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A process for implementing CIM in a small manufacturing facility

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A PROCESS FOR IMPLEMENTING CIM IN A SMALL MANUFACTURING FACILITY

by

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ABSTRACT

This work is dedicated to small manufacturing enterprises seeking to explore Computer Integrated Manufacturing (CIM) technology, which is the recent trend in the manufacturing world. The main theme of this thesis is to improve productivity, product quality and reliability, and to reduce costs by integrating various discipline in small manufacturing environment, using computer technology.

To achieve this goal, a hypothetical small manufacturing company was chosen as a subject. The typical functional and organizational structures were analyzed and possible problem areas were highlighted. The problems relating to manufacturing process were studied in detail, and possible solutions were proposed to computerize the respective manufacturing functions. Technologies suggested to implement the solution include a Sun 386i workstation networked with 80286 microprocessor based PCs using Ethernet connections and industry standard software namely AutoCAD, IDEAS, SmartCAM and FourthShift.

By implementing CIM through such a systems approach following could be achieved:
Direct Numerical Control (DNC), 2-D and 3-D part geometry using CAD-CAM link, improved control over inventory, better

planning of resources, significant reduction in manufacturing cycle time and so on and so fourth.

The main emphasis here is the understanding of principles involved in establishing relationships between functional areas of CIM, and defining problems pertaining to them. The applicability of the CIM system is very broad, however some of the most influential areas are discussed to demonstrate the systems power. Nevertheless, problem issues pertinent to non-technical field is beyond the scope of this work.

It must be emphasized that although CIM must be customized to each industrial business and/or organization, a major part of it is common from the systems design point of view to many industries. And it is hoped that this work will be helpful to many small manufacturing units.

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DEDICATION

To my Parents,

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CHAPTER 1

INTRODUCTION

CHAPTER SYNOPSIS

This chapter describes the evolution of Computer Integrated Manufacturing (CIM) through CAE, CAD, CAM, FMS, GT etc. Its main theme is to express the true need for this work. Today, the drive towards CIM is immense, but generally limited only to large enterprises. This work is dedicated to small manufacturing units who can also benefit from CIM technology.

A. CIM TRENDS

Digital computers have a history of more than 40 years. First created in 1946, computers were not commercially available till 1951. In the late 1960's and early 1970's, with the arrival of microelectronics, came the minicomputers, and more importantly, the microcomputers. Performance of these systems were excellent, cost continually dropped, and these systems found their way into more manufacturing applications.

In 1954, numerical control (NC) was introduced, followed by automatically programmed tool (ATP) in 1955. This marked the start of computer aided manufacturing (CAM). Computer aided design (CAD) appeared publicly early in the 1960's [1].

Computer Integrated Manufacturing - now popularly referred to as **"CIM"**, is barely 18 years old, if one dates it from the origination of the term by the late Joseph Harrington, Jr. in 1973 publication of his book "Computer Integrated Manufacturing". CIM in fact, is a moving target that has undergone an appreciable evolution in its brief 18-year existence. At the beginning, it appeared an ambiguous or fuzzy concept, actually articulated fairly clearly by both Harrington and the U.S. Air Force (ICAM) team. It was not really understood by the eventual corporate users who were wrestling with a definition of CIM that would drive their implementation [2]. That was the period from about 1975 to 1979. As observed in the 1980's computer size and cost were decreasing about 40% a year while processing speed and memory were growing in almost the same proportions. This is a beneficial factor. Though, CIM cannot be implemented as superheat of all possible technology strategies, but it is a strategy focusing on knowing more than other competitors in a few key areas while maintaining parity in other areas. This strategy inevitably requires a greater focus upon the sharing of data between functional departments, divisions, and suppliers [2,16].

Though 18 years old, influence of CIM is now beginning to appear in small businesses. What large industries asked of CIM 10 years ago is now being asked by small industries. The need for CIM in small manufacturing climate arose, but was suppressed by lack of affordable expertise, software and hardware. Therefore, they had to be content with islands of automation.

B. PURPOSE OF THE THESIS

Todays manufacturing challenge -- improved productivity, product quality & reliability and reduced costs cannot be met just by better machines, skilled operators or better managerial tools. The only tool that can meet these challenges is the integration of various disciplines using computer technology. With sophisticated tools at its disposal, CIM is an on-line, real-time environment which is just beginning to touch the surface of its full capability.

Though automation and integration are the backbone of CIM, without implementation it is like sitting on a gold mine without a shovel [17]. At the helm of successful CIM implementors list are Allen Bradley, Hewlett Packard, GM, McDonald Douglas, GE etc., who are industrial giants. Many people feel that computer integration is the domain of large companies with large financial resource. Small manufacturing companies who are, however, also hard pressed by heavy competition - they who need CIM **the most** are highly skeptical about its existence in their environment. Questions like :

a) What are the requirements to build a CIM system?

b) How should different technologies be integrated into a CIM environment?

c) What is the cost involved to do so?

d) What benefits can be achieved? and so on and so fourth remain unanswered, making CIM a nightmare for small manufacturers.

The following discussion is intended to assist a potential CIM developer and implementor in the decision making process. This is a practical approach for a small company or an individual who wants to bring together several technical components, typically observed in a small manufacturing environment, to form a complete CIM system. The reader is exposed to vital technical issues, like software & hardware components and guidelines for selecting them, networking concepts and procedures, standards etc. affecting the CIM environment, to give the necessary background to make an evaluation and selection possible. There are virtually thousands of combination of hardware and software available. Emphasis is made on the building blocks for CIM which act as a guide to successful CIM implementation. This is not intended to discuss the pros and cons of a turnkey CIM system installed by the vendor, for ready use. But, this discussion is developed, taking into account the inability of small manufacturers to afford the fees for engaging professional consultants.

C. ORGANIZATION OF THIS THESIS

In Chapter 1, the historical development that led to the birth of CIM from CAD, CAM, FMS, GT, etc. is discussed. However, the prime objective of this section is to express the need for this topic. This work is mainly aimed at small enterprise group interested in building a CIM system.

The next chapter (Chapter 2) is rather generic, meant for a complete novice, to explain vital concepts about CIM system. Herein, topics defining CIM, its current status and its future are discussed. The most important word in the phrase "Computer Integrated Manufacturing" is "Integration" of system - is also touched in this section. An exhaustive list of benefits gives the reader an idea about the capabilities and limitation of CIM system, when applied to small business.

The following section (Chapter 3) focuses on the main technology basis that makes up a CIM system. Features of hardware and software, accompanied by selection criteria listing, help to simplify the systems selection process.

Today, the hardware and software market is very confusing becuase of the availability of a large number of products. Therefore, a systems selector should be well aware of his/her requirements. Peripheral devices are briefly discussed too. The topic also deals with concepts of networking in light of systems integration. Since Local Area Network (LAN) is the most suitable type of network, for small manufacturing enterprise, it is dealt with in detail.

Chapter 4 reviews a case study to develop a CIM system. Discussed, herein, is the procedure to evaluate a manufacturing system in a hypothetical situation used as a standard to measure the developing CIM system. It is particularly meant to give a direction to the system implementor. In addition, issues pertaining software, hardware and networking procedure involved in the case study are discussed. Finally, the study is supported by illustrations.

Finally, the realized and projected results bring this section and the thesis to an end.

CHAPTER 2

COMPUTER INTEGRATED MANUFACTURING

CHAPTER SYNOPSIS

This chapter serves as an introduction for a complete novice to the field of CIM. The generic meaning of CIM with reference to small manufacturing companies, its current status and the future of CIM are also discussed based on the extensive literature survey. Systems Integration, which is frequently overlooked, is discussed in detail. The art of Computer Integrated Manufacturing revolves around the concept of integrating different technologies (machine tools and computers) to achieve and optimize the benefits from the system. The evolution of CIM from CAD-CAE-CAM and the bond that exists between them are discussed. The field of CIM is relatively new to the manufacturing industry. This chapter also focuses on the advantages of CIM when applied to small manufacturing units.

A. WHAT IS CIM?

1. INTRODUCTION

In the modern history of manufacturing, no concept has captured the imagination of the industry as much as CIM. The definition of CIM changes as time goes on and industry perceives it differently [1]. In the early 80's, it was associated with large-scale automation. Five years later, it was considered more of an interfacing and communications concept. It is at this point, that small manufacturers first started to realize the potential of CIM in their environment.

2. DEFINITIONS OF CIM

To most people today "CIM is an information systems view, an extended computer system, the goal of which is to reproduce all of the product, process, management & business functions in terms of computer data which can then move freely and be of use throughout the system". CIM is a business philosophy aimed at achieving a more efficient and effective product design and production process by integrating the control and distribution of information throughout the entire process [3]. Successful companies whether large, medium or small do recognize that CIM represents changes in management practice as well as changes in technology. In fact, the management bureaucracy in small companies is comparatively less and therefore immensely aids the speedy implementation of CIM where early productivity benefits are realized [2].

"CIM" can also stand for control, information and mechanization architecture of a company. The control portion of the CIM architecture deals with management (control) technologies, including the concepts of work simplicity, value analysis, and group technology to achieve product and process stabilization and synchronized flow techniques or Just-in time (JIT) strategy to eliminate waste and to increase production. CIM architectures which represent automation technology such are CAD, CAM & CNC as well as information technology such as Material requirement Planning (MRP) and cost systems [4].

A CIM "factory of future" will consist of modular subsystems that are controlled by computers, which in turn will be interconnected to form a distributed computer network. When a complete CIM system is implemented, the flow of both products and information is automated throughout the business organization, from the entry of an order through shipment of the finished product. The output of one business function serves as an input to the next function.

In short CIM is maturing from a little understood, widely interpreted, and fairly educational discipline into a generally accepted code name for employing computers throughout the manufacturing process to ensure quality, increase throughput and uptime utilization rates, implement continuous-flow production; reduced inventory and in-process overhead, and make the manufacturing function a more consistent, flexible and responsive tool in the service of overall corporate objective [2].

B. WHAT IS SYSTEMS INTEGRATION?

1. INTRODUCTION

While much automation has occurred in small manufacturing industry during the past decade, it has occurred primarily as isolated activities within function - the so called "islands of automation". To achieve significant productivity improvements integration of activities within and across functional areas is necessary. A third perspective of CIM as a complement to the user and technical perspective is integration and sharing of data to ensure quality, consistency and flexibility in the total automated structure of the enterprise [1]. Integration is not a destination, but a direction. It is a tailor made program, because every organization has different corporate objective & structure.

2 MEANS OF INTEGRATION

To address the requirements of integration, means of integration must be defined and built - the objective of which is to achieve integration of various independent islands of automation. Fundamentally there are three means to integrate a small system:

i) INFORMATION INTEGRATION: To achieve the planning, tracking, and control, information must be available where needed and in the form needed. This requires various pieces of computer hardware and software to pursue various databases, all with absolute data integrity.

ii) CONTROLS INTEGRATION: To achieve the closed-loop process control that can link each process and operate each process, control strategies and systems must be integrated.

iii) MATERIAL FLOW INTEGRATION: To achieve transfer line speed with job shop flexibility parts must be handled in known orientation through known moves [6].

3. <u>GENERAL BENEFITS OF SYSTEMS INTEGRATION</u>

The following are some of the general benefits that flow from integration :

a) Improved product quality through error reduction.
b) Prototype simulations and evaluations prior to manufacturing and support.
c) Shorter design time to meet customer requirement.
d) Ability to evaluate more alternatives.
e) Better control of materials and other resources.

f) Improved tracking of manpower and project activity.

g) Better comprehension of the nature of design in the context of product options and their impact on downstream functions [7].

A schematic of isolated data (Figure 2.1) and integrated data (Figure 2.2) relating six major areas through which information and/or material must move within a typical manufacturing environment before the product can be delivered to the customer is represented. In case of the isolated data transfer, the data for each function is locally accumulated and hand transferred. Whereas, in the integrated data transfer system, a common database is the medium for mutual communication [8,9,14,17].

C. EVOLUTION OF CIM FROM CAD-CAE-CAM

Prior to understanding CIM, it is necessary to have knowledge of the ingredients of the CIM system.

Computer-Aided Design (CAD) involves any type of design activities which makes use of the computer to develop, analyze and modify an engineering design. The process of designing is characterized by Shingley [22] as an iterative procedure consisting of the following six phases :

1) Recognition of need
2) Problem definition
3) Synthesis
4) Analysis and optimization
5) Evaluation and
6) Presentation

Recognition of need involves the realization by someone that a problem exists, for which some corrective action should be taken. Definition of the problem is a through specification of the item to be designed. This specification includes cost, quality, operating performance etc. Synthesis and analysis are closely related and highly iterative in the design process. Evaluation is concerned with measuring the design against the specifications established in the problem definition phase.

These various design-related tasks can be grouped into :

1. Geometric modeling
2. Engineering Analysis
3. Design review and evaluation and
4. Automated drafting

Geometric modeling is concerned with the computer-compatible mathematical description of the geometry of an object. The mathematical description allows the image of the object to be displayed and manipulated on a graphic terminal through signals from the CPU of the CAD system. Any complex solid is built by utilization of union, intersection and difference operation on primitives like sphere, cylinder, tube, block etc. There are several different methods of representing the object in geometric modeling e.g. wireframe, boundary-representation etc. The basic form, uses wire frame to represent the object. Wire-frame geometric modeling is classified into three types, depending on the capabilities of the Interactive Computer Graphics (ICG) system. They are 2-D, 2 1/2-D and 3-D modeling. Most advanced method of geometric modeling is solid modeling in 3-D, with enhancements like hidden-line removal feature, surface representation etc.

The Engineering Analysis involves analysis of stress-strain calculations, heat-transfer computations, or the use of differential equations to describe the dynamic behavior of the system being designed. The analysis of mass properties is the analysis feature of a Computer Aided Engineering (CAE) system that has probably the widest application. It provides properties of a solid object being analyzed, such as the surface area, weight, volume, center of gravity, and moment of inertia. For a plane surface the corresponding computations include the perimeter, area, and inertia properties. By using the Finite Element Analysis technique, the object is divided into a large number of finite elements (usually rectangular or triangular shapes) which form an interconnecting network of concentrated nodes [22]. By determining the interrelating behaviors of all the nodes in the system, the behavior of the entire object can be assessed. Color graphics capabilities can be used to display and compare the pre and post analysis models.

Checking the accuracy of the design can be accomplished conveniently on the graphics terminal [23]. Layering, interference checking etc. are techniques used for design review. Most common of all is the kinematic analysis of a mechanism. The existing kinematic packages provide the capability to animate the motion of simple designed mechanisms such as 4-bar mechanism.

Finally, automated drafting involves the creation of hard-copy engineering drawings directly from the CAD database. These packages have features that include automatic dimensioning, generation of crosshatched areas, scaling of the drawing, and the capability to develop sectional views and enlarged views of particular part details. Engineering drawings can be made to adhere to company drafting standards by programming the standards into the CAD system.

This CAD system offers the opportunity to develop the data base needed to manufacture the product. In an integrated CAD/CAM system, a direct link is established between product design and manufacturing. This includes all the data on the product generated during design (geometry data, bill of materials and parts lists, material specifications, etc.) as well as additional data required for manufacturing. Further, the CAD/CAM system develops the complete product structure, or bill of materials, for the benefit of the material planning and control systems. This information is needed for the material requirements planning, which must explode the master production schedule generated from orders received and/or finished goods inventory decisions into detailed production schedules and purchase orders for all of the component parts of the product. The field of CIM is not limited to the technical aspect of a machine shop, it extends to general ledger, accounts payable & accounts receivable, order entry, inventory control and various other activities pertaining to the effective administration of the shop.

D. RELATIONSHIP OF CIM ACTIVITIES IN SMALL MANUFACTURING ENVIRONMENT

Certain constraints, active especially in a small manufacturing environment, prohibit the complete formulation of a CIM system.

Most of the small machine shops are drafting based, because the scope of research oriented projects is limited. Besides they are not adequately equipped to own and operate advanced

ISOLATED DATA TRANSFER - SMALL MANUFACTURING UNIT

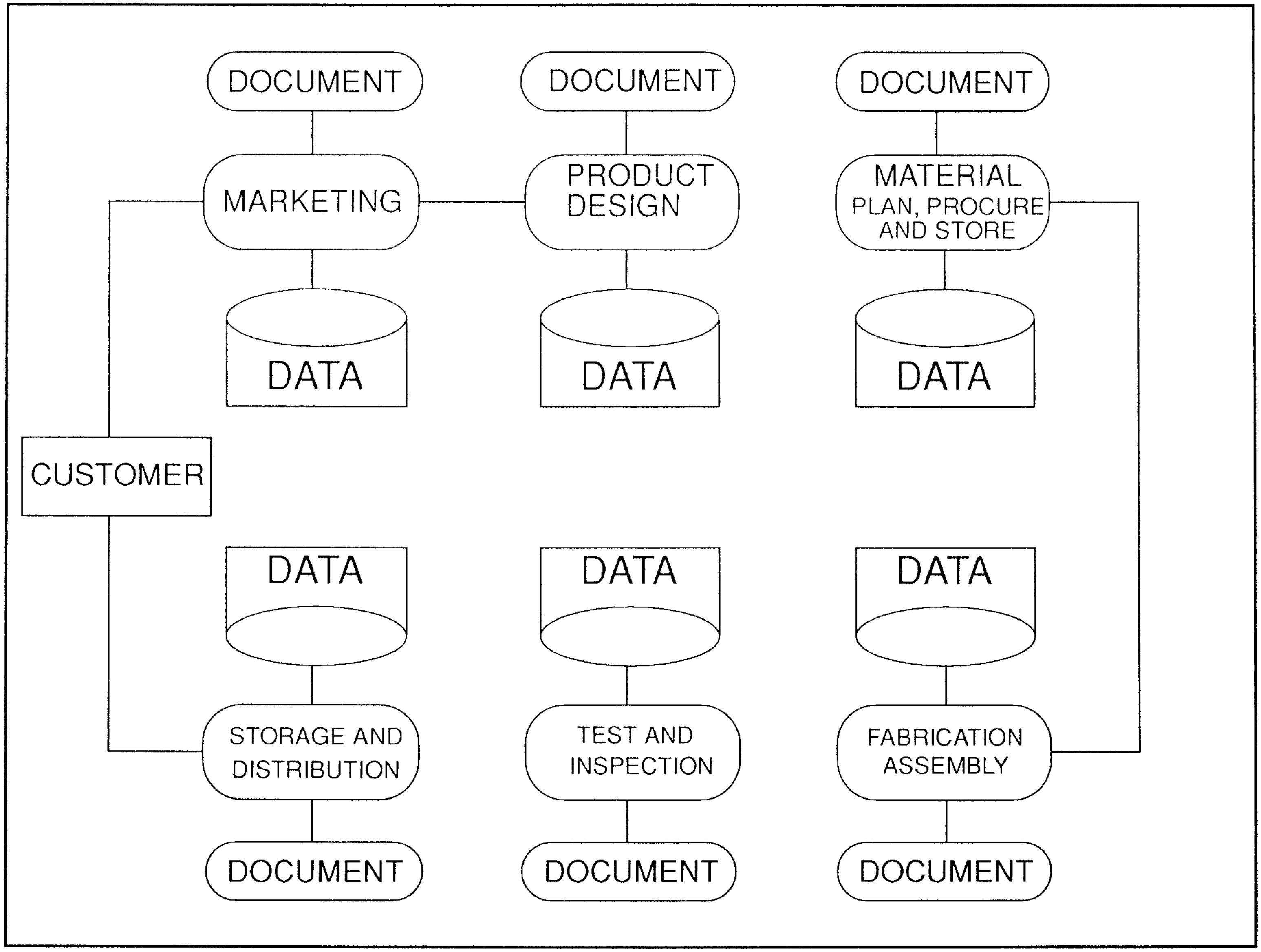


Fig. 2.1

INTEGRATED DATA TRANSFER - SMALL MANUFACTURING UNIT

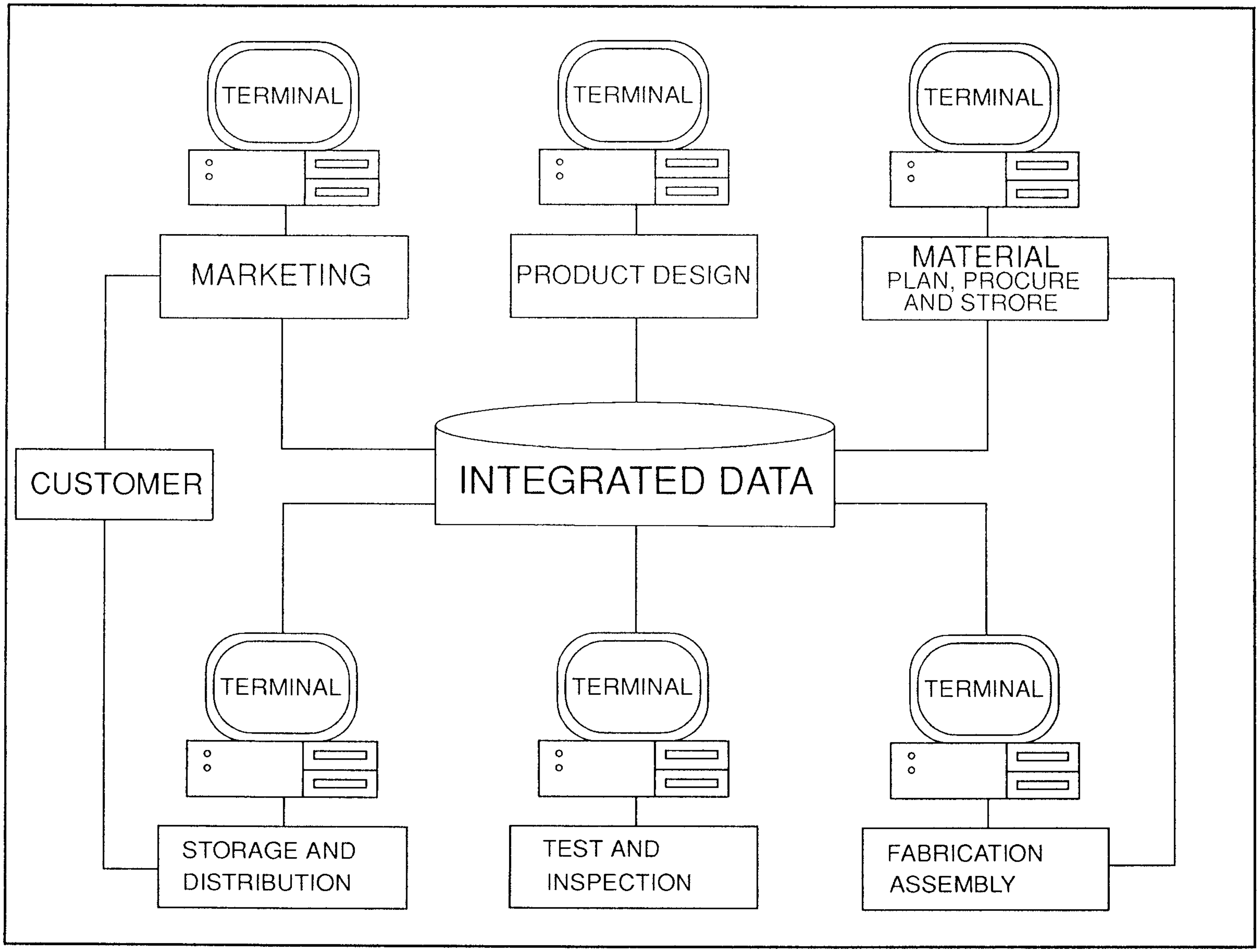


Fig. 2.2

CAE system. Therefore "islands of automation" are generally sufficient to satisfy their operation, rather than imposing a true CIM environment comprising the CAD-CAM, Manufacturing Planning & Control and Business Function link.

There exist a weak relationship between the CAD-CAM-CAE and Manufacturing Planning & Control islands, because the amount of information transfer between them is limited to Bill of Material. Electronically transferring the data of the Bill of Material is feasible, but it is more convenient to do so manually, considering the environment of operation.

On the other hand information generated from Business Function and that from Manufacturing Planning & Control have close relations in terms of Inventory Control, Man-Machine Scheduling, Project Planning and so on. In other words it is not feasible to have a system that does not co-relate the data from Manufacturing Planning & Control and Business Functions. Thus, it is necessary to have a strong link between these two islands. CAD-CAM-CAE functions are normally independent of the Business Functions.

In short, the CIM technology in small manufacturing units proves more beneficial when linked into islands, rather than establishing a true link.

E. WHERE IS CIM TODAY?

A turning point in the evolution of CIM is the transition from 'what originally appeared to be strictly a technology focus' to 'the so-called small enterprise level view'. Here manufacturing is seen not as a discrete entity to be modernized solely on the shop floor and in the engineering office, but rather a critical path of the overall corporation.

Industrial automation has occurred from the bottom up. The computer software technology that makes it possible to consider CIM today, has only recently become available at acceptable economical level for small companies. Anyone attempting to set up such a system 20 years ago would have had to make an enormous investment in computer hardware and would have spent more money and years of time getting the software written and debugged [16]. This is certainly by no means an economically feasible solution to the problem. The result, however, is that manufacturers are hostages to the vendors of the various automated systems they have acquired. CIM may be a concept whose time has come, but if implementing it means junking all the individual systems already in place and acquiring a completely new integrated system, hardware and software, a small manufacturer may well hesitate - because it not only involves loss of vital investment but also changing people to adopt to the new system. Nevertheless, there are obvious advantages to CIM.

F. WHAT THE FUTURE HOLDS FOR CIM IN SMALL MANUFACTURING UNITS?

Although some of the technologies and methodologies still need substantial development, CIM has matured to the point where it is now possible to conceive of, as well as implement in some rudimentary ways, the flow of data between not only manufacturing and engineering; but also the business functions in a small firm.

The importance of information flowing back upto the engineering office was cited by many experts as one of the CIM's driving forces in the next few years [2]. Companies active on the leading edge of CIM also reported moving back to a design and CAD driven process, where manufacturing is planned at the same time, 3-D design area, common access to the data to drive process planning and shop floor within an integrated system, the ability to capture trends in real time to prevent large losses due to production error, real-time modeling capabilities for proactive decision making; are other forms in which CIM is moving. Also promising to be a key focus of the upcoming years is a renewed emphasis on basics, on understanding process on simplifying the manufacturing parameters and production scenario prior to laying the CIM electronics and software on top of the process.

The push for standards continues. There is wide recognition that application of automated manufacturing could be accelerated if appropriate standards were applied to define hardware and software interfaces and other important parameters that would enable equipment and components of different manufacturers to be linked together without special adaptors, postpocessors and other ancillary techniques [2,16]. This issue does not greatly influence the small manufacturing world, because modification of standards to suit the appropriate requirement is relatively easy.

Another strong thrust that will characterize this next CIM period will be the effort to develop, debug and apply relational database technology and query languages [17]. This allows one to manipulate and combine the data in a way to take advantage of the information flow because data integrity is essential. Large-scale database integration between disciplines like design, process control, scheduling and the shop floor - is a CIM capability that will be built very slowly. The day when one can manage geometric information as if it were business text is not here yet [16].

The other problem that will be addressed in the next period is the difficulty of interfacing existing software. Developing translators for software portability is running at about 20-40% of the original software cost and a comprehensive project involving multiple programs can add upto as much as five times the cost of the original software which is certainly a limiting factor of software in small companies [18]. Another big thrust for CIM will be to emphasize people and training as keys to successful CIM implementation.

G. HOW SMALL BUSINESSES CAN BENIFIT FROM CIM?

CIM covers the entire manufacturing process. Mentioned underneath are a number of benefits in varied field, related to small manufacturing units. All below indicated advantages may not be pertinent, however, most are applicable to small environment [2,4,22].

1. Business Planning & Support Functions

   a) Aids in product cost analysis , simulation and development of projected future cost.

   b) Helps to reduce costs for part purchasing, premium transportation and expediting.

   c) Ease of processing of customer orders from order entry through picking and invoicing.

d) Provides accurate up-to-date financial information on accounting.

e) Ease of payroll systems.

2. <u>Engineering Design</u>

<u>CAD - Computer Aided Design</u>

a) Improved engineering productivity

b) Shorter lead times

c) Reduced engineering personnel requirements

d) Customer modifications are easier to make

e) Faster response to requests for quotations

f) Avoidance of subcontracting to meet schedules

g) Minimized transcription errors

h) Improved accuracy of design

i) In analysis, easier recognition of components interactions

j) Provides better functional analysis to reduce prototype testing

k) Assistance in preparation of documentation

l) Designs have more standardization

m) Better designs provided

n) Improved productivity in tools design

o) Better knowledge of costs provided

p) Reduced training time for routine drafting tasks and NC part programming

q) Fewer error in NC part programming

r) Provides the potential for using more existing parts and tooling

s) Helps ensure designs are appropriate to existing manufacturing techniques

t) Saves materials and machining time by optimization algorithms

u) Provides operational results on the status of work in progress

v) Makes the management of design personnel on projects more effective [1,20,21,22,23,24]

w) Assistance in inspection of complicated parts

x) Better communication interfaces and greater understanding among engineers, designers, drafters, management, and different project groups

3. Manufacturing Planning & Control

3.1 CAPP - Computer Aided Process Planning

a) Reduces new product design lead-time

b) Reduces new part introduction cost

c) Increases capacity utilization

d) Reduces setup time

e) Reduces scrap

f) Rationalizes and reduces the number of parts in database.

3.2 MRP - Material Requirements Planning

a) Reduces inventory

b) Improves customer service

c) Quicker response to changes in demand and in the master schedule

d) Reduces setup and product changeover costs

e) Better machine utilization

f) Increased sales and reduction in sales price

3.3 <u>CNC Machine Tool</u>

a) Reduces non-productive time

b) Reduces fixturing

c) Reduces lead time

d) Greater manufacturing flexibility

e) Easier to accommodate engineering design changes on the work-piece

f) Improve accuracy and reduced human error

g) Reduces operator skill requirements.

h) Increases product quality

i) Reduces scrap and rework

j) Improves product quality due to unmanned operation capability

3.4 <u>CAM - Computer Aided Manufacturing</u>

a) Increases productivity

b) Increases product quality

c) Increases flexibility with respect to hard automation because of reprogramming

d) Increases reliability of "workforce".

e) Reduces production floor space requirements.

f) Substitutes for humans in hazardous, monotonous, or drudgery-laden work .

3.5 NC Verification

a) Reduces the time and cost of producing NC programs for machining centers and milling machines.

b) The rapid turnaround encourages programmers to use NCV to fine tune programs for optimum efficiency.

c) Potential NC programmers can be trained rapidly, and without danger.

d) The use of NC verification reduces the wear on machines.

4. Shop Floor Monitoring

a) Maintains labor and machine estimated or standard hours of each operation.

b) Provides for both primary and alternate routing for each inventory item.

c) Provides tooling control information.

d) Standardizes operations for multiple routing.

e) Helps to effectively plan, schedule, control and evaluate the flow of work on shop floor.

f) Provides flexibility in reflecting the overall production plans of management allowing planned production to be based on predicted demand.

CHAPTER 3
TECHNOLOGIES FOR CIM

CHAPTER SYNOPSIS

This chapter gives sufficient background information to a potential CIM systems developer and implementor. The required components of CIM system e.g. software, hardware, peripherals and networking are discussed. Selection criteria listing in this chapter aids the process of selection of the components for the CIM system.

A. HARDWARE BASE

1. STANDARD WORKSTATION FOR CIM APPLICATION

1.1 WORKSTATION AS A SUPERMINI COMPUTER

Workstations such as the SUN 386i can be classified as a supermini computer. Like most supermini's the newly developed workstations run on a 32 bit processing power, have a lower entry cost than mainframes, and have operating speeds of over 5 MIPS (million instructions per second). These higher speeds are made possible due to ECL (emiter-coupled logic) integrated circuit technology [27]. Another characteristic common to both is a virtual-memory operating system. Operating systems performs basic housekeeping and permit other program to run. Virtual memory operating systems automatically swap portions of a program between main memory and disk storage.

1.2 THE STANDARD WORKSTATION HARDWARE

Workstations, like microcomputers (PCs) are desktop or deskside machines, but generally run 32-bit software. Workstations are typically divided into two broad categories : low and high ends [26]. Low-end and high-end workstations are distinguished by their graphics power, memory size and processors. Appropriate software is added to low-end workstations, along with special hardware to boost it's performance. Whereas, high-end engineering workstations contain powerful graphics processors. Hardware in these systems generally consists of a high-resolution graphic display, a processor capable of over one million instructions per second (MIPS), 1Mb or more of primary memory, and the ability to operate in a network environment with other workstations or host computers.

Most such workstations today are powered by Intel 80386 or the Motorola 68000-series 32-bit microprocessor chip. Recently, high-end workstations based on Reduced Instruction Set Computer (RISC) chips, also referred to as Scalable Processor ARChitecture (SPARC) by Sun's Workstation Families have been introduced [30]. Typically, workstation vendors offer a family of products. Often, these products are based on different microprocessors and will have different memory capacities, floating point processing power, graphics capabilities, and expansion slots. Low-cost, monochrome and color workstations, often used in 2D applications usually cost less than $20,000. Color, 3D workstations list price ranges from $20,000 and $75,000, generally used to do wire-frame modeling, solid modeling, and limited animation [31].

2. MICROCOMPUTER FOR CIM APPLICATION

2.1 THE STANDARD MICROCOMPUTER HARDWARE

A variety of factors have limited where PCs are applied. The processor in most PC/AT and compatible computers, the Intel 80286, is a 16-bit chip that operates at relatively low speeds when compared to the 32-bit computer architectures. Another problem in the PC/AT is unable to address large memory. This is primarily a software problem. The original PC operating system, DOS, addresses only 640K of RAM. This means that, on ATs engineering programs run in overlays, or sections. As the program runs, each successive overlay is dragged into main memory as the previous section completes operation. Overlay slows the program performance and limit problem size.

Today, new hardware and operating system software have eliminated the restrictions of original PCs. In fact, new PCs such as the Compaq 386/25 and the PS/2 Model80, which are based on 32-bit Intel 80386 processors, are in the same power league as low-end workstations from vendors such as Sun Microsystems, Apollo and DEC [33].

Standard DOS still has the same limitations of memory that it has on PC/AT machines, but it runs faster because the operating speed of 32-bit processors hover around 20 to 25 MHz. DOS expanders are special compilers and programs that modify the basic operating system so the processor can address much more RAM. Expanders allow machines to access up to 4M bytes of RAM. However, Programs running under expanded memory do not have access to a large address space. Therefore, the engineering programs operating in an expanded memory environment must still be run in overlays because they will not fit into allocated RAM. The main advantage of Unix over DOS is that it does multitasking [34]. In the machines, multitasking is done by dividing available CPU cycles among the various jobs the processor must perform. However, the biggest problem with Unix is its many variations. Each variation requires software vendors to make program changes, which in turn requires them to recompile the program.

On the hardware side, microcomputers have Micro Channel ARchitecture (MCA) buses. The bus differs from the PC/AT bus by allowing multiple CPUs to work independently on the bus, but communicate to each other through shared memory. It also eliminates CPU bottlenecks that occurred when high-speed, 32-bit processors tried to communicate to a PC/AT bus that was designed to handle 16-bit data at 8MHz. Now all the microcomputers have hard drives and diskette drives, coprocessors, mass storage devices, graphics controllers and memory.

2.2 COMPARISON OF PCs AND WORKSTATIONS

In terms of sheer processing power, the 80386 based machines qualify as low-end workstations. The key element in this growth is the constantly improving speed and capability of new processors available for personal computers, in particular the Intel 80386 and Motorola 68020 and 68030.

The newly developed PCs like the Compaq Deskpro 386/25, Macintosh IIx, IBM PS/2 Model 70-A21 , ALR Flex-Cahce 25386 and so on are truly powerful system having fast hard disks, several megabytes of fast memory, powerful floating-point processor, high-resolution & high-speed video, and a multi-tasking operating system; all standard features available in a workstation. Table 3.1 compares the most important functional elements of three PCs and two low-end workstations [37]. With a few exceptions, the focus here is on currently available technology.

It's worth noting that personal computers and workstations share two common elements: each has one CPU per user, and each offers fast response time. Both types of machines avoid the main problem facing minicomputer and mainframe users: slow response time as more users are added [37]. For a PC or low-end workstation, each new user means a new processor and no impact on others' response times.

Hardware and standards borrowed from the workstation world are increasingly finding their way onto personal computers. These additions are making existing applications work better and faster and are encouraging the development of new programs and even new types of programs.

Workstations are striving to stay ahead of personal computers by borrowing such elements as the 80386 (and also the 80486) and by increasing the connectivity of their units to personal computer networks. The sheer power of the workstation's CPU is being improved through the use of fast micro-processors at the low end and RISC architectures at the high end.

Many of the problems facing personal computer users relate less to hardware performance than to operating system and application access to the hardware's capabilities. The DOS 640-Kbyte memory limit, the continuation of the 64-Kbyte segment size limitation under Unix, and the lack of a Multifinder version that takes advantage of the 68030 are all examples of this kind of problem.

COMPARISON OF TECHNICAL WORKSTATIONs & PCs

FEATURES	Apple & PCs Macintosh IIx	Compaq Deskpro 386/25	IBM PS/2 Model 70-A21	Sun 386i Model 250	Apollo DN4500
CPU	16 MHz 68030	25 MHz 80386	25 MHz 80386	25 MHz 80386	33 MHz 68030
MIPS	2 5	5	5	5	7
FPU	16 MHz 68882	25 MHz 80387	25 MHz 80387	25 MHz 80387	33 MHz 68882
Video Resolution	640 X 480	640 X 480	640 X 480	1152 X 900	1024 X 800
Number of Colors	16/64	16/64	16/64	256/16 7M	256/16 7M
Screen Size	12 inches	13 inches	14 inches	16 inches	19 inches
Disk System	SCSI	AT/IDE	ESDI	SCSI	ESDI
Transfer Rate	8 Mbits/sec	10 Mbites/sec	10 Mbites/sec	14 Mbits/sec	28 Mbits/sec
OS	Multifinder A/UX	DOS OS/2, Unix	DOS OS/2, Unix	SunOS. Unix 8086 DOS apps	Domain/OS Unix Apollo AEGIS
Hard disk Size	80 MB	110 MB	120 MB	91 MB	155 MB
RAM	4 MB	4 MB	4 MB	8 MB	8 MB
RAM cache	On-chip 256-byte	Intel 82385 32 KB	Intel 82385 64 KB	Intel 82385 64 KB	64 KB
Available slots	6	2 8-bit 4 16-bit	1 16-bit 2 32-bit	1 8-bit XT 3 16-bit AT	1 8-bit XT 6 16-bit AT
Network	10 Mbites/sec Ethernet	10 Mbits/sec Ethernet	10 Mbits/sec Ethernet	10 Mbits/sec Ethernet	12 Mbits/sec Token Ring
List Price $	11,000	16,000	16,000	21,000	28,000

Table 3.1

High graphics resolution monitors are standard for technical workstations. Though this standard is not adopted in microcomputers it does not limit the capability. A 1024X768 VGA board is to be the default standard for microcomputers. This makes the microcomputer's display capabilities equivalent to those of the workstation.

2.3 SELECTION CRITERIA: WORKSTATION & MICROCOMPUTER

The following is a check list of factors to be verified before purchasing the computer (workstation or PC)

1) Clock speed
2) Processor type
3) Memory size
4) Disk storage capacity
5) Floating point processor
6) Operating system e.g. DOS, UNIX
7) Graphics capability
8) Monitor resolution
9) Auxiliary attachments e.g. mouse, digitizer, light pen
10) Compatibility with application software
11) Network compatibility e.g. ethernet, IBM token-ring, IBM token-bus, Novell
12) Network software e.g. DECnet, TCP/IP,MAP/TOP

13) Possibility of distributed processing over the network e.g. can it be operated as load sharing device?

14) Environmental requirement - for factory shielding from electromagnetic interference, electrical noise

15) Communication ports e.g. serial, parallel, ethernet

16) Software support

17) Hardware support

18) Maintenance contract

19) Training session

20) Documentation

21) Cost price

22) Market credibility of vendor (establishment)

3. NECESSARY INTERFACE FOR CIM APPLICATION

Interfaces are critical to any purchase of any computer. To build a CIM environment it is not necessary to purchase more than one workstation - geared with the capability to perform graphics function and networking abilities. Microcomputers can be used as host to prepare the network, thereby saving the cost of hardware. However before buying a workstation it should be determined that it has the ability to run a network, a printer, a plotter, one or more CNC's, and could be connected to a modem. Parallel, serial and a network outlet like the ethernet port.

3.1 THE STANDARD SERIAL PORT

A serial transmission is beneficial for long distance communication. This is a device that converts the digital pulses which all travel down the data bus in parallel into serial pulses, following one after the other down a single data path. The serial port can be RS-232-C, RS422, RS423 communication port, depending on the necessary data rates [28]. Normally either a 25-pin or a 9-pin RS-232-C port is already built into the mother board of the workstation. Additional serial port can be incorporated by adding a board in the free slots.

3.2 THE STANDARD PARALLEL PORT

A 36-pin parallel port has become a widely accepted standard for computer-to-printer communication [21]. The interface has eight data bit lines to carry information in parallel. The transmission of these data bits is controlled by the computer supplied STROBE pulse.

4. NECESSARY PERIPHERAL DEVICES FOR CIM APPLICATION

4.1 PRINTERS

The printer is one of the most important peripheral device on a CIM network. The printer could be utilized to produce a hardcopy of anything ranging from a sales forecast to a shipping bill. The current trend is to share printers on the network, so that users can access a faster printer with high quality output at a lower price per user.

The printers are mainly classified as impact or non-impact kind. The impact printer technology such as dot matrix and daisywheel systems have good image resolution at lower cost, but cannot function effectively on a network because their slow speed hampers user productivity.

The non-impact class includes laser, light-emitting diode (LED), ink-jet, thermal transfer and liquid crystal shutter variety. The thermal transfer and ink-jet printers are suitable for standalone workstation and for operating in quite zone [36]. The ink-jet provides reliable, high quality output for text and graphics for less price, but is very slow. Compared to the former, the laserjet is expensive, but is acknowledged for its speed, reliability, high image quality and color capability. They are ideal for multiuser environment.

In the future, the laser printers may be sharply challenged by a non-impact system known as LED. They offer the greatest reliability because they have no moving parts. The image quality is higher than laser printers because the unit exposes the photo-conductor with linear LED array and an entire line is exposed at the same time. With laser technology, an image is exposed one pixel at a time and any fluctuation in the speed of the photo-conductor degrades image quality.

4.2 PLOTTERS

The plotters are an essential part for and CAD/CAM system. They are a reliable source of conceiving hard copy for design and drafting purposes. Other output devices include hard-copy unit, electrostatic plotters and computer-output-to-microfilm (COM) units. Compared to printers the plotters have equally good resolution, a maximum of 300-by-300 dots per inch (dpi) and speed not exceeding 1,000 steps per inch (spi) .

Plotters are mainly classified based on the paper size they can accommodate. Available are A-size (8 1/2" by 11"), B-size (11" by 17"), C-size (12" by 24"), D-size (24" by 36"), E-size (36" by 48"). Generally D & E-sizes are used in machine shops.

Paper movement is another criteria of distinction. The D & E-size plotters use mainly roller beds in which the paper rolls beneath the pens as they draw. In case of flat bed plotters the pen moves over a stationary paper. The accuracy of a plotter determines its ability to crate sharp and intricate drawings. The "% accuracy" is the ratio of measure of accuracy over a long pen movement. Plotters with pens numbering up to 20 are available [37]. Pen speeds are adjustable. Automatic pen-capping mechanism is an added feature to avoid the ink from drying.

The information downloaded from the computer to the plotter is stored in the buffer before being transferred to pen or paper movement. Larger buffer size aids to speed the plotting capability. The plotter ROM are programmed with a graphics language such as Hewlett-Packard graphics language (HPGL) or Houston Instrument's DM/PL which instruct to draw the various entities that make up a finished plot. Different manufacturers emulate different graphics language to improve the plotter compatibility. Most plotter are interfaced through a serial of a parallel port.

4.3 SELECTION CRITERIA : PRINTERS & PLOTTERS

The following are some factors to be considered while purchasing a printer and/or plotter

1) Color/monochrome
2) Speed of operation
3) Graphics and/or text capability
4) Type of interface e.g. serial, parallel or proprietary hardware
5) Printer resolution
6) Maximum paper size e.g. A, B, C, D, and E sizes
7) Number of colors it can print or plot
8) Special media requirement e.g. glossy or ordinary paper

9) Consumables required e.g. ink cartridge, ribbon, pen

10) Capable to draw wireframe or solid shaded images

11) Physical dimension

12) Price

13) Market credibility of the vendor

B. THE SOFTWARE BASE

One of the preliminary pillars necessary for facilitating CIM implementation is software tools. These tools allow for interactive creation, editing, and proofing of specifications. Software should possess enough flexibility to modify the system quickly and accurately. Beneath are references to some software critical to CIM development.

1. CAE SOFTWARE

Computer Aided Engineering (CAE) software covers a vast region spanning from conceptual design to systems analysis and down to CNC machining. 2-D & 3-D Solid Modeling, finite element analysis, mechanism design, automated drafting and so on are all subsets of CAE. These CAE systems are generally turnkey systems, comparatively expensive and not suitable for small machine shops. These systems are high end programs having links to popular database management systems [31]. These features differentiate between true production tools and drafting programs. PC Computer Aided Design and Drafting (CADD) packages can meet some needs of design engineers. The modern packages have much advanced capabilities as compared to PC CADD packages. Though, not widely used by small manufacturers now, they will prove to be a handy tool in the near future. Note that most small companies are drafting based and their requirements are limited to automated drafting.

2. DRAFTING SOFTWARE

The use of Computer Aided Design & Drafting (CADD) is spreading widely. CADD systems automate design and drafting. The benefits realized is not only in the creating the drawing but in storing, retrieving and modification of the drawing. There are dozens of PC CADD programs on the market today ranging from $ 49.96 to $ 10,000 or more [38].

2.1 SELECTION CRITERIA FOR CADD SOFTWARE

The following is a list of factors to be considered before buying any CADD package

1) User interface e.g. ease of use, setup and extending
2) Drawing entities e.g. 2D & 3D basic and complex entities
3) Drawing aids e.g. object orientation and placement, grid, snap, elevation
4) Analysis of the geometry e.g. area, volume, list geometric entities
5) Dimensioning e.g. editing, automatic/associative

6) Speed e.g. performance

7) Memory required e.g. database creation

8) File and data control and manipulation

9) Documentation/On-line help

10) Customization and flexibility

11) Viewing control e.g. multiple views, hidden lines removal

12) Non graphic and graphic data output e.g. dynamic link, report generation

13) Link to CNC software

14) Overall assessment e.g. price, vendor credibility

3. THE CAM SOFTWARE

The CAM software referred to, in this topic is mainly intended for DNC. Almost all of the CAM packages have a drafting feature to aid the development of part profile geometry. Since, the drafting options are not as extensive, generally the CAM packages possess an ability to import CADD geometry via the DXF of IGES connection. The Geometric Numerical Control (GNC) module of IDEAS (SDRC) package has a link to the CADD software. This module is also directly linked to the solid modeling module of IDEAS.

Some other vital features beyond the drafting capabilities are tool features. They permit the operator to select the necessary tool and decide the tip-depth and spot diameter [39]. The CAM package permits the simulation of tool path and generation of CNC code. Usually, a link module is available to direct the CNC code to a CNC machine.

The recently developed CAM software has a 3-D machining module. This notable feature includes ability to generate surfaces by defining generator and director curves. Edges or boundary profiles are used as Generator and Director profile. As their names imply, the Generator profile gets directed by the Director profile to generate the surface. To generate CNC code for machining of surfaces, it is not necessary to model the entire surface. Only the boundaries that define the surface need to be created. These surface boundaries are then used to create the tool path that will machine the surface.

The 3-D machining module in SmartCAM (version 4.5), has a different approach to model an object. It lets one enter geometry on any work plane using "Plane" co-ordinates. This information is then processed through a mathematical formula (a transformation matrix) that transforms the Plane coordinates to world coordinates [39]. A work-plane includes three pre-defined planes, XY, YZ, XZ, and permits to create any other user defined plane.

In this module surfaces can never be created directly. Only the boundary elements are needed to represent a surface. Surface Boundaries are represented with elements lying on the edges of surfaces. Surface primitives like profiles (lines, arcs), pockets and planes can be created by mathematical formulas that define planes, cones, cylinders, sphere and Tori.

These surface primitives are the building blocks for Composite surfaces. Developed surfaces such as Spun, Translated and Ruled are included in this module. Sculpted surfaces that can't be constructed using surface primitives are made possible using the type of data produced by a CAD system or contained on a drawing.

3.1 SELECTION CRITERIA FOR CAM SOFTWARE

1) Number of axis supported (2 1/2, 3, 4, 5 axis)
2) Number of standard post-processors available
3) 2-D and 3-D part profile generation capability
4) Ease of writing a new post-processor or modifying and existing one
5) Types of machines supported e.g. milling, lathe, router, EDM, burner etc.
6) CAD software it can support
7) Service contract
8) Utilities available e.g. IGES, tape to shape, to CNC machine, from CNC machine
9) Ease of installing a DNC
10) Documentation
11) Credibility of the vendor

4. THE MANUFACTURING SYSTEMS SOFTWARE

The manufacturing systems packages are a recent development. It includes various modules, symbolically linked to one another, covering almost all the functions (technical as well as non-technical) of the manufacturing process [45,46]. Most of these modules were developed independently and the linked by transferring data from one to the other. These modules cover areas of manufacturing planning, manufacturing control and administrative functions.

Various turnkey manufacturing softwares are available. However, these are not suitable to be adapted in a small manufacturing environment which is constantly under evolution. A turnkey system restricts the usage of the system because it cannot be modified at will.

4.1 SELECTION CRITERIA FOR MANUFACTURING SYSTEMS SOFTWARE

1) The modules and add-ons should satisfy the requirements of the company
2) Ease of customizing the software
3) Hardware requirement
4) Speed of data transfer - local and on network
5) Error handling capabilities
6) Database manager capabilities
7) Operating environment
8) Ease of transferring data to outside software

9) Multi-tasking capability
10) Security arrangement to limit access to datafiles and menu selection
11) User training and hotline
12) Documentation
13) Vendor credibility
14) Price

C. THE NETWORK BASE

1. <u>DEFINITION OF NETWORK</u>

Shared data structures carried in neutral database that supports engineering, manufacturing, quality assurance, purchasing, and other interfacing functions linking major functions in an organization is referred to as CIM network. Full integration of automated functions permits fully interchangeable data elements among all functional applications. Significant cost reduction can result from single point updating capabilities, minimum data entry requirements and elimination of time lag errors. The total organization can operate at maximum effectiveness, with minimum unnecessary activity [9].

2. <u>THE NEED FOR A NETWORK</u>

Today's technical support systems are generally hierarchical in nature and transaction driven and many operate as batches, as opposed to interactive systems. Data resides in a heterogeneous computer environment and generally cannot be shared among different computer systems. Although many new automated systems are being developed for individual functions, these systems are being developed with an eye for their own function's automation and not for total system automation and integration. This results in many groups of automated "functional islands" that do not (or cannot) operate as a total automated system, thereby losing the required gain in total system design productivity.

The solution is to drive data requirements by intended use, a data driven instead of a functionally driven system. Neutral data formats like IGES (Initial Graphics Exchange Specification) and GENCODES (Generalized Coding) are being developed, which address geometric and textual data communications between computers and graphics terminal.[9]

3. CRITERIA FOR DEVELOPMENT OF A NETWORK

A coordinated CIM program requires an effective communication network selected on the following criteria:

a) Business Strategies: Networks utilized in a company's facilities must be consistent with the organizational strategy. For example, if quality is deemed to be of paramount importance, the quality assurance department may be given access to all production and scrap information and the ability to immediately forward high priority status alerts to plant management or shut down the assembly process [11].

b) Flexibility: A totally flexible system is virtually impossible to design. The best strategic planning can generally only predict trends and rates of change. It is seldom possible to anticipate very far in advance which specific tools will be needed or available.

c) Capacity Required: It includes data flow-per-unit time and response time requirements for each node on the system. Capacity planning, however, should also include anticipated growth strategies consistent with the strategic plan.

d) Environmental Conditions: Every aspect of an information environment must be considered.

e) Economics: Life-cycle costs should be accurately predicted for any information system before it is constructed. Since return on investment is not easy to predict with normal accounting methods, the value of an integrated information system must be in the context of all the possible corporate functions.

f) Common Sense: Communication in a factory environment can be accomplished in a variety of ways: occasionally by tow or more methods at the sametime. An effective network plan will evaluate all possibilities and select the most appropriate [9].

4. TYPES OF NETWORK FOR CIM APPLICATION

Computer communications networking, for a company in general, exists at two major levels : long-haul or wide-area or global and local. The networking technology developed at each level has led to commercially available systems which have accelerated and expanded the practical application of computers communicating with one another.

Global networks are those established for high speed data transmission between widely separated computers without any geographical limitations. Common carrier lines, satellite and microwave systems are utilized by such networks.

However, for small manufacturing environments Local Area Networks (LAN) prove to be low-cost and have high-speed data communications capability between computers within the building [41]. LANs can be divided further into two categories: business and industrial. Although not clearly defined, business-type LANs are used for administrative functions. Industrial-type LANs serve the more specialized technical needs of manufacturing arising from the accelerating CAD/CAM application in small units.

There are many different LANs available commercially. Unfortunately, many are proprietary. A small number can be effectively applied to both business and manufacturing needs. Normally, what is found in many small companies is that there are many computers of different makers. Each has its own operating system, database manager, and filing structure. It is neither cost-effective nor practical to change over this data processing environment totally to a single vendor [45]. Hence new techniques for linking heterogeneous hardware are evolving. These often take the form of an intermediary that presents to the users a single image that is transparent as to how and where data are stored but also allows many internal views of the data. Refer Figure 3.4 where LANs are connected together and local data is stored at the point of collection or the point of use. Only those data necessary is transferred to central depository.

5. <u>LAN TOPOLOGIES</u> :

LAN cabling is arranged in predetermined configuration called a topology. The topology in LAN goes hand in hand with the hardware selected [11]. The most common of these topologies are:

a) Linear Bus Topology: A simple design with a single length of cable: known as the bus or trunk. All devices on the LAN are attached to the bus and share this single

HYPOTHETICAL CIM DATA CONFIGURATION

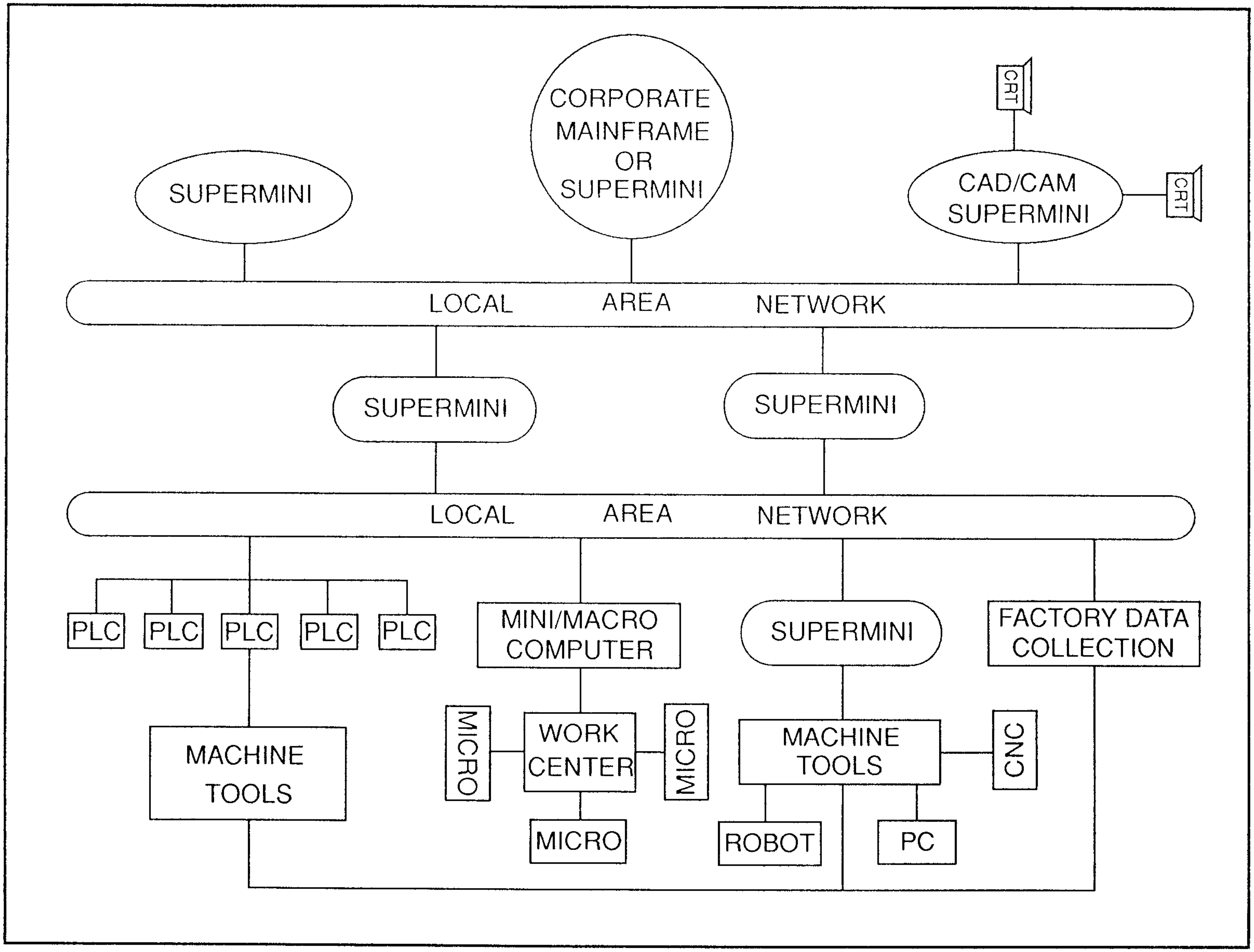


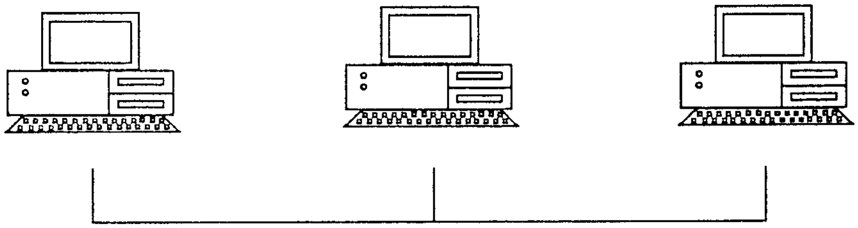
Fig. 3.1

communications medium. The linear bus topology is simple and economical. The only consideration in wiring a bus is that the cable pass by each networked device: this is not the case in other topologies. Because all devices share the bus, the cost of the wiring may be lower than with topologies that require lengths of dedicated cable. The failure of any networked device has no effect on network operation, but failure of the cable failure can be extremely difficult to locate in large linear networks. (Refer figure 3.1 a).

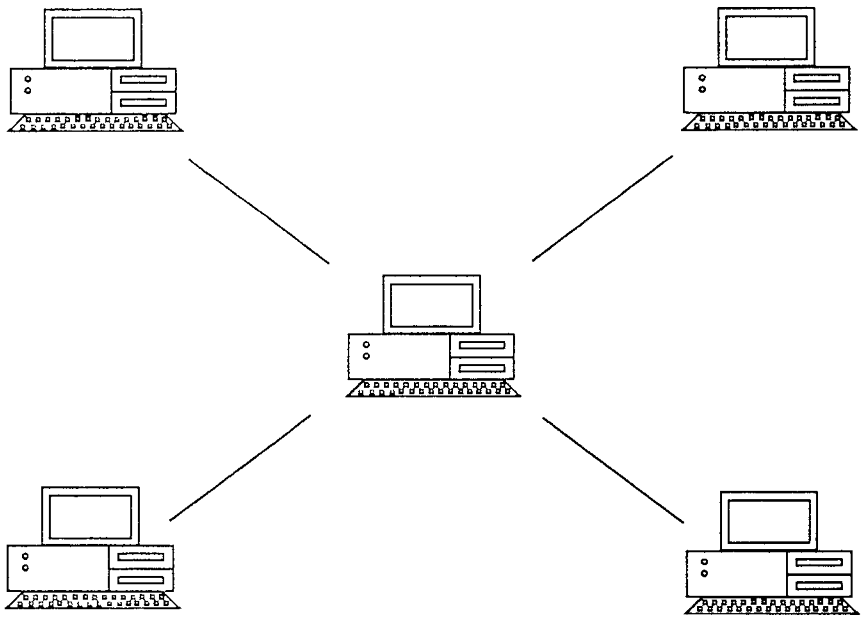
b) Star Topology: The star topology is arranged like a star, with cables extending from the network server cables are not shared; each PC workstation has its own dedicated cable. In this situation, more cables usually must be purchased. This feature also reduces the chance of system failure because a cable fault affects only the workstation attached to that particular cable. (Refer figure 3.1 b).

c) Distributed Star: The distributed star topology connects PC workstations by means of a dedicated cable to a control point. The control point is a connection box called a hub, which is attached to a shared linear cable. Usually, four to eight workstations can be connected to each hub. (Refer figure 3.1 c).

LAN TOPOLOGIES



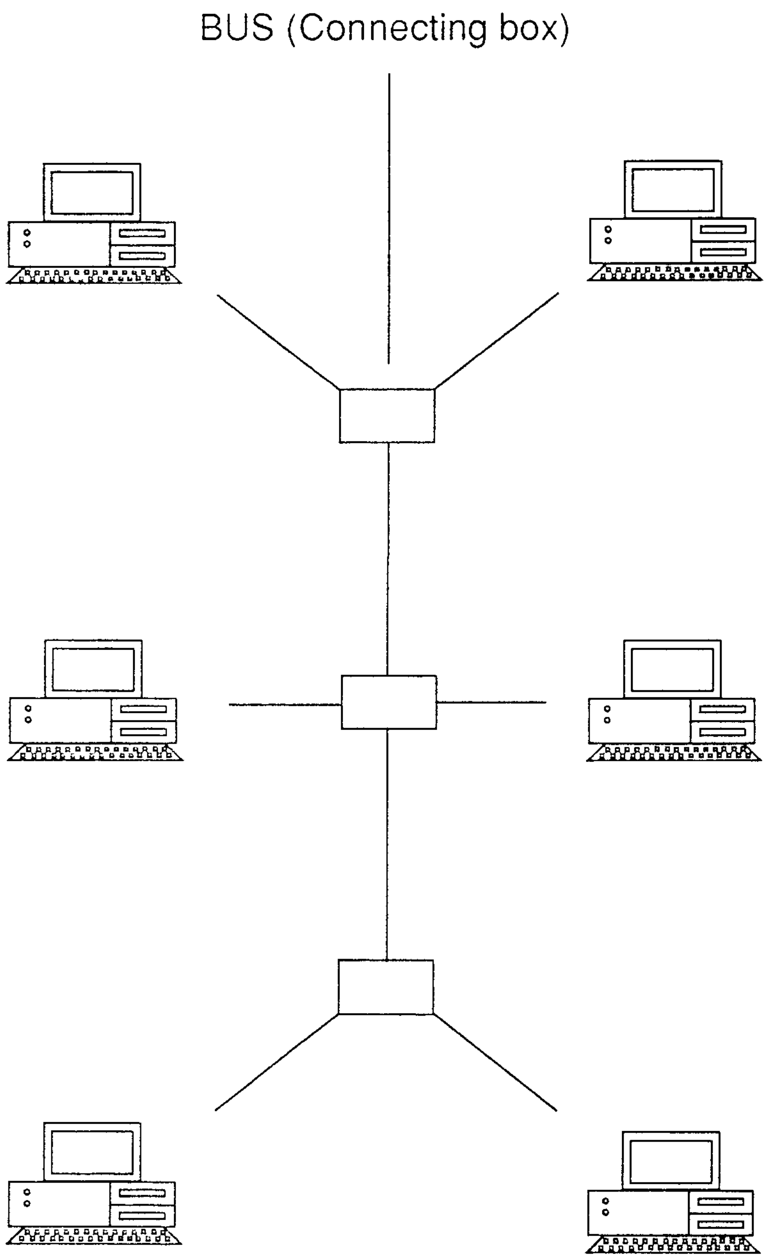
(a) Linear Bus Topology



(b) Star Topology

Fig. 3.2

LAN TOPOLOGIES



(c) Distributed Star Topology

Fig 3 2

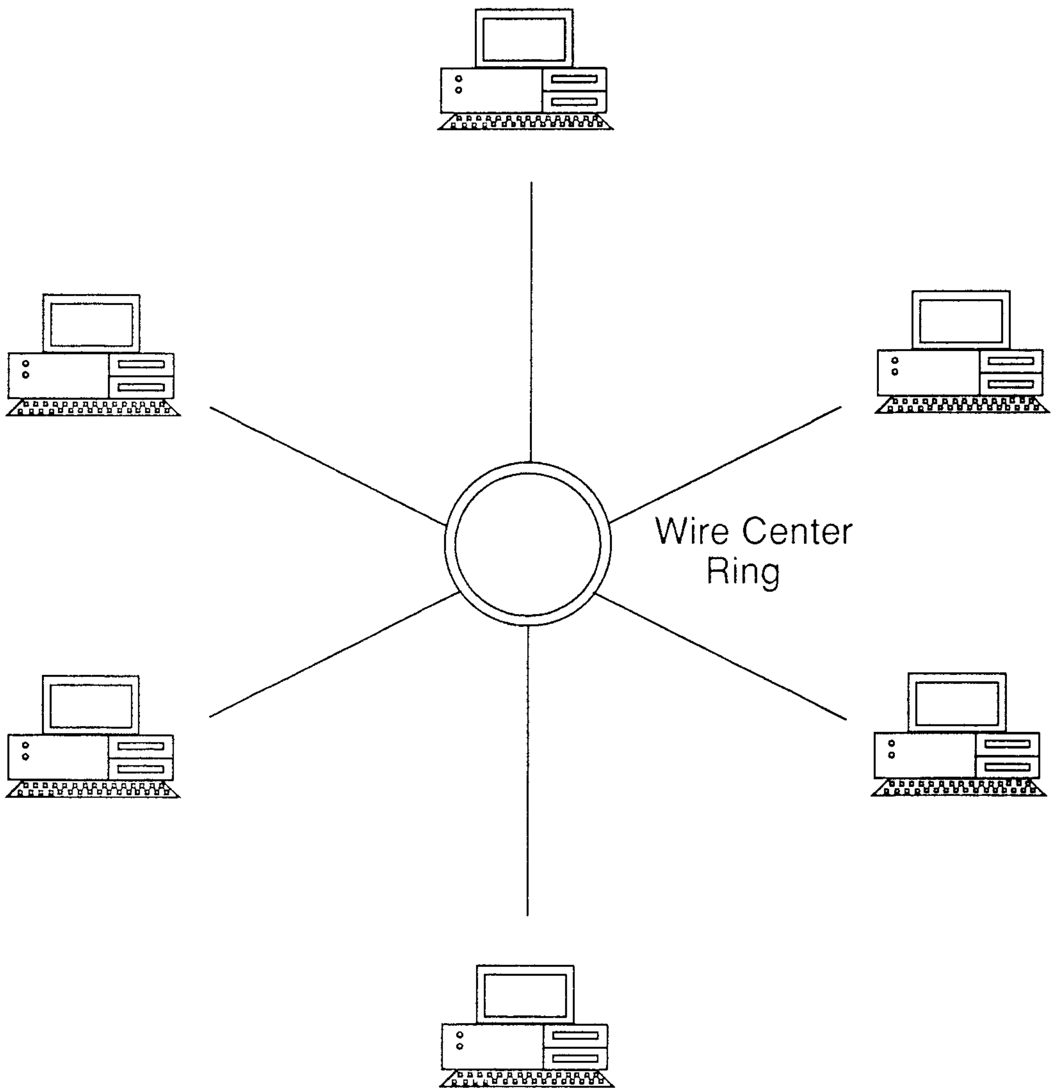
d) Star-Wired Ring Topology: Like the distributed star, this topology uses a combination of shared and dedicated cables. Dedicated cables radiate from a central wiring concentrator. Control messages are passed from workstation to workstation, as in a ring. The ring is a part of the LAN's logical design but is not physically evident. On the other hand, in both the star and distributed star topologies, messages are passed from the central point to the workstations[11]. (Refer figure 3.1 d).

D. CIM STANDARDS

To achieve successful CIM, information must pass freely and reliably between different makes of computers, machinery and equipment. Also, every buyer should give consideration to future upgrades and replacements of integrated systems when new technology appears.

Standards can be viewed at two levels - industry and corporate. Industry standards are adopted by vendors and implemented in the design of their products - software, hardware, machinery and equipments [40]. Corporate standards (beyond the scope of this topic) are adopted by users and implemented in their purchases of vendor equipment and in the specification of their internally developed system.

LAN TOPOLOGIES



(d) Star Wired Ring Topology

Fig 3.2

Industry standards have three specific benefits:

i) Generally lower the cost

ii) Increase options for buyers when installing systems and equipments, and

iii) Simplify the task of systems development and integration

There are many standards being currently like:

1. **MAP/TOP:** Both communication protocols (the protocol is a formal set of rules governing message exchange between computer devices) are the brainchild of GE, based on the Open Systems Interconnection (OSI) model of the International Standard Organization (ISO) and are primarily intended to standardize networking and connections among different computers and computer-driven equipments.

Three layers of protocol are of particular importance to machine-shops (refer Table 3.6). The first layer defines the physical requirements of an interface - the electrical parameters such as: voltage levels, size of wire, numbers of wires, shielding, connector type, and so on. Layer 2 covers the protocol which defines how data is to be formatted, what characters should be used for control of data transmission and what they mean, and what checking procedures should be used. The 7th layer deals with defining what data can be transferred e.g. part program, tool data, probe status etc.

OSI STANDARD LAYERS

ISO LAYER	ISO FUNCTION	PROTOCOL (Standards)
Layer 7 Application	Provides all services directly comprehensible to application programs	ISO ACSE, FTAM, MMS and Directory Services
Layer 6 Presentation	Restructures data to/from standardized format used within the network	ISO Presentation Kernel
Layer 5 Session	Names/addresses translation, access security and synchronize/manage data	ISO Session Kernel
Layer 4 Transport	Provides transparent, for data transfer from end node to end node	ISO Transport Class 4
Layer 3 Network	Performs message routing for data transfer between nodes in the same LAN	ISO Connectionless Network Protocol
Layer 2 Datalink	Provides the means to establish, maintain and release logical data links between systems, transfer data frames between nodes in the same LAN, and detect & correct errors	IEEE 802.2 Class 1/Class 3
Layer 1 Physical	Encodes and physically transfers messages between adjacent nodes	IEEE 802.4 10MB Broadband or 5 MB Carrierband

Table 3.2

2. **Unix:** An operating system (OS) that has been proved favorable in CAD/CAM environment, is highly portable and powerful. It is designed and developed by AT & T. Much recently developed softwares are written for this Operating System.

3. **IGES:** A standard data conversion interface for graphics data, the Initial Graphics Exchange Specification makes possible the transfer of CAD/CAM data among unlike systems. Most CAD/CAM vendors offer an IGES interface, because IGES only exports what is common between the systems, but unfortunately much information basic to manufacturing - such as tolerances is lost in this type of interface.

4. **Parallel Processing:** An approach to CAD/CAM activities that allows all users across an entire CIM network to access part information at the same time while preserving an integrated data base.

5. **BDI:** Business Data Interchange is an emerging standard, developed by ANSI, to facilitate order processing shipping and receiving, invoicing, and payments between separate firms.

CHAPTER 4

IMPLEMENTING CIM SYSTEM IN A SMALL MANUFACTURING ENVIRONMENT

CHAPTER SYNOPSIS

The previous chapters help to prepare a thorough base for CIM system's development. This section deals with a hypothetical case study compiled. This typical small machine shop utilizes CIM technology to take a step in the future. This chapter describes the way in which the organizational structure should be analyzed. Discussed herein is the formation of database for CAD-CAM system, production planning and control and administrative function. There exists a weak link between CAD-CAM and the other database, and therefore the complete integration , especially in the case of small manufacturing environment is not economically justifiably. The goal of this chapter, is to reduce the manufacturing turn-around time by introducing the state of art in a small manufacturing environment.

A. ORGANIZATIONAL STRATEGY

The first step in this process can be described as analyzing the existing organizational and operational structure. The fundamental building block of the new organization involves setting up a CAD/CAM system, eventually resulting into Direct Numerical Control for CNC milling machines. This is particularly instrumental in reducing the time taken for information transfer from drawings to finished product. Some problems in Manufacturing Planning & Control can be dealt with, by computerizing the existing paper based data. A similar line of action can adopted to deal with business function problems. The limitations of forming an isolated database can be overcome by the use of software like FourthShift which not only has modules to store the manufacturing & business function data, but are symbolically linked. Hence change, in data on a module in FourthShift correspondingly updates the related modules. This provides an up-to-date database at any given time.

Further, note that complete integration is not needed in a small manufacturing environment. The only data required by the business function activities, from CADD system is the bill of material. Besides, CAM software database has no significant information to be sent to the business function activities. In other words, there exists a link which is weak. Hence, as observed, there exist two separate islands namely "CAD-CAM" and "Production Planning & Control along with administrative functions". Realizing that there is no significant data required to be transfer between the two islands, it is advisable to avoid complete database integration. Many of these improvements can be in stages of installation and implementation with as little disruption to the manufacturing process as possible.

B. PRE CIM SYSTEM

1. TYPICAL OPERATING PROCEDURE

On sensing the need of a product (usually through an inquiry), quotations are sent to the perspective buyer and kept open for certain period. Administration staff is responsible to prepare the quotes. On approval of the order, every new project is assigned a particular purchase order number (referred to as P.O.#). Products/Machines are generally built based on either the client's design or are designed in-house. In the latter case preliminary design drawings and sketches are prepared by manual drafting techniques. It is the duty of the Chief Engineer to prepare the conceptual design. On being approved by the client, detail drawings are developed by the draftsman under the supervision of the Chief Engineer. With the aid of these drawings, bill of material is prepared by the draftsman.

The necessary mechanical and electrical parts and raw material for machining are ordered, each assigned with an appropriate P.O.#. The only thing common to purchasing process is the P.O. # assigned to the particular project. While awaiting for the material and parts to arrive, shop floor routing and manufacturing methods are decided. The

Manufacturing Planning and Control activities are governed by the administration personnels.

On the arrival of ordered material, it is stacked in the closest available storage area and the receipt invoice is filed in the project file. Manufacturing drawings are sent to the shop for part machining, under the instructions of the administration personnels. As the parts are being machined by machinist, subassemblies are simultaneously being fabricated. These subassemblies are eventually placed together by mechanical assemblymen to realize the complete machine.

It is of utmost importance that every manufacturing company possesses formal procedures of quality control. Normally, a dedicated individual is necessary to execute the quality control procedures. The absence of such an issue leads to lowering of quality value resulting into lot of rework and adversely affects the image of the company.

On completing the mechanical assembly, electrical components are mounted on the machine by electrical assemblymen, under the instruction of the electrical engineer. The finished machine is then tested in the presence of the client or as per the client's specification. The administration personnels also verify the testing of the machine. Finally, after being approved it is partially knocked down and packed to be shipped.

2. INFORMATION FLOW

The flow of information is represented in Figure 4.1. In most small machine shops, main activities are handled by a small group of people, termed as operation management personnels. Decisions for quotation, purchase of material, inventory control, production planning, shop floor monitoring and quality control are taken by the operation management team. The designing of machine, component machining, assembling of components and testing activities are performed by a group of specialists. It is observed that in a small manufacturing environment there is no need for complete information integration, because of its structure and capabilities it posses. Therefore, as indicated in Figure (4.1) dotted lines indicate a weak link between the functions. In other words, there is not much data that flows from the CAD package to the Manufacturing System package. However the CAD has a strong link to CAM. Likewise there is very restricted information that is passed from the machining center back to CAD or to the Manufacturing Systems module. This information can be more efficiently transferred manually.

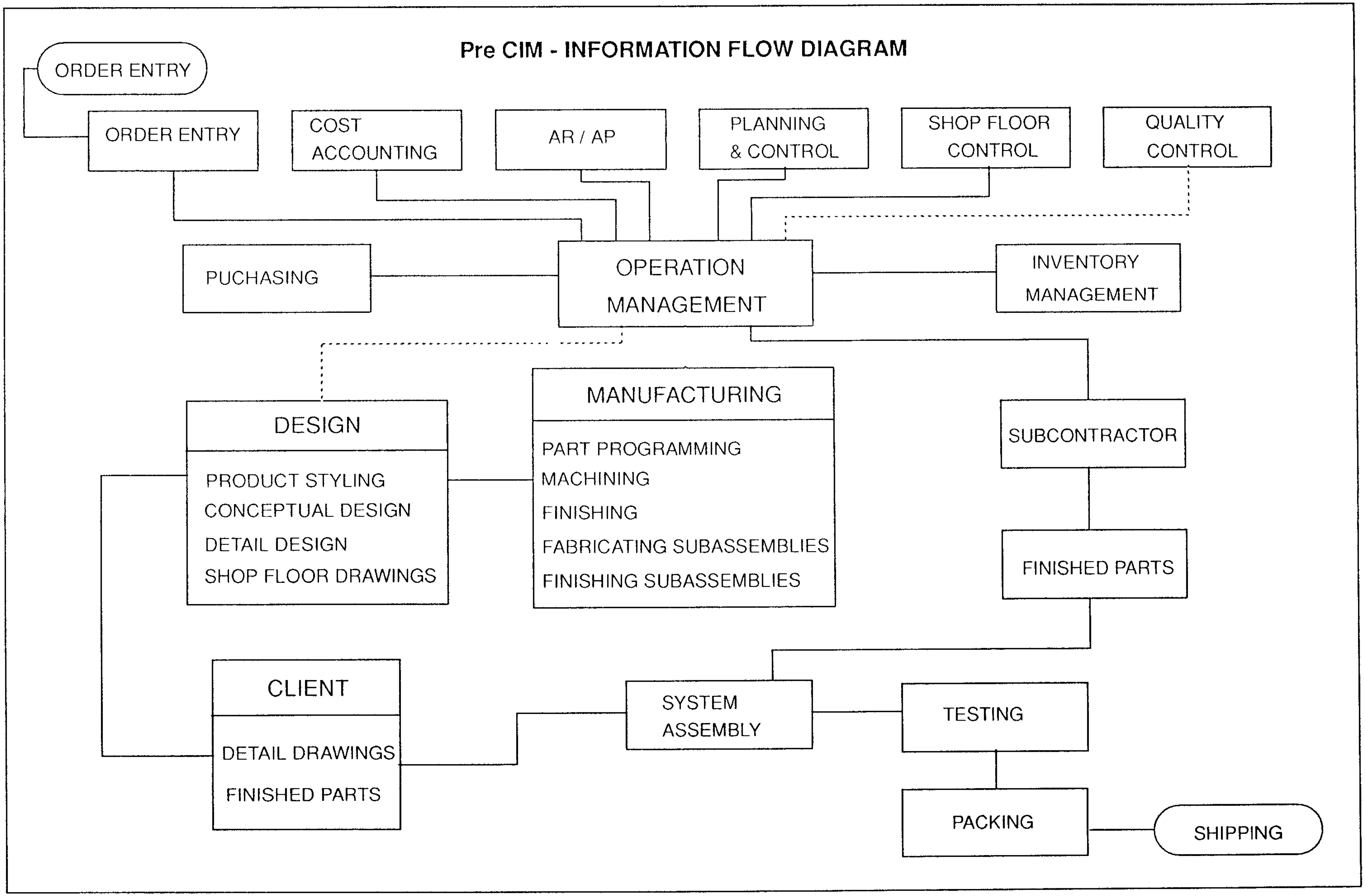

Pre CIM - INFORMATION FLOW DIAGRAM
ORDER ENTRY
ORDER ENTRY
COST ACCOUNTING
AR / AP
PLANNING & CONTROL
SHOP FLOOR CONTROL
QUALITY CONTROL
PUCHASING
OPERATION MANAGEMENT
INVENTORY MANAGEMENT
DESIGN
PRODUCT STYLING
CONCEPTUAL DESIGN
DETAIL DESIGN
SHOP FLOOR DRAWINGS
MANUFACTURING
PART PROGRAMMING
MACHINING
FINISHING
FABRICATING SUBASSEMBLIES
FINISHING SUBASSEMBLIES
SUBCONTRACTOR
FINISHED PARTS
CLIENT
DETAIL DRAWINGS
FINISHED PARTS
SYSTEM ASSEMBLY
TESTING
PACKING
SHIPPING

Fig. 4.1

C. PROBLEM CLASSIFICATION

1. FUNCTIONAL ANALYSIS

In general organizational structure is decomposed into 4 major technical and non-technical business functions.

* Administrative Functions
* Design Engineering
* Manufacturing Planning (includes DNC)
* Manufacturing Control

To understand the future applications and deployment of CIM technology; how the systems within the islands of automation can be integrated functionally and to pinpoint specific areas of maximum opportunity in which technology can be applied to support the business strategy, the above mentioned 4-major areas are broken down into lower level processes or functions. This top-down network also helps to trace the relationship between elements of division and specific elements of the integration process.

2. PROBLEM DEFINITION

Mentioned beneath, is the citation of problems that surround the four major functions in general.

2.1 ADMINISTRATIVE FUNCTIONS

On the receipt of an order, project plan is made by the head of each department for their respective responsibilities. An overall project plan is weakly defined by each department, resulting in failure to link various inter-departmental activities. Eventually, dead line commitments are affected.

Customer order entry and billing is typically a manual process. Though it is not very difficult to execute it the first time, but tracing an order entry or customer's bill for future reference is a tedious job.

2.2 ENGINEERING DESIGN

The process of conceptual design and drafting is manual and therefore time consuming. Modification of any drawing involves unnecessary recalculation and recreating of the model. Often, eventhough the orders are repeated the project has to be started from scratch, which is once again, a waste of time and resource. The preparation of bill of material is a time consuming process. In addition, finding a past bill of material is a difficult proposal in any manual system.

2.3 MANUFACTURING PLANNING

One of the main time consuming activity, is found to be the transfer of complete and correct drawings from the engineering department to the shop floor. Many shop drawings have to be rectified after finding it unsuitable for machining purposes.

Another source of time consumption is the NC part programming. Since there is no facility for even a partial verification of the program, trial runs result in unnecessary man-machine time, material wastage and machine wear.

Material Requirement Planning is another barrier in the path to cut the turn-around time. Re-ordering, poor follow-up of ordered material and misplaced material add to inflate the turn-around time.

2.4 MANUFACTURING CONTROL

In a manual system, it is found that there is insufficient information for follow-up of raw material, in-process and finished good inventory. There exist no feedback records of the materials being used. On realizing the shortage, material is immediately ordered but often it is too late. On the other hand re-ordering of material often occurs. Excess inventory occupies space and adds to unaffordable investment. In-process inventory is normally formulated based on the parts machined per day and not related to the project for which it is to be utilized.

The activity of purchasing and receiving material is executed by many people. No common database is available and so chaos is the end result. This firmly affects the preceding activities of shop floor routing, man-machine

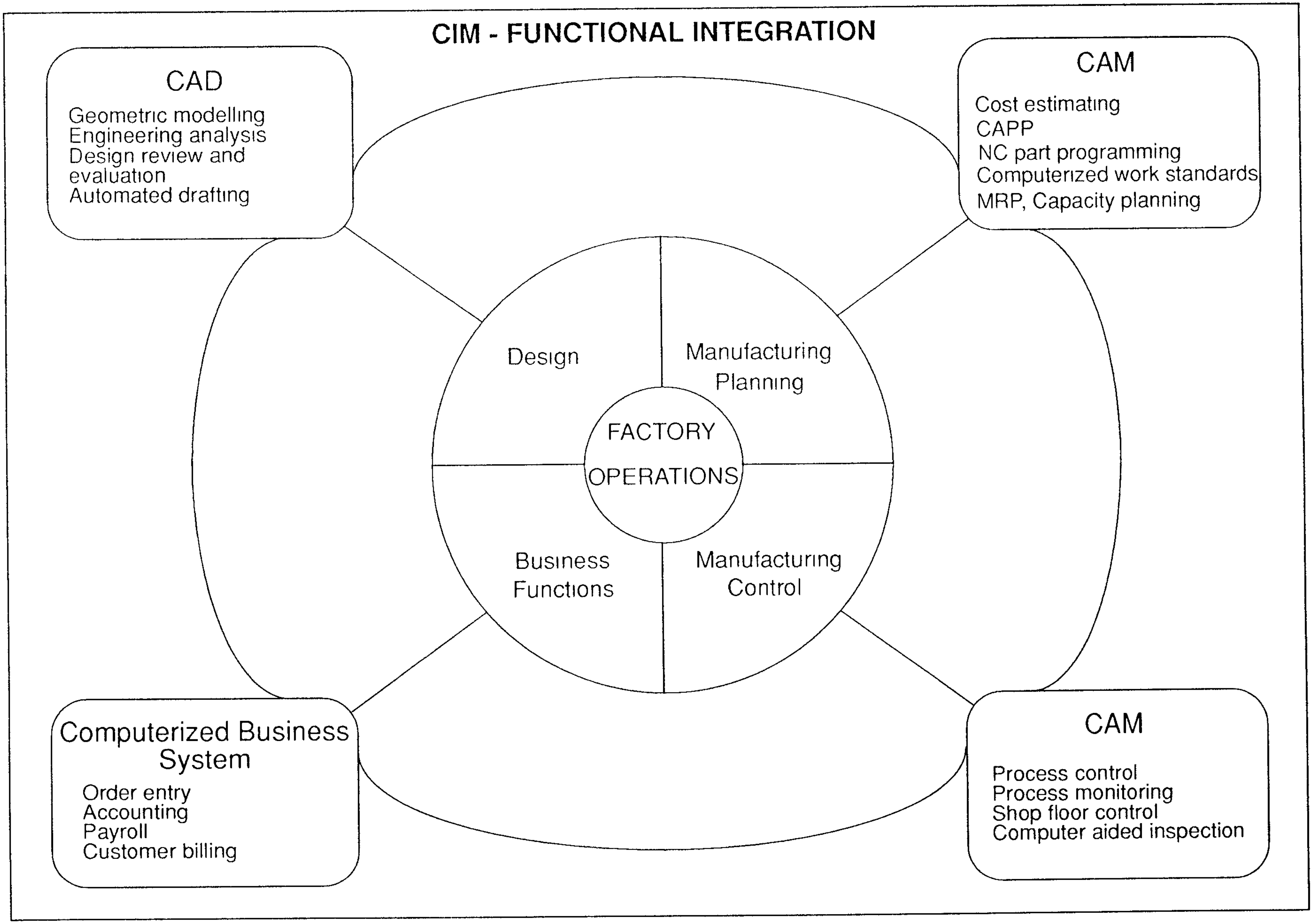

CIM - FUNCTIONAL INTEGRATION
CAD
Geometric modelling
Engineering analysis
Design review and
evaluation
Automated drafting
CAM
Cost estimating
CAPP
NC part programming
Computerized work standards
MRP, Capacity planning
Design
Manufacturing
Planning
FACTORY
OPERATIONS
Business
Functions
Manufacturing
Control
Computerized Business
System
Order entry
Accounting
Payroll
Customer billing
CAM
Process control
Process monitoring
Shop floor control
Computer aided inspection

Fig. 4.2

scheduling, product costing and also reduces the optimum utility of the facility. Also disrupted are assembling, finishing and testing activities.

D. POST CIM SYSTEM

This visualized CIM system applies computer technology to the operational functions and information processing functions in manufacturing from order receipt, through design and production, to product shipment. Unlike large companies, here CIM potential cannot be applied to functions like marketing, facility planning, automated material handling and so on because they are not developed sufficiently.

The components of the integrated computer system, and their relationship to this model of manufacturing is illustrated in Figure 4.3. This figure demonstrates how the various functions of a typical small unit are effectively linked together. Customer orders are initially entered, the customer given an ID number and P.O.# assigned to the order into a computerized order-entry system. The order contains the specifications describing the product and the customer.

New products are designed on a CAD system by the design engineer. The components that comprise the product are designed, the bill of materials is compiled, and the assembly drawings are prepared on the computer by the draftsman. Partial output of the design department serves as the input to manufacturing engineering, where process planning and similar activities are accomplished by the respective personnels, to prepare for production. Output from CAD system serves as an input to CAM system where in machine codes are generated internally to aid the CNC machining, thereby establishing a DNC. Many of these manufacturing engineering activities are supported by the CIM computer system. Process planning is performed using Computer Aided Process Planning (CAPP), NC part programming and NC verification are done on a CAM system by the designer or the CNC machine operator. The output from manufacturing engineering provides the input to production planning and control and the business functions. Figure 4.3 illustrates that the functions of design and manufacturing are closely related to one another. However, the business database is not widely dependent on the design and manufacturing database. The dotted line indicates that common database is not necessary for a successful CIM system in a small manufacturing environment.

The organizational structure can be classified into four regions namely administrative functions, engineering design, manufacturing planning and manufacturing control. The "Post CIM System's" administrative functions include forecasting, scheduling, customer order servicing, inventory management,

Post CIM - DATABASE MANAGEMENT

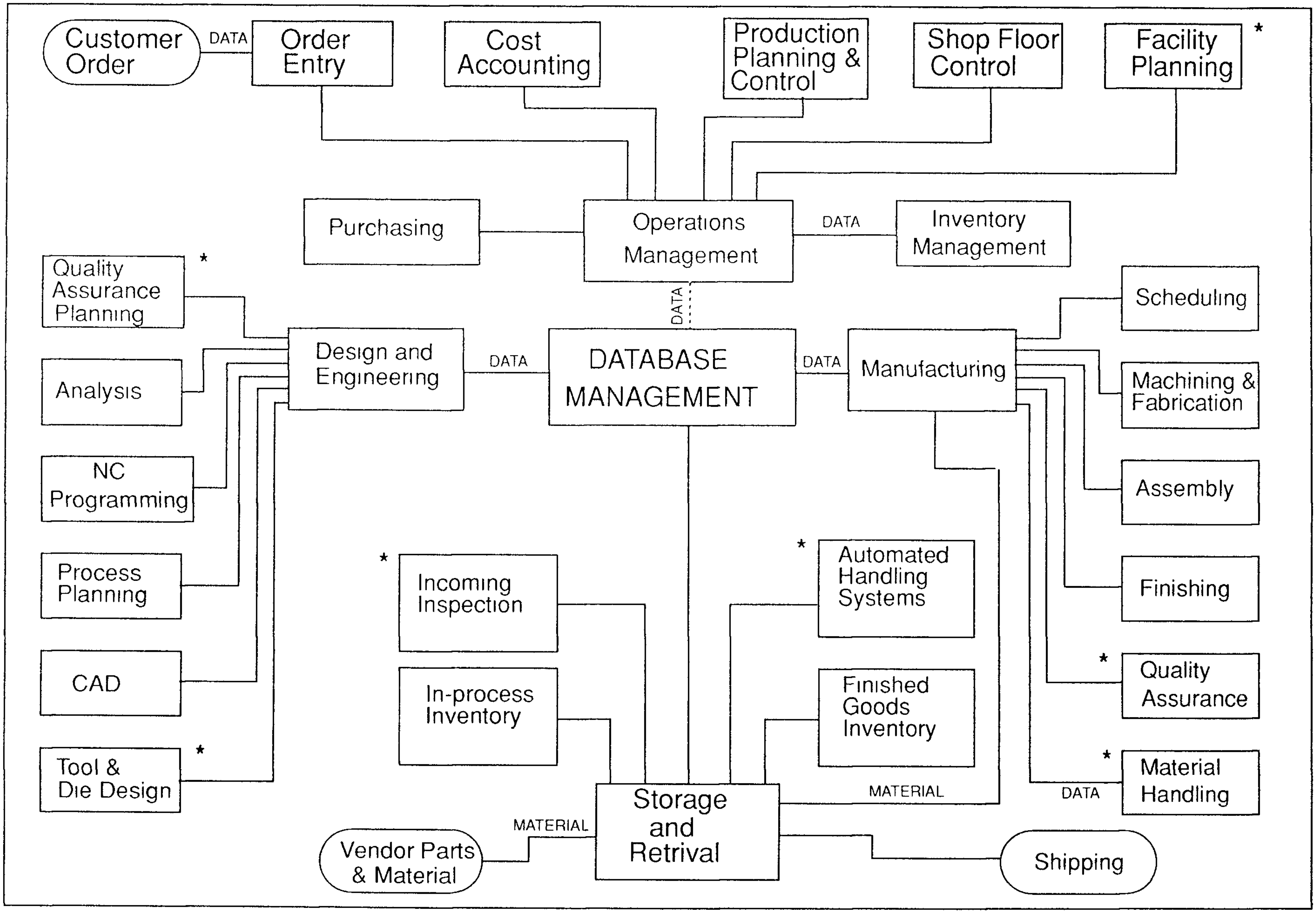


Fig. 4.3 (* - not applicable for small manufacturing units)

purchase order processing, invoicing, and accounting. These activities are normally conducted by the company's administration executives with support from trained staff in the respective field.

The engineering design functions include design and drafting activities, and the use of modeling and simulation to obtain optimal designs without extensive prototyping. In a typical system, the design engineer inputs design concepts into a computer that stores data on models, computes the best design for different options, displays the results for approval, and permits efficient iteration of the process. Such a kind of design process asks for the requirement of a multiuser system. On the approval of the product design the draftsmen take over to develop the detail drawings of the product.

Manufacturing planning covers process planning, materials requirements planning, routing and rating, tool design, and parts programming. An optimized manufacturing process plan is generated by computer on the basis of product design outputs, scheduling and line balance algorithms, and the varying conditions of purchased part deliveries, available resources, product mix and priorities.

Manufacturing control includes shop floor monitoring and process automation. Process automation covers NC, DNC, CNC, and all automatic inspection, assembly and testing methods. In the "Post CIM System", these discrete control systems are partially linked by computers to provide only the required control, feedback, and diagnostic and correction capabilities. In a typical small manufacturing outfit, the function of production planning and control is undertaken by the executive staff.

This is a CIM setup specifically for a small machine shop, handling job type of production. Though a truly integrated system with common database is ideal, it is not effective in the small machine shop due to the nature of information link between various islands (refer Chapter 2 section B). With a weak link between the three major groups namely, CAD-CAM, Manufacturing Planning & Control and Administration function an efficient CIM system is possible.

It should also be noted that this CIM system can be developed using the existing technology. There is no giant additional cost involved in purchasing a turnkey system, or utilizing the expertize of a professional consultant. Therefore, the feedback of such a system may be influenced by the above mentioned constraints, but their impact is tremendous due the benefits of CIM system in such a machine shop.

E. THE SOLUTION

1. SOFTWARE

1.1 SOFTWARE ELEMENTS

1. CAD	-AutoCAD (Release 10.0)/SDRC-Ideas
2. CAM	-SmartCAM (Version 4.5)
3. Manufacturing Systems	-FourthShift
4. Word processor	-MS Word, Word Perfect
5. Miscellaneous	
Corporate aid	-Project, Quattro, HavardGraph

After extensive study and review, of most popular software available in the above mentioned categories, a concise report is prepared. This could become a typical guideline for comparing and then selecting the software, which is best suitable for the application (Refer table 3.2, 3.3, 3.4, 3.5).

1.2 OVERVIEW OF SELECTED SOFTWARE FEATURES

1.2.1 AutoCAD (Release 10.0)

AutoCAD is a general-purpose drafting package with 2D and 3D capabilities. It is widely accepted as an industry standard package. In release 10.0 commands can be executed from screen menus, pull-down menus, icon menus, dialog boxes, and tablet menus. AutoCAD supports all the basic entities in 3D space: lines, arcs, polylines, circles and surfaces. But a surface, bounded by a curve, can only be approximated by a series of line segments.

AutoCAD provides access to symbols through two entity types: blocks and shapes. Blocks are essentially combinations of any other drawing entity. These blocks can be edited by scaling, rotating or exploding. Shapes are not as flexible as blocks, having no provision for attributes. This package is equipped with drawing aids such as Object Snap, Snap, Grid, Axes, Dragging and Rubber banding. A series of inquiry commands provides attribute and location information about all entities. The user-definable coordinate system (UCS) is a feature that allows the user to define the location and rotation about three-axes coordinate. With this the user can locate any point within a 3D drawing, as if carrying an imaginary camera. Pan and zoom are other features. Besides release 10.0 supports viewports to allow display of multiple views on the screen. However, capability to make changes affecting any single viewport does not exist. Also unlike VersaCAD, AutoCAD does not have the capability of the Bill of Material. But, this aspect of the manufacturing process is covered in the Manufacturing Systems software and is not a crucial decision factor.

AutoCAD allows managing multiple subdirectories of drawings, configuration files, and block libraries. Customizing capability is also a very good feature. Using AutoLisp programming language, most third-party support available can be utilized. This package is well documented with a tutorial booklet and installation manual, however examples are very limited. To obtain the full benefit of AutoCAD, customizing the software to suit the need is necessary. There are other CAD packages available, but are not very powerful and flexible to be accepted as industry standard. The AutoCAD DXF output serves as an input to the shape module of the SmartCAM. Note that AutoCAD release 10.0 has DOS operating system, whereas the AutoCAD release 9.0 has Unix operating system. Moreover, the drawings made in release 9.0 can be read in release 10.0 but the reverse is not true. AutoCAD drawings from release 10.0 can be used as database for SmartCAM 4.0 version which is a DOS version. In short, though the AutoCAD drawings cannot be read in a higher version, but they still serve as input to SmartCAM by using a different version.

1.2.2 SmartCAM (Version 4.5)

SmartCAM is a complete CAM system that can increase productivity from design to production. SmartCAM lets you address the entire CNC programming process in single, integrated system - from job planning and documentation to CNC programming, code generation and communications.

JOB PLAN: With SmartCAM, complete job documentation is an integral part of the process. The Job Plan establishes machining parameters and tooling for a particular machine or job. Better documentation helps operators run the job efficiently. It also saves time and cuts costs on re-runs.

SHAPE: In this module, you graphically define and interactively manupulate tool path to get the exact tool motion you need to do the most efficient job. SHAPE automatically defines part geometry and lets you generate machine-specific code at the touch of a key.

CODE GENERATORS: These module defines exactly what code is to be generated and how it is output for your machines. You don't need to compromise or work around the limitations of post processors.

COMMUNICATIONS: The standard communications protocols built into SmartCAM can be used or you can create your own. Tape punches, machine tool controllers and other devices can be directly accessed from SmartCAM's main menu.

SmartCAM supports a wide variety of CNC machines, including mills, lathes, punch presses, burners, flame cutters, laser cutters and EDMs. Custom post-processors are generated using special machine and template files that can be modified by the user to meet individual preferences.

SmartCAM's part geometry and tool path definition capabilities are quite extensive and easy to use. Some of its powerful features are:

a) Roughing and pocketing routines

b) Viewing and plotting of tool path

c) Copy, move, rotate and image functions

d) Good user command facility

e) Cycle time calculation

SmartCAM removes the limitations of programming languages, post processors, and poor integration. SmartCAM automatically performs the funcions typically associated with programming (defining the correct tool part, inserting tool changes where apprepriate, etc.) and establishes a dynamic, graphics database that holds the actual machining sequence. It eliminates the need for extensive procedural planning. It goes beyond CNC programming to let you interact directly with a graphic model of the manufacturing process. SmartCAM's intelligence solves trigonometry problems to define accurate tool path, even when several dimensions are missing from the print. SmartCAM will buffer up to three unsolved elements and display all possible solutions. You pick the one you need.

With SmartCAM's superior visualization capabilities, one can verify tool motion as it actually will occur at the machine tool - before one generates the code. The screen display always represents the machining parameters you set in the JOB PLAN and the Code Generator you selected, plus the current tool path. Functions like interactive viewing, selective masking and layers help you identify the most effecient machining sequences and find innovative ways to save time, cut manufacturing costs.

The tool path generation process in SmartCAM is not as easy as other drafting package. The greatest advantage of SmartCAM lies in CAM Connections, which is an optional package that translates CAD drawing files (DXF files) into tool path for use with SmartCAM. CAM connection automatically organizes and orders points, lines, and arcs from the drawing into tool paths. This information can then be graphically edited in SmartCAM prior to generating CNC code. CAM Connection is available for a variety of CAD software packages like AutoCAD, VersaCAD etc.

1.2.3 MANUFACTURING SYSTEMS SOFTWARE (FOURTHSHIFT)

This is a software that covers the entire range of manufacturing activities and meets most industry standards. It is divided into various modules that interface into each other. Changes made on one module automatically updates the other unless specified. Though the structure of the system is difficult to remember, it is easy to learn, particularly because of the extensive training session, good documentation and on line help. This package can be customized under certain limitations. The most vital feature of this package is its database manager, which provides flexibility and efficiency to accommodate greater amount of data as the need grows. It can also import data from some other software.

The inventory module is used to maintain item information and inventory balances by location. The bill of material screen helps to provide the structured (single and multiple level) information for all items used in the manufacturing of machines. Order entries are also easy to make. Options to procure material, create and manage purchase orders and record receipt are available. The material requirement planning module calculates and maintains an optimum manufacturing plan to keep the supplies and demand in balance. Above all, the manufacturing order manager helps to create orders, check shortages, generates pick-list and issues component, report labour and tracks and receives orders.

The recommended hardware and software requirements for operating the FourthShift Manufacturing software are:

a) 640Kb of primary memory

b) One fixed disk with a minimum of 10MB storage capacity,20Mb recommended

c) One dual-sided diskette drive

d) One color monitor or monochrome monitor

e) One printer and related connectors

f) DOS Version 3.0 or higher

The optional hardware and software requirements are:

g) Take backup unit to speed the creation of backup copies of the database.

h) Uninterruptable power supply (UPS) to protect against power outrage.

i) Letter quality printer to print documents.

j) Modem and communication to enhance the capability of data transfer with outside world.

k) Print spooler to increase the throughput of printing task.

Since the Manufacturing Systems softwares are beginning to be introduced in the market, none of them have an effective connection with the CAD-CAM link. Therefore, the bill of material generated by CAD package cannot serve as a direct input to the MRP module. Inputs have to be done manually.

Report : CAE Software

SYSTEM NAME	OPERATING SYSTEM	SYSTEMS CHARACTERISTICS	NETWORK SUPPORTED	FEATURES	SUPPORTED STANDRADS	REMARKS	PRICE
Anvil 5000	Hardware dependent	Digital VAX, Apollo HP 9000, Sun, IBM 5080, Prime 50 Series	Ethernet, DECnet, Others	2-D/3-D rotation. Mirroring, 3-D graphics, Solid Modelling, Rubber banding, windowing, third party library	IGES ANSI BSI ISO	Other modules are: 3-D design, drafting, Surface modelling, Omni solids, Omnifem, Numerical control, 5-Axis numerical control machining	$500 per Workstation
I-DEAS (SDRC)	MVS/TSO VM/CMS AEGIS, Sun/OS HP-UX VMS	IBM, Apollo, GE Calma, Sun HP Silicon graphics	Ethernet	3-D graphics, solid modelling, shading, zooming, shadowing, panning, user defined library	ANSI ISO Ethernet Unix	Other modules are: Geomod, Geodraw, Supertab(FEM), design, Mechanism Frame analysis	$20,000 to $75,000
CADAM	VMS, VMS/XA AIX DOS	IBM 9300, 308x, 3090 9370, 5080, RT PC, PS 2	---	3-D isometric view, 3-D graphics, solid modelling, graphics database management, mirroring, zooming, panning, rotation, layering,	IGES	Other modules are: 3-D Interactive geometry interface, 3-D Mesh/FEM Numerical control PCB design, 3-D piping	$20,00 to $40,000
EUCLID	VMS VM	Digital VAX, IBM	---	2-D/3-D graphics, solid modelling, shadowing, mirroring, rotation, view ports, shading	IGES	Integration with MRP and NC machining $150,000	$26,000 to

Table 3.3

Report : CADD Software

PC CAD PACKAGES	OPERATING SYSTEM	REQUIRED HARDWARE	MAJOR FEATURES	SUPPORTED FORMATS	COST OF PACKAGE	ADD-ON PACKAGES	COST OF ADD-ONs
AutoCAD Rel. 10	MS DOS (2.0 or later)	PC/XT, PC/AT or PS/2 640K RAM, Intel 8087, 80287 or 80387 coprocessor 10MB hard drive, RS-232 serial port, parallel port, Mouse, and digitizer	2D drafting, 3D modelling, ADI Advanced user interface, third party support	DXF IGES	$2500	AutoShade AutoFlix Architectural Autosolid	$500 to $1000
CADKEY Rel. 3 12	MS DOS (2.0 or later)	PC/AT or higher 640K RAM, Intel 80287 or 80387 coprocessor, 3.5MB or more hard drive, parallel port, mouse, and digitizer Hardware lock	2D drafting, 3D modelling CADKEY solids CADKEY 3$^+$(memory extender), third party support	DXF IGES	$3000	CADKEY solids IGES(advanced) IGES(basic) Solid synthesis CADKEY 3$^+$	
CADVANCE Rel. 3.0	MS DOS (2.0 or later)	PC/XT, PC/AT or PS/2 640K RAM, Intel 8087, 80287 or 80387 coprocessor Floppy drive, serial and parallel ports, mouse, digitizer, & hardware lock	2D drafting, 3D modelling, Tow-way link to DbaseIII, Visual guidance system	DXF IGES	$2600	DXF Translator IGES Translator	$150 $750
VersaCAD Rel. 5.4	MS DOS (2.0 or later)	PC/XT, PC/AT or PS/2, 640K RAM, Intel 8087, 80287 or 80387 coprocessor, 20MB hard drive, floppy drive, serial port, mouse and digitizer	2D drafting, 3D modelling, Bill of Material, Mass properties calculation, Third party support	DXF IGES VLINK	$2600	VersaCAD Mech. experts series, Symbol libraries (electrical, hydraulic, and mapping)	$100 to $190

Table 3.4

Report : CAM Software

PC CAM PACKAGES	MACHINE AXIS	TYPE OF MACHINES SUPPORTED	CAD PACKAGE LINK	TYPE OF CAD/CAM LINK	PRICE
NC Programmer	2 1/2	Milling, turning, punching profiling	AutoCAD	DXF	$2000
I-CAM	2 1/2	Turning, milling	AutoCAD, Cadkey, VersaCAD, RoboCAD Generic CADD		$750
SmartCAM	3	Milling, turning, punching, profiling	AutoCAD, Cadkey VersaCAD, I-DEAS Anvil 1000MD	DXF	$5000
CIMMPLICITY	3	Milling, turning	AutoCAD	DXF IGES	$9000
NICAM I NICAM V	2 1/2 5	Turning, punching cutting, profiling	AutoCAD, Cadkey, Anvil 1000MD, Micro CADAM	IGES	$5000 $6000

Table 3.5

Report : Manufacturing Systems Software

PRODUCT	OPERATING SYSTEM	REQUIRED HARDWARE	NETWORK FACILITY	MAJOR FEATURES	MODULES AND ADD-ONs	PRICE
MYTE MYKE IQ	PC-MS DOS UNIX	PC/XT, PC/AT or PS/2 640K RAM, floppy drive, 20MB or more hard drive serial & parallel ports, mouse	Novell IBM PC & Token Ring	File export to DbaseIII & LOTUS, userfreindly, fast computation, histogram, bar graph, complex math calculator	Foundation, General ledger, accounts payable & receivable order entry, billing, purchasing, sales analysis, inventory control production forecast, MRP, shop floor control, manpower planning	$14,000
FOURTH SHIFT	PC-MS DOS	PC/XT, PC/AT, or PS/2 640K RAM, 8MHz or faster coprocessor, 20MB hard drive, monochrome color monitor, printer, network interface card	Propritary LAN module	Has industry standard On-line inquiry & printing user interface, database manager for more flexibility and efficiency, file export/ import to/from DbaseIII & LOTUS, easy to customise	System control, inventory control bill of materials, product costing, MRP,order entry, manufacturing order management, general ledger, payroll connection, data export/import, accounts payable & receivable, management reports Multi-user LAN	---
MCBA	PC-MS DOS UNIX system in RM/COBOL	---	---	User interface, very flexible- can be customized, integrated system, reliable for multi-user environment, menu driven, operates on variety of environment	Bill of materials, capacity require- ments planning, job costing, labor performance, master scheduling, shop floor control, accounting and distribution package	
'FACTS' from 'Interdiscipline Consultants, Inc.						

Table 3.6

2. HARDWARE

2.1 HARDWARE ELEMENTS

1.	Technical Workstation	-	Sun 386i
2.	Microcomputer	-	Personal Computer based on an Intel 80386 processor with hard drive

2.1.1 TECHNICAL WORKSTATION :

MAKE : Sun 386i

WORKSTATION TYPE : Personal Workstation

WORKSTATION CHARACTERISTICS :

Processor Type: Intel 80386

CPU Clock Speed, MHz: 25

MIPS: 5

Floating-Point Co-Processor: Intel 80387

IBM PC AT Co-Processor: 4 AT/XT bus slots.

Main Memory, bytes: 8M

Mass Storage, bytes: 320M

I/O Devices Supported: Cartridge tape, mouse, printers, plotters.

DISPLAY CHARACTERISTICS

Monitor Size, inches: 19

Resolution, pixel: 1152-by-900

Refresh Rate, Hz: 66

Grayscale: No

SYSTEMS SOFTWARE

Operating System: SunOS (Unix), MS-DOS

Multiple Window Management: Yes

Graphics Libraries: GKS

Database Management System: SunIngres

Graphics Software Supported: SunCore

2.2 JUSTIFICATION OF SELECTED HARDWARE

The choice of a Sun Workstation was made because of it's open systems approach. This approach is built upon the base of enhanced UNIX operating environment and covers networking, data communications, standard graphics packages, database management systems, programming languages and office automation tools. In addition, PC compatibility products like PC-NFS connects the Sun 386i to personal computers. The Network File System (NFS) provides transparent file access to remote file systems, as well as access to all computing resources on the networking. By transparently sharing files, designers can share files with manufacturing engineers working on the CNC machines, while maintaining data integrity and reducing storage requirement. Besides 386i's comprehensive data communications products enable its workstations to communicate over a variety of physical media using several industry-standard networking protocols, such as DECnet, SNA, TCP/IP and MAP/TOP. This helps the user to download or upload information from their client's or vendor's network.

Also Sun's own software offerings, more than 1,100 software and hardware products, from over 450 companies are available through the catalyst [15]. This helps to support many CIM applications.

The SUN terminal can be equipped with AutoCAD, SDRC-Ideas and SmartCAM which are both powerful Unix based software and are used for developing detail and manufacturing drawings, which are used to generate the NC part program. This part program when transmitted to the CNC machine via standard serial RS-232-C link on the terminal itself, saves immense time from making a drawing to producing a part. In short, for its price Sun 386i is an appropriate machine for the applications.

A PC, based on Intel 80386 processor is also a powerful machine for its price. This machine can be connected to a network using an Ethernet board. However, every buyer should verify a three digit code, located on front-left of the mother board, engraved in a white background. This code should be D7 or later version. The mother boards, having code less than D7 are not equipped to be networked, using Ethernet. Transmission and reception of data from the machine on the network are comparatively quick. Using a color monitor (800-by-560 resolution) one can easily run graphics application on the monitors.

F. IMPLEMENTING THE SOLUTION

The issue of implementing the solution using the CIM system is enlightened with the aid of a component machining illustration.

The basic design and analysis of the component is typically executed by Design Engineer using the capabilities of the solid modeler named IDEAS from SDRC. For the ease of understanding the system it is classified into two broad categories:

1. Administrative Category:

The administration uses Fourthshift software (manufacturing system software) to execute business and production planning functions. On receipt of the order for manufacturing of this component, a unique customer order number (CO #) are assigned. Details pertaining to the order and customer is specified on Customer Master List for each new customer. Bill of material is entered in the Bill of material module, representing a tree structure of parent-child relationship of all components. Depending on the order quantity, material and tooling requirements are decided. An Item Master is prepared, which contains information about raw materials, tooling and resources (man hours and machine hours). Raw material and tool inventory is checked for availability. If there is any scarcity, a purchase order is prepared to replenish the necessary items. On reciept of the ordered material, relavent information is logged in the computer, along with the location of stored item. When all the required items are available, the manufacturing order is released, accompanied by engineering drawing, and picklist showing locations of the items. The corresponding machine codes are downloaded to the CNC machines through the network. A master schedule is maintained to indicate the job finish date, quantity to be manufactured, lead time, lot size to be machined and inspection lead time. The finished components are moved to the finished product store location. The shipping details are prepared along with the shipping picklist. Thereafter, the component is shipped to the customer.

2. Engineering Category:

Simultaneously, the detail drawings are prepared on a CADD system, so that they are readily available for future modification and also serve as ready manufacturing database. The part is broken down, based on the machining operation to be executed on it. Normally, profile geometry to be machined alike are made to reside on a single layer. For the illustrative component, the upper side is turned, while the bottom is milled. The turning geometry is located on layer 1, whereas a part of the milling geometry is located on layer 2. A DXF file of the choosen layer is prepared.

A few important tips for preparing drawing in AutoCAD meant to be shipped to SmartCAM are as follows:

a) The numeric data should be accurate.

b) Part information should be to the scale.

c) Notes and dimension should be located on a separate layer from the profile layer.

d) Avoid duplicate or overlapping drawing entities.

e) See the drawing tolerances match manufacturing practices.

f) All closed profiles in the CAD drawing will have counter clockwise direction in the CAM.

Using the Cam connection module of SmartCAM read the DXF files in the shape module. The geometry from AutoCAD, now acts as part profile in SmartCAM. Two separate files, one for lathe and the other for milling are prepared. Selection of appropriate tools and the corresponding part profile the part program is generated. Also appropriate postprocessors are utilized to develop the machine codes.

It is important that the SmartCAM software offers the option of creating a new or modified postprocessore (code generator). The postprocessor used to translate geometric data into machine code consists of two parts, the template file and the machine file. The template file sets the structure of the postprocessor. It consists of certain sections like START, END, TOOLCHANGE, LINE, ARC, etc. Each section can be defined individually by using word, literals, and conditionals. The word are predefined and produce a certain output or control the output. The words are followed by specific machine code (literals) which enables the machine to do the task. They are used as variables for positioning, spindle control, feed data, etc. The words can be used as conditionals, meaning that the template word will be only output if the conditions has to be changed. Leterals will be output exactly as they appear in the template section. Each time the postprocessor is generating machine code the template sections are scanned.

The machine file is the second part of the postprocessor. It controls the content and the format of each template word. Block number control, units and axis orientation, feeds, speeds, dwell, tool change, rapid positioning, linear profile moves, circular arc profile moves, profile contouring, cutter compensation, and cycle time are defined giving the machine command words (G and M codes) to the file. The smallest increment in which the machine can be commanded to meve is entered in the file. While defining the machine file, the software is working through a menu asking for each machine command or data.

These G and M codes are sent to the respective late or milling machine and the component is machined.

G. NECESSARY CIM SKILLS

The CIM engineer is working with computers, thus must be familiar with the hardware architecture and the way software projects are designed, coded, maintained and documented. The CIM engineer should have the ability to describe, define and analyze different computer integrated models as a system by specifying its components and their functional relationship. The understanding of the operating system such as DOS and Unix plays an important role in hand shaking of peripherals and networking procedure.

In addition, engineering knowledge is also of prime importance to understand the capability and limitations of various commercial software and the methodology to incorporate it into the existing system. An understanding of the mechanical process governing the company is of utmost importance along with reasonable communication and inter-personnel skills.

In addition, a CIM engineer must have the ability to perform an economic and time analysis, based on known facts and information which is not available, but can be obtained by simulation.

In general, he/she must not only be technically or computer oriented but possess enough managerial talent to get the company personnels committed to the project to make the system a successful proposal.

H. CHECKLIST FOR CIM IMPLEMENTATION

The following items are designed to simulate thought and they act as a check list in developing a strategy and implementation program for CIM in a small manufacturing enterprise:

1) Define the business strategy and goals
2) Make a detailed feasibility study. It should include an analysis of every activity, its inter-relationship and their influence on the overall operation of the company.
3) Based of this study, a tentative report stating the likely areas to be automated, the cost involved, duration of implementation, projected tangible and intangible benefits and the necessary resources required, should be developed
4) Approval of top management official and the personnels involved is necessary to seek their co-operation in making the system successful.
5) Thorough market survey of hardware and software component from the point of view of CIM system is required before making the choice.
6) Phase wise implementation of hardware and software components.
7) Network the influenced areas

8) Training of personnels involved in their respective areas

9) Constantly review and update the system.

This is just a guide and not an exhaustive list. Each company will have to develop its own set of items to address.

CHAPTER 5

CONCLUSION

CHAPTER SYNOPSIS

CIM is a journey and not a destination. The development of a CIM system for a small machine shop is a slow and steady process, wherein a revolutionary marriage of the old and new technology has to be established. With the vast variety of available technology and the enormous rate of development of computer technology makes the correct choice a task. The major barrier in this process is the handshaking (interfacing) of various technologies.

It is very difficult to analyze the benefits of the system while it is still in the phase of implementation. A quantitative approach, is therefore, not feasible at this stage. In this chapter an effort is made to reflect the outcome of the CIM system supported by an illustration.

The applicability of the CIM system is very broad, however some of the most influential areas are discussed to demonstrate the systems power.

Drafting function can be very convenient now, with the development of libraries for pneumatic, hydraulic, mechanical and electrical symbols. Clients can now communicate their drafting data electronically. The simulation of tool path for components to be machined is an important feature to determine the tool movement, cycle-time and tool collision with jig, fixture or other machine component. This feature can help to considerably reduce trial runs, in virtue of which man-machine time utilization can be increased, material utilization and machine wear could be minimized. Workstations with window facility can expidite the process of working on several projects at the same time, while the other projects are being executed in background.

Some other fringe benefits which could be realized from this type of CIM system include the development of solid marketing tools like manuals, presentation transparencies, charts and graphics representation material etc. and timely follow up of possible future projects using the computer database.

All in all the Computer Integrated Manufacturing set up can improve product quality and reliability, product quantity with considerable reduction in cost and turn-around time.

APPENDIX A

LIST OF COMMONLY USED ABBREVIATIONS

APT	Automatically Programmed Tool
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Process Planning
CASA	Computer and Automated Systems Association
CIM	Computer Integrated Manufacturing
CNC	Computer Numerical Control
DMA	Direct Memory Access
DNC	Direct Numerical Control
EDM	Electro Discharge Machining
FMS	Flexible Manufacturing System
GT	Group Technology
ICAM	Integrated Computer Aided Manufacturing
ISO	International Standard Organization
JIT	Just-In Time
LAN	Local Area Network
MAP	Manufacturing Automation Protocol
MIPS	Million Instructions Per Second
MRP	Material Requirement Planning
NC	Numerical Control
NFS	Network File System
OSI	Open Systems Interconnection
RAM	Random Access Memory
RISC	Reduced Instruction Set Computer
TOP	Technical Office Protocol

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