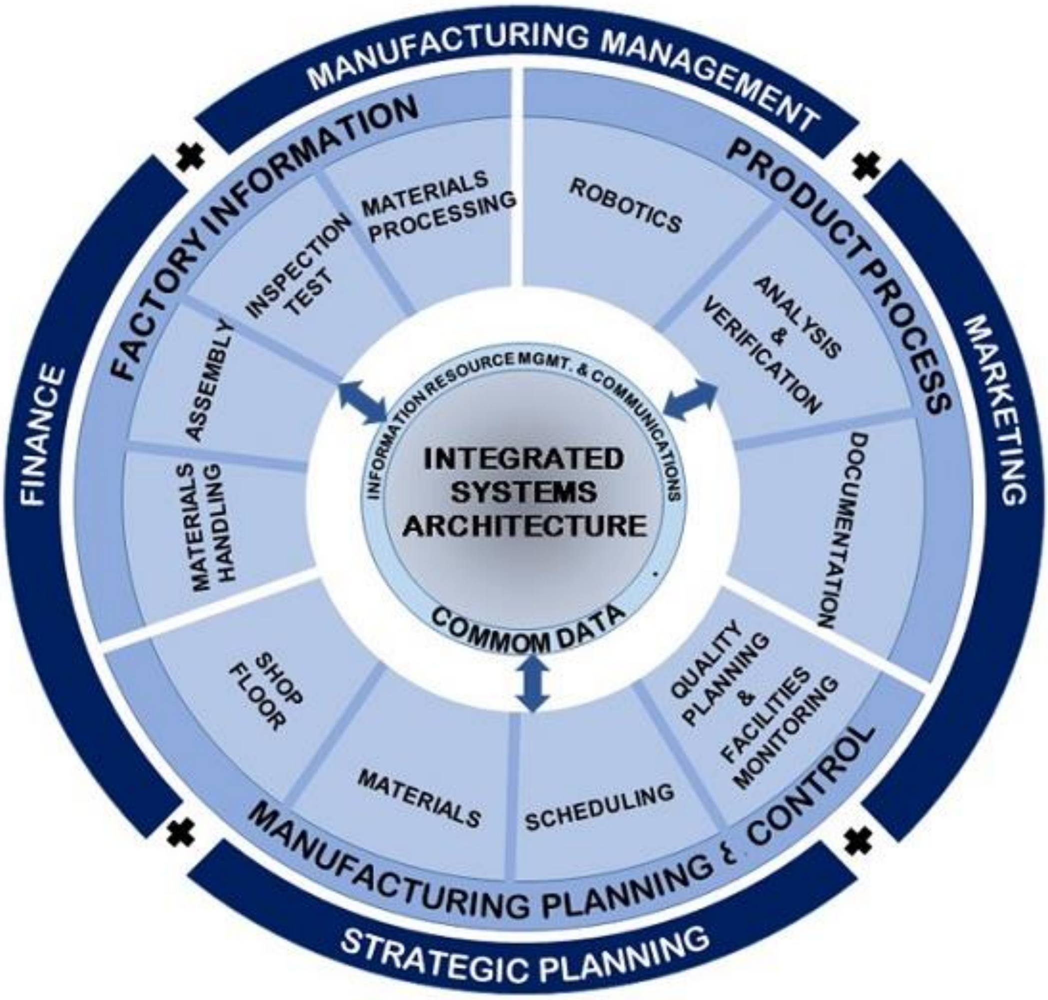

Fig.1.3 - CIM wheel-an embodiment of the concept of computer-integrated manufacturing

It depicts a central core (integrated systems architecture) that handles the common manufacturing data and is concerned with information resource management and communications.

The radial sectors surrounding the core (wheel hub) represent the various activities of manufacturing, such as design, material processing, and inspection.

These activities have been grouped under three categories-manufacturing planning and control, product/process, and factory automation-as depicted in the wheel's inner rim.

The outer rim represents the upper management functions, grouped into four categories: strategic planning, marketing, manufacturing, and human resource management, and finance.

The outer rim was added in 1985 to emphasize the need of including both management and technology functions within the scope of CIM. As the wheel illustrates, CIM is broad enough to encompass all aspects of the manufacturing enterprise and its management, including those of personnel and finance.

1.8 Evolution of CIM

CIM has been evolving since the mid-1970s; however, until 1980 it was merely a concept. The 1980s, especially the second half, saw CIM expand into a technology. By now, the industry has realized that CIM is a necessity rather than a luxury.

Computer-integrated manufacturing continues to evolve so that any claim that a "true" CIM plant exists is debatable. Progress in this direction has been phenomenal, however, and several full-blown CIM plants will probably be operating by the turn of the century. Today, numerous companies market an array of products that, when put together intelligently, can convert an average manufacturing facility into a CIM operation.

Primary factors that have led to the development of the CIM concept and associated technologies include the following:

1. Development of numerical control (NC)
2. The advent and cost-effectiveness of computers
3. Manufacturing challenges, such as global competition, high labor cost, regulations, product liability, and demand for quality products
4. The capability-to-cost attractiveness of microcomputers.

1.9 Impact of CIM on Personnel

Computer-integrated manufacturing and its building blocks such as CAD or CNC affect all company personnel, from operators to the CEO and president. Early predictions that only unskilled workers would be affected have been proven wrong.

The restructuring and downsizing of a company reduce middle management positions as well. Employees in the 40-to-50 age group are being asked to retire, and those younger are being asked to retrain.

Harrington (1985) identified some of the changing skills of people working in CIM environments. For example, operators of NC machines need additional skills in part programming and CNC technology. Jobs of expediters are being eliminated.

Reading inspection instruments is less demanding since they have digital readouts and can print out the inspection results. As another example, cost estimating has been computerized to the point that anyone with keyboarding skills and some training can carry out this function.

Even areas that normally require higher skills have changed. For example, a designer's creativity and skills are challenged by CAD workstations that instantly test their ideas on design improvement.

Knowledge-based software systems can even assess the quality of the designer's creativity by evaluating the manufacturability of an idea. Moreover, in CIM, designers need to know more about manufacturing, for example, part programs not just for machining but also for assembly, CMM inspection, or robotized packaging.

Most of all, management may need to undergo a cultural change. To begin, the president and CEO must believe in CIM. Their primary task is convincing other board members of CIM's leverage. Since CIM affects all three functions of management-planning, implementation, and control-change is required throughout the organization.

Managers must switch from hard copy reports to electronic mail. The real-time environment under CIM demands faster turnarounds on decision making, which becomes a group activity. Meetings may be sudden, short, and highly focused since the input information for the meeting will be clear, concise, and current.

CIM demands that specialists understand functions outside their areas. Specialists need to generalize more, and generalists need to specialize more. Under CIM, jack-of-all-trades but master of none will give way to jack-of-all-trades and master of some. This may initially be difficult, but knowledge-based computer systems smooth the transition by providing a helping hand.

Thus, the skills and practices of the past undergo profound change with CIM. As Harrington (1985) explains: "Indeed, it is safe to say that the impact of computer integrated manufacturing will be greater on the people involved than on the technology itself". The transition from conventional practices to those required under CIM benefits from training and retraining of the people affected.

1.10 Role of Manufacturing Engineers

In CIM environments, manufacturing engineers interact very closely with designers. They need to understand design, especially CAD, and the design process. CAD requires them to have insight into the principles of computer technology and the associated terminologies such as bits and bytes, RAMs, and ROMs.

The same is true for first-line supervisors or foremen who interact with operators, management, and plant equipment. Maintenance staff needs to work more as a team with a common pool of expertise in areas as diverse as electronics, computers, hydraulics, pneumatics, and the usual mechanical and electrical systems.

Commissioned by the SME, A. T. Kearney Inc. surveyed to predict the job descriptions of manufacturing engineers by the year 2000. Entitled "Countdown to the Future: the Manufacturing Engineer in the 21st Century" and known as Profile 21, the survey results are based on the opinions of 7,500 manufacturing practitioners, a series of roundtable discussions, a Delphi study, a chief executive officer questionnaire, and an extensive literature search. It predicts that the environment in which future manufacturing engineers will operate will change due to CIM drastically.

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