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COMPUTER INTERGRATED MANUFACTURING:

Concepts, Technologies, and Strategy for Implementation

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ABSTRACT

Today, the most critical problem facing U.S. industry is the decline in their companies' competitiveness in both the domestic and international markets. To overcome this problem, many companies are investigating the implementation of Computer Integrated Manufacturing, CIM.

CIM implementation has many benefits. A National Research Council study showed that the benefits obtained from partial implementation of CIM can include productivity increase between 40% to 70%; manufacturing lead time reductions of 30% to 60%; and engineering cost reduction of 15% to 30%. Further benefits can be expected as full integration is approached. The benefits achievable are depend upon the company.

While CIM is a important concept which promises many benefits, it has not been fully realized, any where in the world. At present, only rudimentary integration between the various islands of automation exist. Today, many technical and organizational challenges to CIM implementation remain. Of these technical challenges, the development of the supporting technologies is the most important.

There are four basic supporting technologies which allow for the establishment and control of communication

networks. They are Network topology, Communication protocol, Network control, and Data base systems. Due to the importance of these four basic technologies, they are examined in detail. This thesis will cover the basic concepts, approaches, and implementation issues of each supporting technology.

Aside from the basic network topology configurations, the different transmission technologies and transmission media will also be covered.

The description of the OSI Reference Model, and the General Motors Manufacturing Automation Protocol are the key elements covered in the Communication Protocol chapter.

The Network Control chapter compares the advantages and disadvantages of the following control strategies: Host, distributed, and the National Bureau of Standard's Hierarchical Control Architecture.

In the Data Base Systems chapter, the different system architectures are compared and their suitability in a CIM environment examined.

To complete the examination of the four basic technologies, selection and implementation criteria for each technology are described. A basic CIM implementation plan is also suggested, along with a description of the work which still remains (to be done by those who follow).

CHAPTER 1 - INTRODUCTION TO CIM

In recent years, the word "CIM" has become very popular. Many articles have been written on the subject. And recently, new publication have been established to cover the developments in "CIM" and other related technologies. Although the "CIM" is now the buzzword of industry, many people have a false understanding of "CIM". In this chapter, the basic concepts of "CIM" will be introduced.

CIM DEFINED

CIM is an acronym standing for Computer Integrated Manufacturing, and what it means varies from individual to individual, and company to company. Since there are many definitions of CIM, it will be defined as the following for this thesis:

CIM is the application of computer, communication, and data base technologies to integrate the various activities of manufacturing into a single smoothly operating system.

VIEW POINTS OF CIM

While defining the word CIM, provides some insight into what CIM is all about, it is insufficient for a detailed understanding of CIM. Is CIM a system, a program, a philosophy, or a concept? The answer is, "It depends upon your point of view".

There are three widely different viewpoints of what CIM is within a manufacturing enterprise. They are the user viewpoint - demand for information, the technology viewpoint - supply of information, and the enterprise viewpoint - economics and benefits.(2)

The user viewpoint of CIM is based on his/her need to collect, process, and utilize the necessary data to allow for efficient operations of the manufacturing facility in a dynamic and competitive market place. This viewpoint has resulted in the demand and installation of various types of automated/computerized systems, such as CAD (computer assisted design), CAM (computer assisted manufacturing), MRP (material requirements planning), CNC (computer numerical control), SQC (statistical quality control), FMS (flexible manufacturing system), etc.. In effect, the user viewpoint of CIM concentrates on the various components of CIM able to help the user improve his/her ability to manage corporate assets. The viewpoint in the past has, unfortunately, been less concerned with integration than with new technologies. In fact, the introduction of new technologies have also been know to alter the user's viewpoint.

While the user viewpoint is concerned with increasing productivity, it is narrowly focused. No consideration is generally given to understanding of how these various technologies interrelate in a manufacturing enterprise.

The technology viewpoint examines CIM based on the technical problems associated with communicating, storing, and utilizing the information necessary to operate a manufacturing facility. It is the viewpoint adopted by most hardware and software vendors, and most universities.

With this viewpoint, CIM is a system composed of a communication network linking various computer components together, a data base management system (DBMS), and various application programs. It is the technological view of CIM which has lead some managers to wrongly believe that CIM is a product which can be purchased.

Both the technological and user viewpoints play a very important role in the evolution of CIM. The user's views identifies the problem areas which needs to be addressed by technology, thus promoting vendors to produce products to meet the needs of the users. The technological viewpoint allows the engineering and scientific community to identify and focus on the various barriers of CIM implementation.

While the two viewpoints, user and technology, are important in achieving CIM, they are not adequate in describing what CIM is. The user viewpoint identifies the needs, and the technology viewpoint provides the solutions. It is the enterprise viewpoint which uses the products of the two previous viewpoints in an efficient manner.

The enterprise viewpoint identifies the fact that CIM is a management issue and not purely a technical issue. In other words, for CIM to become a reality, it must first become a management style. Integration occurs because automation projects are executed from a purposeful plan, by organized and trained people working within specific business standards. It cannot be brought. CIM is a strategic plan which must be defined, funded, managed, and coordinated by people. If the people are not willing to undertake the task of implementing CIM, it will not occur. CIM, therefore, must be a management philosophy and not a turnkey computer product.

COMPONENTS OF CIM

Computer Integrated Manufacturing is a very broad and general term. It is used to describe a manufacturing system created by the interconnection of the various manufacturing activities. The process of interconnecting the various manufacturing activities require many components of computer, communication, and data base technologies along with various application software. It is these sub-systems to which the phrase, CIM components refer to.

The process of implementing CIM is like building a house. First the foundation is set, then the rest of the parts of the house are placed on top of the foundation in an orderly manner until the entire house is constructed. In CIM, the foundation is composed of the supporting CIM technologies, and the company's organization. Of the different supporting CIM technologies, a good and sound data base is the most important component of CIM. The disk storage requirements of an averaged sized manufacturing plant, have been placed at 100 trillion bytes, by one estimate.(13) This type of data storage requirement illustrates the importance and complexity of trying to manipulate and control such vast amounts of information. Another problem with data base management occurs at the presentation level. While the data most often shared in manufacturing is product and process data, various people and equipment requires and/or desires the data to be presented in different formats in order for the data to be meaningful. The same data format problem occurs when people and equipments are entering information into the data base.

The next component of CIM has to do with communications. Different vendors produce equipments which are unable to communicate. A communication network must therefore be developed. Connecting the various vendor equipment together to allow for the exchange of data, however, will not solve the communications problem. A method of translating the data from one vendor format to another vendor format is required before meaningful data exchange can be accomplished. The communications problem, can therefore, be divided into two components. The first component is the communications network. The network is only concerned with the physical link, and the accurate transmission of data from one device to another. The other component is the protocol converter. This component will typically be an application software, rather than a piece of hardware equipment. The protocol converter will provide the necessary data format conversion to allow for meaningful exchange of data between different devices. The other components of CIM are related to specific applications and functions. The following is a list of some of them: Computer Assisted Design for engineering, Computer Assisted Manufacturing for manufacturing, Material Requirements Planning for production control and inventory control, and Computer Assisted Process Planning (CAPP) for process planning.

The interconnection of these basic components into a single smooth running system is what CIM is all about. This interconnection will result in the establishment of data driven automation. Manufacturing is an information driven process. By increasing the speed by which the information is processed and transmitted, the productivity and efficiency of the entire manufacturing plant can be dramatically improved.

WHY IMPLEMENT CIM

As stated early, the reason for the emphasis on CIM is the desire to obtain the various benefits associated with integrated manufacturing.

In a 1984 National Research Council report on computer integration of engineering design and production (24), the following benefits were cited as a result of CAD/CAM (Computer-Assisted-Design/Computer-Assisted-Manufacturing) integration:

Engineering design cost reduction of	15-30%
Overall lead time reduction of	30-60%
Product yield improvements of	200-500%

Increased production productivity of	40-70%
Work in process inventory reduction of	30-60%
Personnel cost reduction of	5-20%

In the report, the council also stated that further benefits can be expected as full integration is approached.

The above benefits were possible because CIM allows for two very powerful, never available before, capabilities: Data driven automation, and on-line decision making systems.(24)

Manufacturing is information driven. Whatever the manufacturing activity, be it manual or automated, it requires some type of informational input for operation. If paper were the medium of information exchange, the transfer speed from one function to another would be limited by the ability of humans to accept and process the information. The accuracy of the resultant information would be dependent on the interpretation and execution of the human performing the task. With digital data as the medium of information exchange, the data transfer, transformation, and feedback can be much more timely and accurate. The use of digital data, as a transmission medium, has another side benefit. It allows for the development and maintenance of complex data bases, necessary for on-line decision support systems.

In today's manufacturing environment, timely, accurate information on the status and operation on the factory floor can help avoid costly mistakes. A good on-line decision support system will allow plant supervisors to gain a better understanding of how the production process is actually working. It can analyze product test, and process scrap information to determine the causes of product failures or process scraps. It can reduce production costs by identifying production losses through long-term management analysis and suggest corrective measures. Ultimately, on-line decision support systems may be able to allow companies to study anything that can be described and where a knowledge base exists.

At present, the benefits derived from data-driven automation, and on-line decision support systems are few and far between. However, as the National Research Council report indicated, the benefits of partial integration of engineering design and production can produce economically justifiable benefits.

Other benefits of CIM cited in most literatures are cost saving, product quality, and increased competitiveness. The benefits of CIM from its individual elements, as presented by R. G. Willis and M. J. Klich during the Autofact 6 conference (35), are as follows:

CAD

Productivity increases for:	
New Drawings	3 to 1
Revised Drawings	10 to 1
Increased Drawing Accuracy	10 to 25%

GT (Group Technology)

Productivity increases for:	
New Part Design	52%
Shop Drawings	30%
Industrial Engineering	60%
Reduction in:	
Production Floor Space	20%
Raw Material Stock	40%
Set-up Time	69%
Production Time	70%
Work In Process Inventory	62%
Number of Overdue Orders	82%

CAPP (Computer Assisted Process Planning)

Reduction in:	
Planning Activities	58%
Direct Labor	10%
Material	5%
Scrap and Rework	10%
Tooling	12%
Work In Process	5%

MRP II (Material Requirements Planning)

Productivity Increase of	5 to 30%
Reduction in:	
Work In Process Inventories	30 to 50%
Late Orders	90%
Labor Requirements	10%

To summarize, a company should consider computer integrated manufacturing because it can help improve product design and production, reduce or eliminate part shortages, reduce production lead-times, reduce on hand inventory requirements, improve adherence to production schedules, and increase budgetary performance. In short, CIM can improve the competitive edge of a company by increasing its efficiency, productivity, responsiveness, and product quality.

PRESENT STATE OF CIM

Computer Integrated Manufacturing is a wonderful concept which promises great benefits. Unfortunately, CIM has not been fully realized, in practice, anywhere in the world. At present, only rudimentary integration between CAD and CAM exists.(24) Certain progressive factories have taken the necessary steps toward CIM by installing some of the components of CIM such as local area networks, flexible manufacturing systems, CAD/CAM systems, etc..

ISSUES THAT INFLUENCE CIM

There are many issues which will effect an company's view of CIM. Some of these issues will be technical, while others will be organizational and financial.

TECHNICAL ISSUES

At present, the largest problem facing CIM is that all of the technology necessary for bring it about has not been developed. The following is a brief description of the major technical issues facing CIM.

Data Communications

The problem of data communications exists at three levels.(24) The first level is the sharing of data between different programs running on a single computer. Presently, data generated in one application program can not be migrated to another application program without some sort of specially written interface routine. This problem is primarily the result of different data formats required by, and generated by the various application programs. The demands by users for software integration has forced software vendors to develop "integrated" application software families. These application software are able to transfer data only among the software packages within the family. While this is clearly not sufficient for CIM, it is a beginning.

The second level of communication difficulty occurs between computers of a single vendor. Historically, equipment vendors have been too busy producing different models of their equipment to satisfy specific situations to worry about data communication among the various models. The result is a mixture of equipments which can not communication. Presently, hardware vendors have become aware of the data communication problem, and have developed various hardware and software devices to allow for data transfer among their brand of equipment.

The third problem level is communication between computers of different brands. This problem is a much more difficult to solve than the other two problems previous discussed. Communication between computers of different brands can only be achieved if each of the communicating systems use a common protocol for communication control and data representation.

The requirement for a common communication protocol identifies another major obstacle to CIM. The lack of industrial standards. Presently, communications among computers and programming equipments are carried out via proprietary protocols and interfaces. An industrial communications standard is required for compatibility. This compatibility will allow for the integration of the many factory floor devices thereby promoting a multi-vendor network environment. Currently, standards groups are working on developing a complete set of communication specifications.

The International Standards Organization (ISO) has defined a model for Open Systems Interconnection (OSI) that directly addresses this problem.(29) It is in the process of defining the detailed standards for each of the required protocols. A non-proprietary communication protocol seriously being considered an industrial standard is the General Motor's MAP (Manufacturing Automation Protocol).(28)

Data Base Technology

Another technical problem which needs to be address is data base management. A CIM system will be as productive as the quality and quantity of the on-line data it has to work with. When CIM is implemented, a great deal of data will need to be stored, controlled, and verified. Therefore, there are two major issues that must be addressed by any CIM data base. First, the data base must be able to handle the vast amount of data necessary to operate a manufacturing plant. The second issue is how should the data be physically stored.

Relational data base structure and distributed data bases are believed to be the answer. Relational data bases, unfortunately, are not presently capable of handling the vast amount of information necessary to operate a manufacturing plant. The used of a distributed data base architecture also have issues which must be address such as level of redundancy, updates, deadlocks, reliability, backups, privacy, integrity, and security.

Another important data base issue is the establishment of the new data base. The development of a manufacturing data base is a monumental task. Procedures must be established, documentation prepared, and a structure (standardized format) for company data established which will be useful to all segments of the manufacturing process.

Sensors

Computers in automated factories need electric devices to communicate and interact with the world around them. As manufacturing plants become more automated, complex sensors will be required to provide real-time sensory data for computer analysis. At present, the majority of sensors used in a manufacturing environment are binary in nature. As automation increases, the demand for "smart" sensor will increase. While present smart sensor are able to do rudimentary analysis and decision making, the future will demand for more sophisticated, and faster processing sensors. With the advent of CIM and expert systems, faster and more capable smart sensors will be required to preprocess the sensory data prior to transmission to the expert system for processing, thereby allowing for real-time decision making system.

Computers

As Computer Integrated Manufacturing progress toward its goal of a totally automated manufacturing plant, the requirement for both computer process power and speed will increase. Faster and more powerful computer will be required for expert systems to make real-time decisions, and to handle quick real-time processing and transmission of data across the factory floor. While fast and powerful computer do exist today, the cost and the size of these computer needs to be reduced if they are to find their way down onto the shop floor.

ORGANIZATIONAL ISSUES

While technical problems have prevented the implementation of CIM to its fullest potential, organization issues have prevented many companies from even beginning. (20)

User Acceptance

The success of any automation project is very dependent upon the acceptance of its users. CIM is no exception. In order for CIM systems to be productive, interaction with enthusiastic and positive employees is required. The introduction of CIM in an organization should be welcomed as an opportunity for personal advancement, and not feared. To accomplish this, education must be provided to all employees prior to the implementation of CIM.

Organization Structure

Organizations have traditionally been divided into departments according to specific functions. As a result, people within those departments have developed loyalty to their individual departments and disciplines. Such loyalty have been known to create adversarial relationships with other departments, thereby hampering the introduction of new technologies or products. This situation could prevent the introduction of computer integrated manufacturing since CIM effects all parts of an organization.

With the introduction of CIM, departmental boundaries will begin to fade. This merging of departments may cause certain departmental managers and employees to feel a loss of authority, and/or contribution. The anxiety caused by this perception may delay the company's migration to CIM. To counter this potential problem, proper counseling and education should be given the employees before implementing CIM.

Top Management Commitment

Since automating a facility crosses traditional organizational boundaries, top management must be involved. Organization structures have to be evaluated as to their effectiveness in an automated environment, and changes may have to be made. Structuring an organization around a well designed system is the most productive and efficient way of matching the organization to a system. Attempts to integrate a potentially productive system into an existing, and possibly unproductive organizational structure, may reduce the productivity and efficiency of the system. (20)

Top management must be willing to invest large amounts of capital over multi-year time frames without seeing immediate paybacks. It is also very important that they make it known throughout the organization that they are committed to CIM, and are will to support the effort through to completion.

Top management must be willing to implement systems with the uncertainty of success. CIM, at present, is leading edge technology. As such, all of the various problems associated with implementation have not been answered.

Strategic Technical Planning

Implementing Computer Integrated Manufacturing is a long term commitment. As such, long range plans should be developed to provide guidance, and to monitor its progress. The strategic plan can provide the necessary structure to allow for the gradual introduction of CIM into a company. For strategic planning to work, the planner must know and understand the manufacturing process.

FINANCIAL ISSUES

In the past, ROI (Return On Investment) has been used by much of industry to measure the economical feasibility of investments. The procedure, however, is not appropriate for making decisions on investments in new technology.

The ROI methodology assumes stability in the economy, technology, labor, and most important, the marketplace behavior of competitors; assumptions that have been proven false many times.(24) In addition, it stresses short term returns over the long term strategies which may prove to be the most beneficial. ROI would be an appropriate methodology for determining the value of investments if the true costs and benefits could be included. The difficulty, however, lies in the disparity between the apparent ease of quantifying costs and the difficulty of quantifying benefits.

CHAPTER 2 - CIM STRUCTURE

There are different viewpoints as to what Computer Integrated Manufacturing is. In Chapter 1, three popular viewpoints were mentioned. They were the user, technology, and enterprise. The user viewpoint looks at CIM from an application standpoint; just what exactly can CIM do for the user. The technology viewpoint is concerned with the technological issues necessary for CIM. And, the enterprise viewpoint sees CIM as a management philosophy which correctly believes that CIM is unachievable if there is no management support. Now, with all of these viewpoints of CIM, which one is right? The answer is that all of the viewpoints are correct. This is possible is because Computer Integrated Manufacturing is made of a many different elements, all of which are interconnected to form the complete system (See Figure 1).

As depicted in Figure 1, Computer Integrated Manufacturing is composed of many different elements. The elements can be grouped into four major levels. The first and most important level is the foundation. This level identifies the importance of the organizational acceptance of CIM. Without the support of both management and the

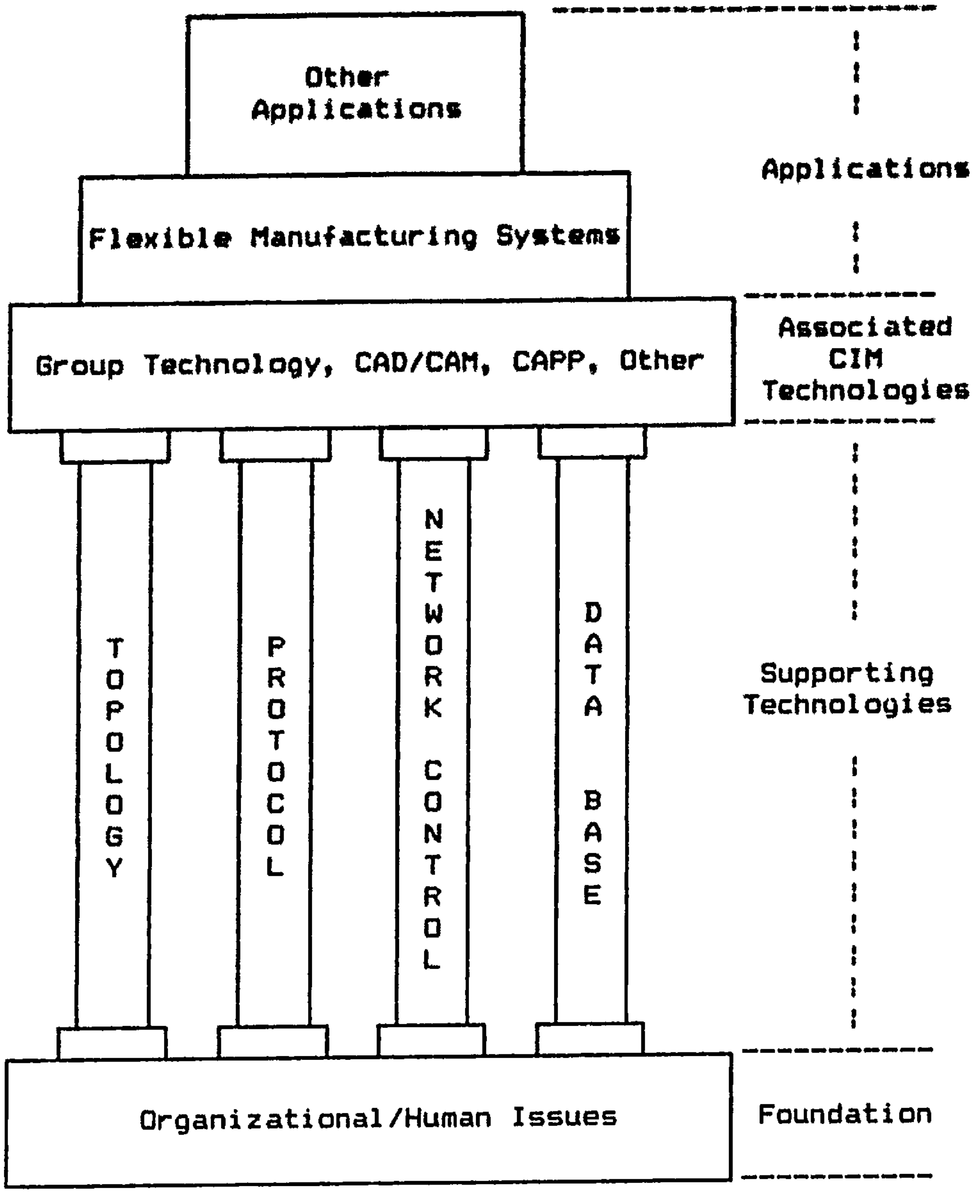


FIGURE 1 - COMPUTER INTEGRATED MANUFACTURING

end user, any CIM implementation will fail. For it is the people that makes projects successful. It is, therefore, important to understand and overcome organizational obstacle to CIM. Some of the most common organizational obstacles were identified in the previous chapter.

While organizational issues are important, the topic is too broad to be covered in detail, in this thesis. A brief discussion of CIM implementation organization, however, has been included in Appendix A.

The next level of CIM is the supporting technologies. The supporting technologies are the backbone of CIM. Without them, CIM cannot exist. These technologies allow for the establishment and control of communication networks. These networks allow for the sharing of data among the different manufacturing process.

There are four basic supporting technologies. They are:

- Network Topology
- Communication Protocol
- Network Control
- Data Base System

Each one of these basic technologies perform a vital function in the establishment of CIM. The first technology, called network topology, determines the actual physical layout of the CIM network. It deal with how the various intelligent devices are to be physically arranged and connected to form a network. It does not deal with the actual machine interface which due to the wide variations in the interfacing methods, will not be covered in this thesis.

A properly designed topology will allow the intelligent devices on the network to share information on demand, and with a reasonable response time. A network topology is, therefore, very similar to a telephone system. It allows an user to communicate with another user through a physical link.

Communication protocol allows for the meaningful sharing of information among the various intelligent devices linked together in a network. Protocols are predefined rules which establish how different pieces of data are to be coded and structured. Using the telephone example, consider two people who want to talk to each other. One person is in the United States, and the other person is in Japan. The telephone system (network topology) allows the two persons to exchange words. Now, since both of them are speaking in a different language, the communication is not meaningful. To establish a meaningful form of communications, translators will have to be present to convert the unknown language into a known language. A communication protocol provides the same purpose as the translators.

Communication protocol operates at two levels. The first level establishes a common alphabet for the exchange of data, and for restructuring the received information into a format recognizable by the receiving device. The next level translates and manipulates the data into an understandable and usable format. Without a communication protocol, data among the various intelligent devices can not be shared. It is, therefore, very important in the establishment of CIM.

Another important supporting technology of CIM is data base systems. A data base system determine how, and where information generated, and gathered within the manufacturing system are to be stored and shared. It is the center of CIM. A good data base system allows for the quick storage and retrieval of information, while maintaining data integrity. It will also improve data security, consistence, and data independence. It is data independence which enables different application programs to share information independent of how the data are physically stored. Data independence is a very important trait of CIM.

The last supporting technology of CIM is network control. A network control system performs two important operations. The first is information flow control. This function insures that the vast amount of information traveling on a CIM network are going to the right place, with a minimal amount of collision. It must make sure that data is moving smoothly, and to the proper destination within the communications network.

Because manufacturing is information intensive, vast amount of information have to be gathered and processed. The task of coordinating this process is the other responsibility of the network controller. The architecture of the network controller determines how information will be processed and shared within the CIM network. A properly designed network controller will allow the CIM network to operate more efficiently, and effectively.

Associated CIM technologies deal with how the information within CIM systems are to be processed and used for the purpose of maximizing the potential benefits of integration. Some technologies in this area are Group Technology, Computer Aided Process Planning, Expert Systems, etc.. In Appendix B the concepts of three associated technologies are introduced.

The highest level of CIM reflect the different user applications installed in a manufacturing system. Applications at this level performs the necessary manufacturing functions, such as machining, material flow, inventory control, etc. The purpose of the previous levels were to establish the necessary foundation for integrating the user applications at this level, i.e. CIM.

As Figure 1 indicate, Computer Integrated Manufacturing is a very complex system composed of many interrelated elements. At the base of CIM are the organizational issues, and the supporting technology issues. The importance of the four basic supporting technologies to the overall success of CIM is immense. Without the existence of these supporting technologies, CIM can not exist. Due to the immense importance of theses technologies to the overall success of CIM, they will be covered in the following chapters, in more detail.

CHAPTER 3 - NETWORK TOPOLOGY

A supporting technology of Computer Integrated Manufacturing is network topology. Topology is the physical manner in which computer systems are interconnected. A properly designed CIM topology will allow intelligent devices on the network to share information on demand, and with a reasonable response time.

The number of various possible interconnections are numerous. All of the various interconnection schemes can be classified into six categories: (33)

1. Shared Memory
2. Shared Bus
3. Point-to-Point
4. Loop
5. Star
6. Hybrid

Each interconnection scheme has its advantages and disadvantages. The selection of a suitable topology will depend upon the understanding the capabilities each of the various topologies.

SHARED MEMORY

A shared memory topology, as the name implies, transfer data between computers through the use of a common memory area. The common memory area can be either the primary or secondary memory of the computer. Typically, the common memory is the secondary memory of the computer. By using the secondary memory location as the common memory, the computer is able to use its own primary memory location for processing, thereby increasing the transmission speed. Shared memory is generally used in dedicated real-time applications where high communication speed is required.

There are various methods of implementing shared memory connections. The simplest method is through the use of a common communication bus. All of the computers are connected to the common memory locations through the same communication bus. A bus controller is used to serialize and prioritize bus access requests. Those requests are then executed, typical in a first in, first out (FIFO) priority.

Shared bus systems have the advantage of having low hardware cost, and simple communication requirements. It is also easy to modify and expand. Expansion of the system may however, degrade the overall system performance. Capacities of systems using shared bus interconnections are limited by the bus data transfer rate. And, failure of the bus may result in catastrophic system failure, if no other line of communication is provided within the system.(33)

Another way of connecting the shared memory to other computers is through the crossbar switching. In a crossbar switch system, a dedicated communication bus is connected to all common memory and I/O (input/output) units. Each computer is connected to the various communication bus. To control the buses, address translator are used. The function of the address translator is to perform conflict resolution and message transfer. One address translator is connected to each communication bus. When a computer sends a memory or I/O request, the address translator will determine if the it is the proper receiver for the message. If it is, then it will allow the computer access to its memory or I/O device.

Crossbar switch systems require very complex interconnections. This complexity increases as the system expands. Potential however, exists for high total transfer rate and system efficiency.

The next approach in common memory interconnection is the multibus/multiport method. In a multiport/multibus system, each computer is connected to each memory unit with a dedicated communications line. The address translation and conflict resolution is placed at the interface of the memory units. This approach allows for very high total transfer rates. Unfortunately, this approach also increases the memory unit costs drastically, since most of the control and message transfer is now located at the memory unit. A great deal of interconnections are also require with this approach.

While the shared memory topology has the advantages of having low hardware cost and simple communication requirements, it is an impractical CIM topology. The common memory size required to handle the entire communication needs of a CIM network is too great to be practical. Shared memory topologies can, however, be used to interconnect process equipments.

SHARED BUS

The shared bus interconnection requires that a common communication bus be used. Depending upon the communication medium, many messages may co-exist on the shared bus. Each message will have its own unique address for identification. Typically, shared bus systems use a time shared approach. In a time shared approach, each computer is allowed to transmit information on the bus in short time durations and at a high transfer rate. Message transfer control in a shared bus system are classified into centralized and decentralized control. Centralized control means that there is a central bus controller responsible for the transfer of information between the various computers within the system.

In a central polled common bus system, the central bus controller poles the various computers. When a computer wants to transmit a message, the computer informs the bus controller when it is poled. The bus controller then forwards the message, informs the computer when the message has been transmitted, and resumes the polling sequence. If the computer does not have a message to send, it responses with a status message to inform the bus controller that it is operational.

Another shared bus implementation scheme is the interrupt driven centrally controlled common bus. As the name implies, the bus controller waits for a Request To Send (RTS) interrupt before forwarding information on the bus, and acknowledging the transmission. This control approach is preferable to a poling system when the request for data transmission is small within a specific time interval.

Controlling information flow on a common data bus can be accomplished by Time Division Multiplexing (TDM). A TDM system controls bus access in two ways. One way is through the use of dedicated time slots. This method assigns each computer with a specific time interval in which it can access the bus. So, if a computer wants to transmit data, it will have to wait for a specific amount of CPU cycles to pass before transmission. This approach, however, requires that all of the computers on the bus be synchronized, which may be a difficult task. A way around this problem is to have a central oscillator sending out timed pulses. So, each computer will be assigned a specific pulse count after which it can access the bus. To ensure that all of the computers are in sync, a synchronization pulse is sent to signal the beginning and end of a count cycle.

The TDM can be implemented through the use of non-dedicated time slots. In a non-dedicated time slot system, a bus controller algorithm resides on one of the computers. This computer is responsible for the timing pulses. It is also responsible for allocating timing slots for other computer usage. Any computer who wants access to the bus must sent a Request To Sent (RTS) to the controlling computer. Before sending the RTS, the requesting computer will monitor the traffic on the bus. If there is no traffic on the bus, the RTS is set to the controlling computer. Otherwise, the requesting computer must wait. Once the RTS are received by the controlling computer, it will develop a table of the requests and assign time slots as required. This approach is similar to the interrupt scheme described earlier. Please note that a mixture of dedicated and non-dedicate time slots may exist within a single system.

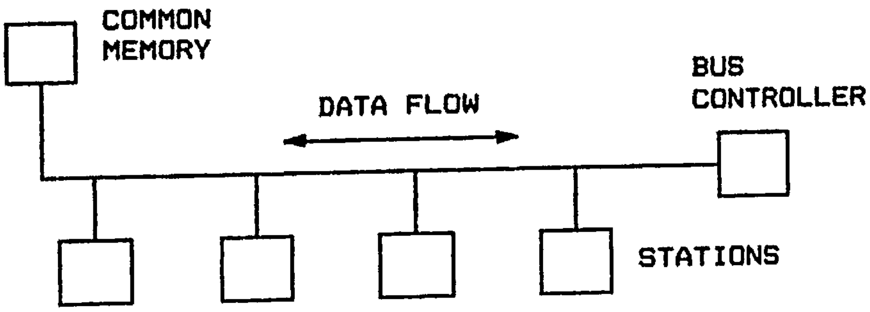
When the transmission medium permits it, the messages transmitted by the computers can be frequency modulated and send directly onto the bus. The message is then demodulated by the receiving computer's modem. Address separation is completed by assigning specific frequencies for each computer. A frequency will be assigned for foward transmission of data for one computer. The receiving computer will be assigned the same frequency, but for receiving only. The computers are, therefore, connected through frequency codes, similar to point-to-point connections (to be described).

Shared bus topologies are commonly used in the Local Area Networks (LANs). Because of the difficulty in fault detection and isolation, shared bus topologies are not recommended for use as the main CIM network.

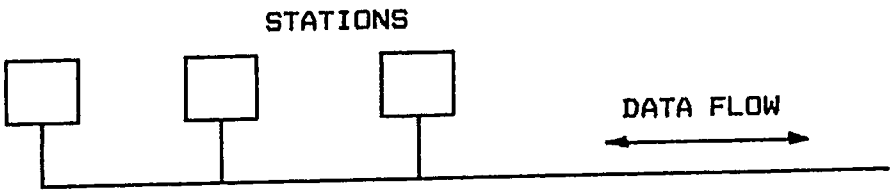
POINT-TO-POINT

A point-to-point interconnection consist of connecting two or more computers with communication lines. This interconnect approach have some advantages over those previous described. One advantage is its fault tolerance. If a single communications link fail, it has little effect on the overall operation of the system. The transmission speed and capacity is also high. This approach also have some disadvantages. Connecting large numbers of computers together is costly. Each new addition requires another communications line to be installed.

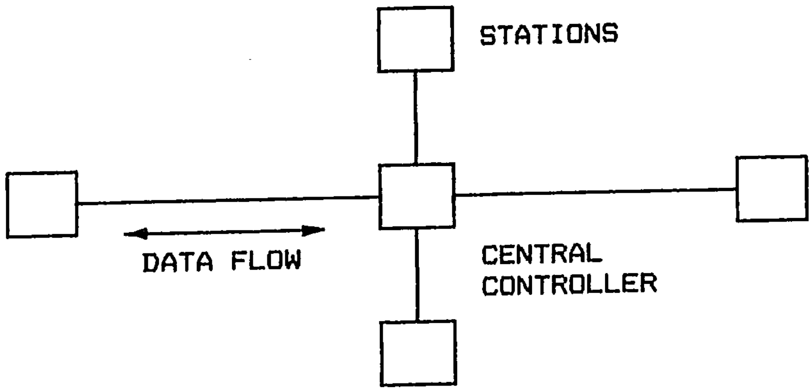
To overcome some of these disadvantages, partial point-to-point connection was developed. In a partial connection system, store-and-forward communication processor are used. The function of this communication processor is to provide circuit switching to establish the correct communication link between the transmitting computer and the receiving computer. Once the circuit has been established, the communications processor provides the transmitter and the receiver exclusive access to the communication path until the transmission is complete. The use of exclusive communications path causes long delays, and inefficient network operation. To overcome



SHARED MEMORY TOPOLOGY



SHARED BUS TOPOLOGY



STAR TOPOLOGY

FIGURE 2 - NETWORK TOPOLOGIES PART 1

these difficulties, packet switching may be implemented.

In a packet switching environment, messages are divided and stored in units called packets. These packets are transmitted to the communications processor for storage, prioritizing, and forwarding. When a communications line is available, the communications processor will transmit one packet at a time. After each transmission, the path is opened for usage by other communication processors. This process will continue until the complete message is forward. Each communications path is dynamically chosen to maximize network efficiency. Benefits to packet switching are equal access to the limited communications lines and ease of implementation. The cost of the communication processor necessary in such a system is, unfortunately, expensive.

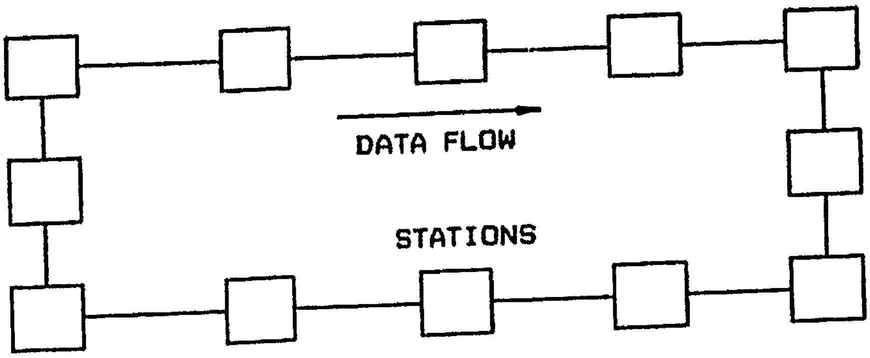
STAR CONFIGURATION

In a star configuration, one computer forms the center of the system. It is connected, point-to-point, other computers within the system. The center computer acts as system controller, prioritizing and routing messages to the other computers. For a computer to transmit a message to another computer, it must first send its message to the central computer. The central computer will then forward the message to the appropriate computer.

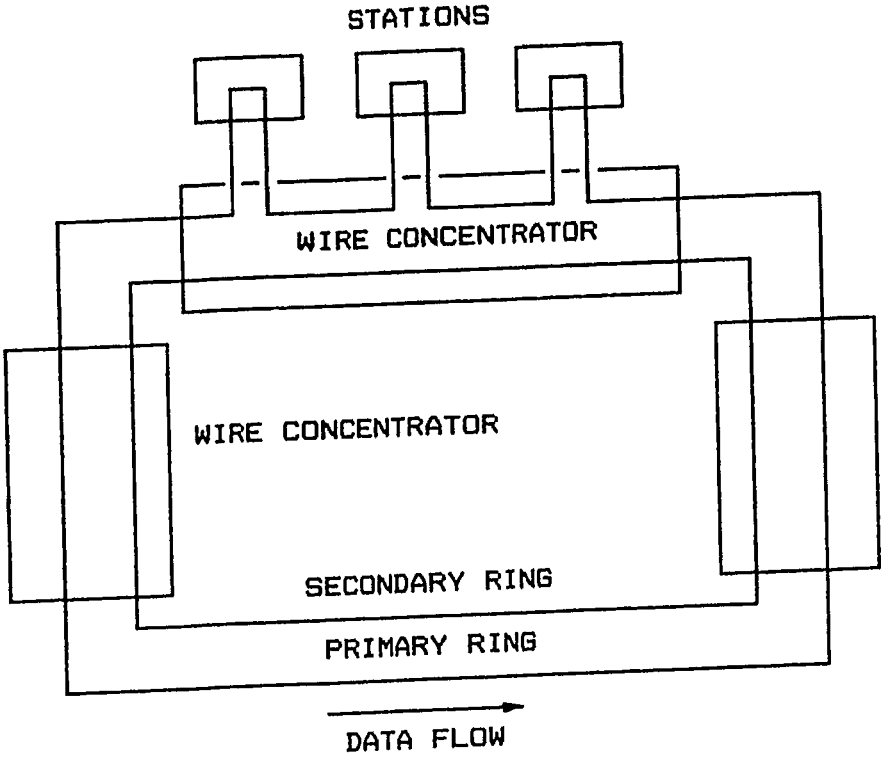
The benefit of a star configuration is the degree of control it has over the entire network. Any and all interaction between computers within the network is known by the central computer. The configuration, however, is not very reliable. If the central computer fails, the entire system fails.

LOOP CONFIGURATION

A loop or ring topology is a unidirectional communication channel arranged in a closed loop. Each computer is connected to the loop through the use of a loop interface. The connection point on a loop is commonly referred to as a node. Communication is accomplished by placing messages on the loop. The message will travel around the loop until the node with the proper address is detected. The message is then read by the receiving computer. The message remains on the loop until either the originating node or the receiving node removes the message. If the originating node is to remove the message, it will do so when the message comes by its node. At that time, the originating computer will check the message for a reception flag set by the receiving



LOOP OR RING TOPOLOGY



STAR - RING HYBRID TOPOLOGY

FIGURE 3 - NETWORK TOPOLOGIES PART 2

computer. A check sum on the message will also be done to identify any errors which may have developed in the message. If the receiving node is to remove the message, the traffic load on the loop can be reduced.

There are three types of network loops.(33) The first is called the Newhall-type. This loop technology uses a token character to control access to the communication loop. A computer can only sent a message if it has the token. A token character is sent around the loop. When a computer desires to place a message on the loop, it picks up the token, and proceeds to transmit its message. If the token is not present, it has to wait for the token before using the loop for transmission. This type of loop does not allow for concurrent message to reside on the loop.

The second loop type is called the Pierce-type. In this system, the communication space on the loop is divided into integer numbers of fixed sized slots into which message packets are stored. Each slot contains a status flag which indicates the status of the slot, full or empty. So, when a computer desires to transmit a message, it divides its message into packets. It the examines the communications slots on the loop as it approaches. If the slot is empty, the transmitting computer will place a message packet in the slot. This process will continue until the complete message is transmitted.

The third type is called Delay Insertion. This implementation scheme requires that each ring interface have a loop controller. The loop controller contains two buffers, a Receiving Shift Register (RSR) for incoming messages, and a Transmission Shift Register (TSR) for outgoing messages. The system operates in the following manner. When a computer is ready to transmit a message, it stores the message into the TSR buffer. The loop controller then opens the loop and channel any messages on the loop into the RSR buffer. At the same time, the contents of the TSR buffer is placed on the loop. Once the transmission is complete, the contents of the RSR buffer is placed on the loop, and the loop is closed. Therefore, messages on the loop, prior to transmission, has been delayed by one message cycle, thus accounting for its name. Performance studies have shown that the Delay Insertion loop is more superior than the other two loop types.

The usage of a loop topology have many advantages. Connections on a loop is easy to establish. Most loops communicate digitally, thereby requiring no modems. The initial capital investment in establishing a loop network is low. Loops are capable of high throughputs since more than one message can be transmitted at any one time.

Although loops have many advantages, it does have a major disadvantage. Loops are low in fault tolerance. If one of the nodes fail, the loop may be opened, thereby causing the entire system to fail. To improve the fault tolerance of loops, bidirectional loops have been developed. In a bidirectional loop, a failure in a node results in a redirection of the communication path around the failed node. The loop folds back on itself to provide a continuous communication path.

STAR - RING CONFIGURATION

Selection of a network topology does not have to be based solely on the basic configurations. Hybrids of the standard topologies can combined to improve performance and reduce the limitations. An example of a hybrid topology is the star-ring.(10)

In a star-ring topology, the network operates like a ring, but physically resembles a star. It provides all of the operational advantages of the ring with the flexibility of wiring configuration and fault isolation associated with a star.

The devices, in a star-ring configuration, are connected through a device called a wire concentrator.

Each concentrator is in turn, connected together by cables, to form the network ring. The wire concentrators are, in effect, the central controllers in the star configuration. It provides the necessary network functions, including fault isolation and detection, carried out by the central controller in the star configuration.

The network ring is actually composed of two rings: a primary ring, and a secondary ring. The primary ring is used in normal operation. The secondary ring is used when failure occurs. When the primary ring is broken, the network automatically reconnect itself to the secondary ring a the nearest wiring concentrator on either side of the break, thereby bypassing the break in the primary ring. When an attached device malfunctions, the wire concentrator will bypass the device by re-routing the primary ring around it. Like in the star configuration, if the wire concentrator malfunctions, all of the devices attached to it will be disabled. Unlike the star configuration, however, the rest of the network can still operate. The network will automatically re-route the ring to bypass the failing wire concentrator, once failure has been detected. Each of the wire concentrators are capable of assuming the network monitoring and control task, like in the ring configuration.

The star-ring configuration has been able to combined the fault detection and isolation advantages or the star topology, with the fault tolerance of the ring. This topology is therefore, a perfect candidate for CIM.

CHAPTER 4 - COMPUTER PROTOCOLS

A major purpose of Computer Integrated Manufacturing is to share data. A network topology allows the attached devices to exchange information in the form of digital pulses. The pulses, by itself are meaningless. A standardized procedure for converting meaningful data to and from the digital pulses is needed. This standardized procedure is called a communication protocol.

Meaningful communications between entities, requires the establishment, and adherence to formal procedures. In human communications, these formal procedures are embodied in custom, and language. In data communications between computers, these formal procedures are referred to as protocols. Protocol is a sets of conventions that defines the format and method of data exchange. Any two computes must be using the same protocol in order to exchange any meaningful information.

In the past, computer vendors developed their own protocols to meet their specific needs. As a result, computer from various vendors can not communicate with each other. To rectify this problem, the International Standards Organization developed the Open System Interconnection reference model.

OPEN SYSTEM INTERCONNECTION (OSI) MODEL

The Open Systems Interconnection model provides a framework that enables incompatible devices to communicate. It provides a common basis for the coordination of standards development for the purpose of systems interconnection, while allowing existing standards to be placed into perspective within the overall reference model.(17)

The OSI model presumes a modularization of the networking support software based on functionality. Each module takes the form of a layer in the model and is responsible for providing selected networking services to adjacent layers. The distribution of functionality by layers is not absolute. In theory, any layer can be replaced by a new layer which provides the same services in a different way without affecting the user's perception of network operation. The OSI reference model depicting the layers and their associated function is shown in Figure 4.

The layers may be divided into three basic categories: Adjacent node, routing, and end node specific. Each of which may be further divided as follows:

LAYERS	FUNCTION	LAYERS
User Program	Application programs Not part of OSI model	User Program
Layer 7 Application	Provides all services directly comprehensible to application programs	Layer 7 Application
Layer 6 Presentation	Restructures data to/from standard format used in network	Layer 6 Presentation
Layer 5 Session	Name/adress translation, access security, and synchronized & data mgmt	Layer 5 Session
Layer 4 Transport	Tansparent transfer of data between end nodes	Layer 4 Transport
Layer 3 Network	Message routing for data transfer between adjacent nodes	Layer 3 Network
Layer 2 Data Link	Error detection and correction	Layer 2 Data Link
Layer 1 Physical	Encoding and physical transmission of data between adjacent nodes	Layer 1 Physical

PHYSICAL LINK

FIGURE 4 - OSI REFERENCE MODEL

Adjacent node specific is concerned with the physical communication of messages between adjacent nodes. Two layers are required to perform this task.

Layer 2 (Data Link)

Layer 1 (Physical)

Routing is concerned with how to send messages between the two (or more) communicating applications in the presence of intermediate nodes. Protocols in this category must be consistent throughout a given network. Only one layer exists for this category.

Layer 3 (Network)

End node specific is concerned with application level services, data format standardization, address translation, access security, and the end-to-end processing. Effectively, there are five layers in this category. At the top is the user program which consists of the application programs.

Layer 7 (Application)

Layer 6 (Presentation)

Layer 5 (Session)

Layer 4 (Transport)

Communication between computers using the OSI model, begins at the application layer of the sender. The data is passed down through the successive layers until it reaches the physical link layer. At the physical link layer, the data is transmitted over a communication link to the receiving computer. The receiving computer will then pass the data up through the various layers until it reaches the application layer, at which time, the transmission is over. Once the data reaches the application layer of the receiver, the receiving computer will be able to use the data immediately. The process is shown in Figure 5.

There are two types of information passed down to the layers, data and control. The data which is passed down to a layer is generally transported transparently, except for the Presentation Layer which reformats the data. The control information is the basis for all the services which are required to process the message. Each layer prefaces the data with a control block prior to requesting the services of the next lower layer. This control block is interpreted by the corresponding layer in the receiving node. As the data is passed to successively lower layers, its size increases. As the data is passed to successively higher layers at the receiving node, the control blocks are removed. This nesting of layer protocols is illustrated in Figure 6.

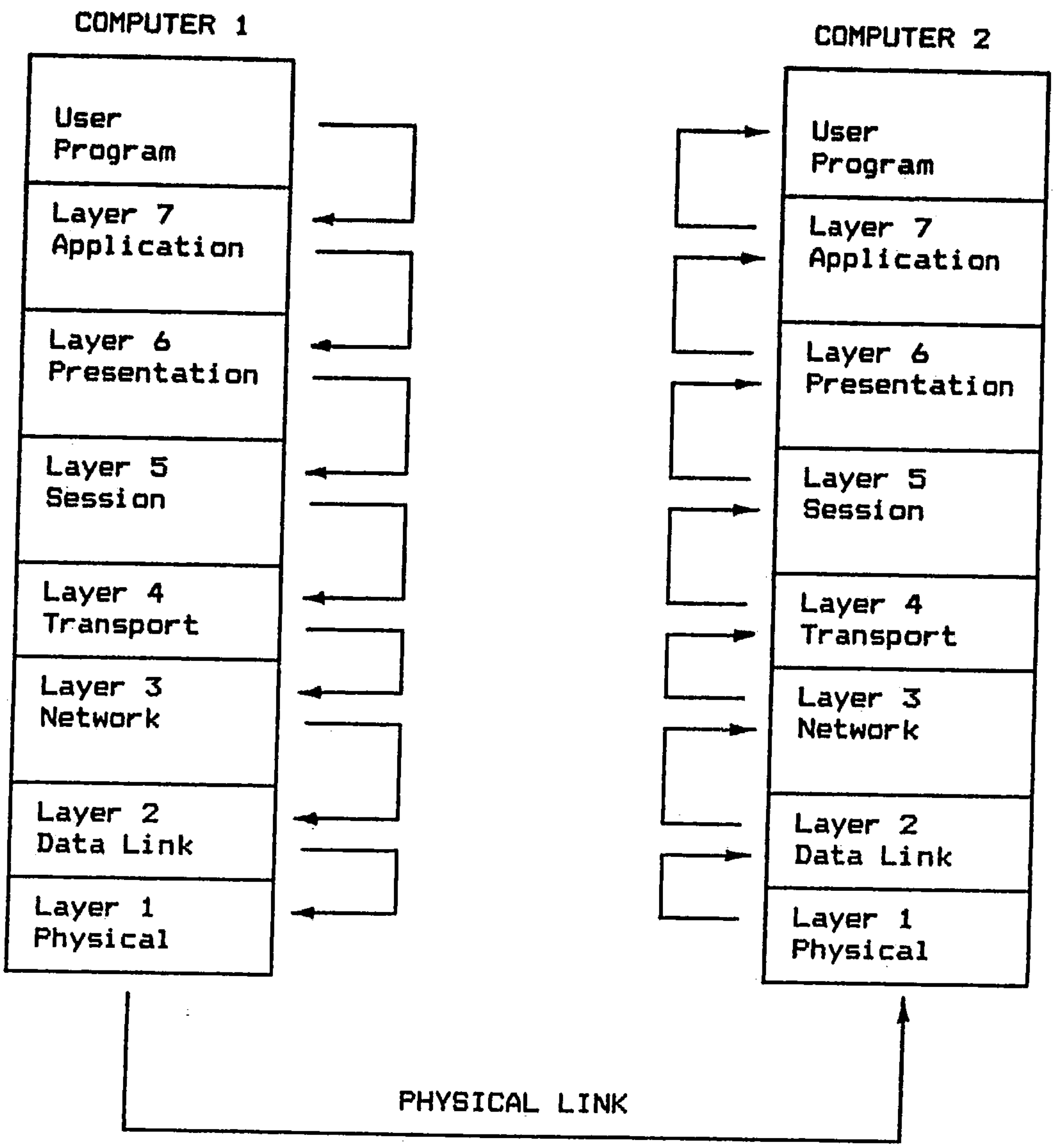


FIGURE 5 - DATA TRANSFER IN THE OSI MODEL

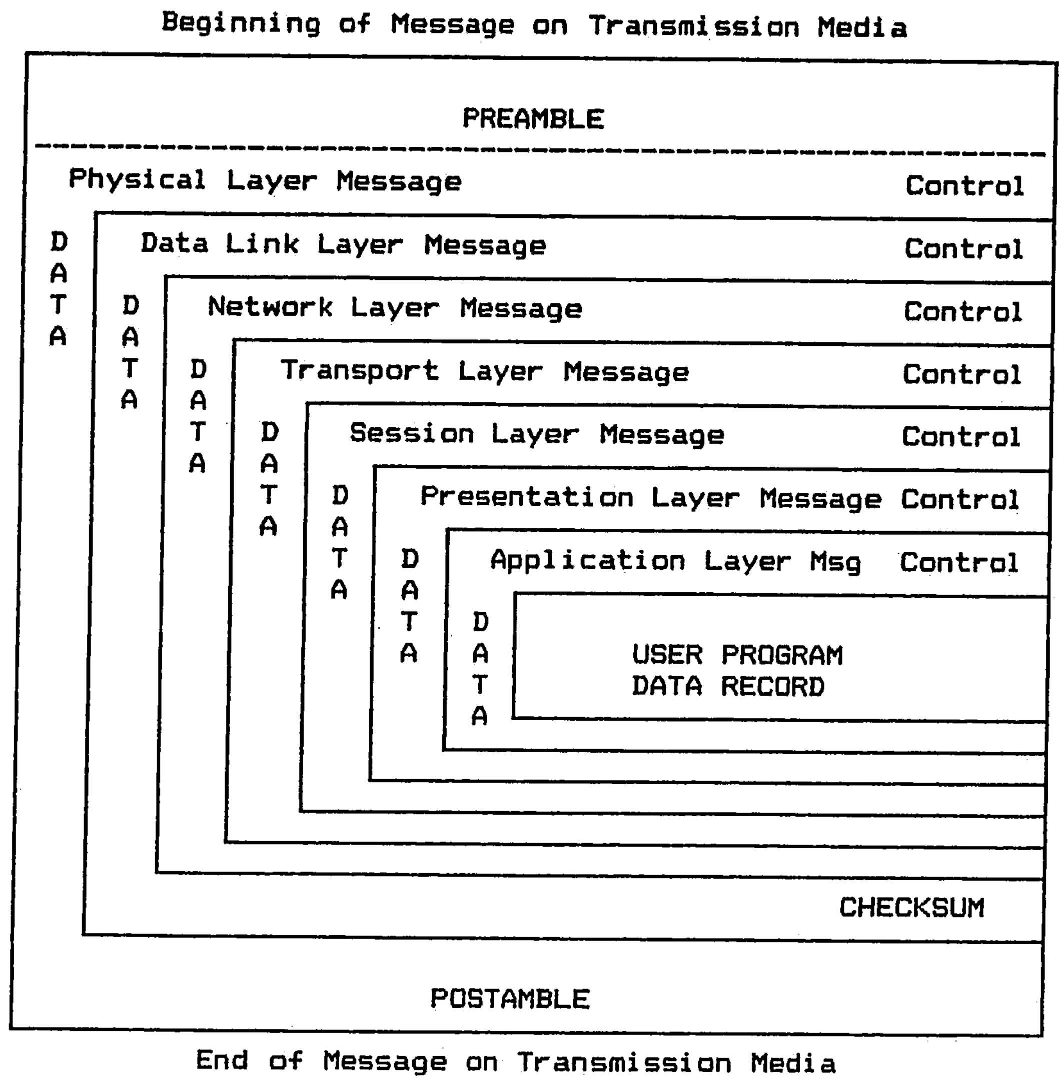


FIGURE 6 – NESTING OF LAYER PROTOCOLS

At the present time, the OSI standard has obtained the status of Draft International Standard. Presently, protocol standards have been developed for only the first three layers: physical, data, and network. No standards have been developed for the other layers.(17)

The Reference Model was designed to be sufficiently flexible to accommodate advances in technology and expansion in user demands. This flexibility is also intended to allow the phased transition from existing implementations to the OSI standard, as the standard evolve. As standards emerge to meet the OSI requirements, a small number of practical subsets will be defined by the standard developers from optional functions to facilitate implementation and compatibility.

While additional refinement is necessary before all details are fully established, the ISO's work is advancing rapidly to produce a basic reference model shape. The major task ahead is the development of protocols for the various layers, particularly the upper layers (layers 5 through 7), where presently, there are no established standards. As technology evolves, protocols at the different layers can be revised or replaced without affecting the other layers. As new applications arise, they can likewise be designed to conform to the reference model. One new application is the General Motor's

Manufacturing Automation Protocol or MAP.

MANUFACTURING AUTOMATION PROTOCOL (MAP)

While the International Standards Organization is working on establishing standards for the various OSI layers, a movement to establish a factory floor communication protocol was started by General Motors. The project was called MAP, an acronym for Manufacturing Automation Protocol. Recently, the overall standards development responsibility was transferred from General Motors to the various standards groups.(7) The following is an overview of MAP.

The goal of MAP is to provide compatibility of communications to integrate the many factory floor devices and to promote a multi-vendor network environment. Standards have been adopted but the complete specification is still emerging. MAP will adhere to the networking protocol structure specified by the International Standards Organization (ISO) Open Systems Interconnect (OSI) Model. This will allow the co-existence of various protocols, virtually unlimited expansion, and concurrent development.

LAYERS	FUNCTION	MAP SPECIFICATION
User Program	Application programs Not part of OSI model	As required for each particular application
Layer 7 Application	Provides all services directly comprehensible to application programs	No standard established
Layer 6 Presentation	Restructures data to/from standard format used in network	No standard established
Layer 5 Session	Name/adress translation, access security, and synchronized & data mgmt	No standard established
Layer 4 Transport	Tansparent transfer of data between end nodes	ISO/NBS transport class 4
Layer 3 Network	Message routing for data transfer between adjacent nodes	No standards established
Layer 2 Data Link	Error detection and correction	IEEE 802.2 Link level control
Layer 1 Physical	Encoding and physical transmission of data between adjacent nodes	IEEE 802.4 Token access on braodband media

PHYSICAL LINK

FIGURE 7 - MAP SPECIFICATION SUMMARY

DESCRIPTION

The Manufacturing Automation Protocol (MAP) is a set of non-proprietary standards for a factory Local Area Network (LAN). MAP is being developed by SME/CASA with the support of the manufacturing and vendor community and the cooperation of various standards organizations such as IEEE, ISO and NBS. The final MAP specification will consist of a list of the subset of available communications standards that define LANs for terminals, computing resources, and programmable devices within a plant or complex. The architecture allows for the interconnection of multiple LANs and for connection to Wide Area Networks or digital PBXs for long distance communications.

MAP Layers

Physical Layer:

The physical layer is responsible for the physical aspects of data communications. The MAP standard is for a broadband CATV (Cable Television) compatible system with data channels operating at 5, 10, or 20 Mbps (Mega bits per second).

Data Link Layer

The data link layer is responsible for the transfer of data across a single data link. For MAP, the IEEE 802.2 Class 1 Logical Link Control and the IEEE 802.4 Media Access Control (Token Passing Bus) have been selected for use together.

Network Layer

The network layer is responsible for routing transport protocol data from the source system to the destination system. At the present time, no standards have been established.

Transport Layer

The transport layer is responsible for providing reliable end-to-end data delivery. For the transport layer, the ISO transport protocol (ISO IS 8073) has been selected. The Class 4 protocol is to be used on IEEE 802.4 LANs, and Class 2 protocols will be used with X.25 wide area networks, and possibly for use in cell control subnets.

Session Layer

The session layer is responsible for controlling dialog between systems and for providing check points and resynchronization in the event of failure and subsequent recovery. At present, no standards have been selected.

Presentation Layer

The presentation layer is responsible for negotiating transfer syntax and for transforming data from the local syntax to the transfer syntax. Currently, MAP does not use a presentation layer protocol. Instead, presentation layer issues are resolved by requiring the application to encode data in a common transfer syntax. This may change in the future.

Application Layer

The application layer provides the user interface to the communication services provided by the MAP network. Services provided at the application layer define the capabilities of the system relative to communications. MAP provides two application layer capabilities to the MAP user.

1. FIle Transfer, Access and Management

   As currently defined, this capability

provides for the creation and deletion of files on a remote system and for transfer of files between systems. In the future, this capability will be enhanced to provide for record level access to remote files.

2. Messaging

   This capability defines message syntax and semantics for communications between computers and programmable control devices.

Topology

The objective of MAP is to allow for the interconnection of various program devices into a common communication network. The total number of interconnected devices in a manufacturing environment will however, typically exceed the capacity of a single network. To overcome this limitation, and to maintain design and performance criteria, the total MAP network will be composed of various subnetworks. This subnetwork strategy will overcome geographical and organizational limitations. Connections among the various subnetworks will be accomplished through the use of gateways, bridges, and routers.(7)

Gateways

Gateways are devices used to connect different network architectures together. They provide for protocol translation between different networks, and performs message storage, forwarding, and flow control resolution. Gateway operation is non-transparent, utilizes all seven OSI layers, and supports Network Management programs for multiple networks.

Bridges

Bridges are similar to gateways. They are devices used to connect segments of a single network together. Bridges, therefore, do not have to provide for protocol translation, and are transparent in operation. Bridge operations are restricted to the first two levels of the OSI model.

Routers

Routers are devices used to connect several networks together at a common point. This device allows for path selection and alternate routing based on the status of connected networks. Router operation is restricted to the first three layers of the OSI model.

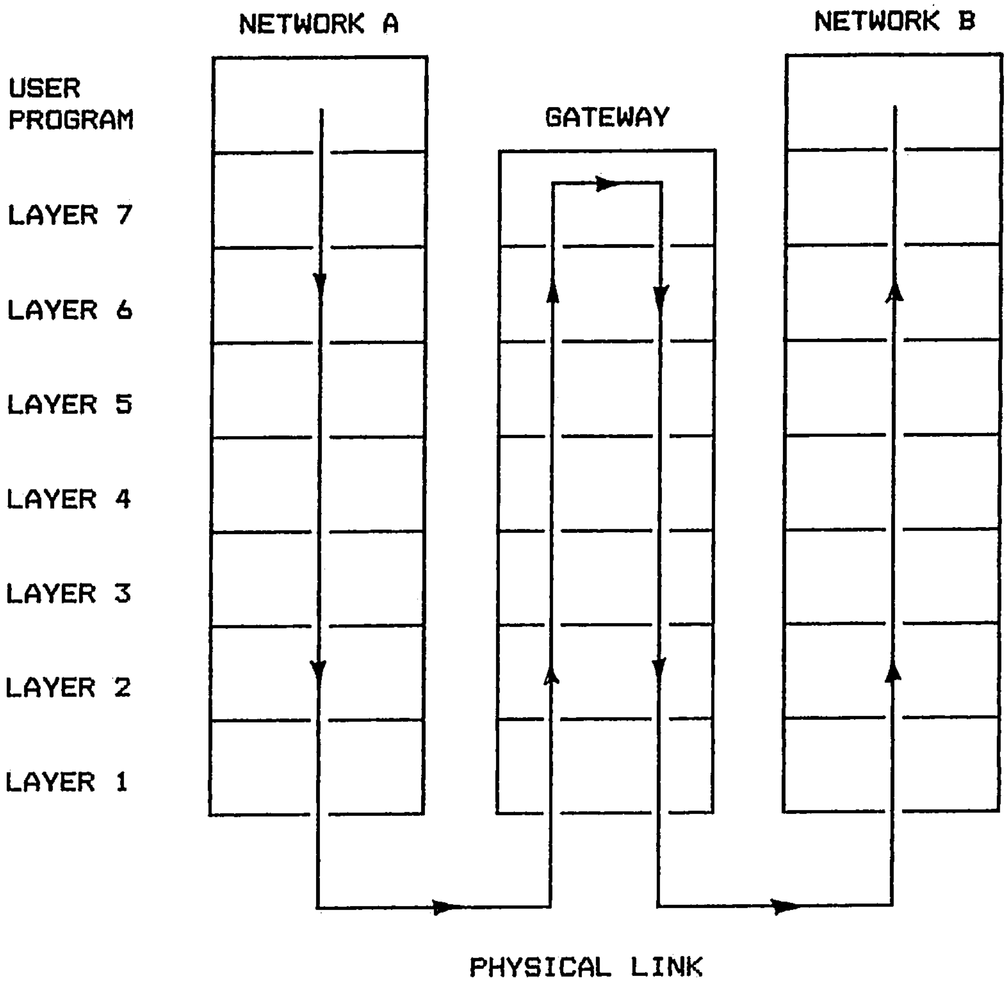


FIGURE 8 - GATEWAY ARCHITECTURE

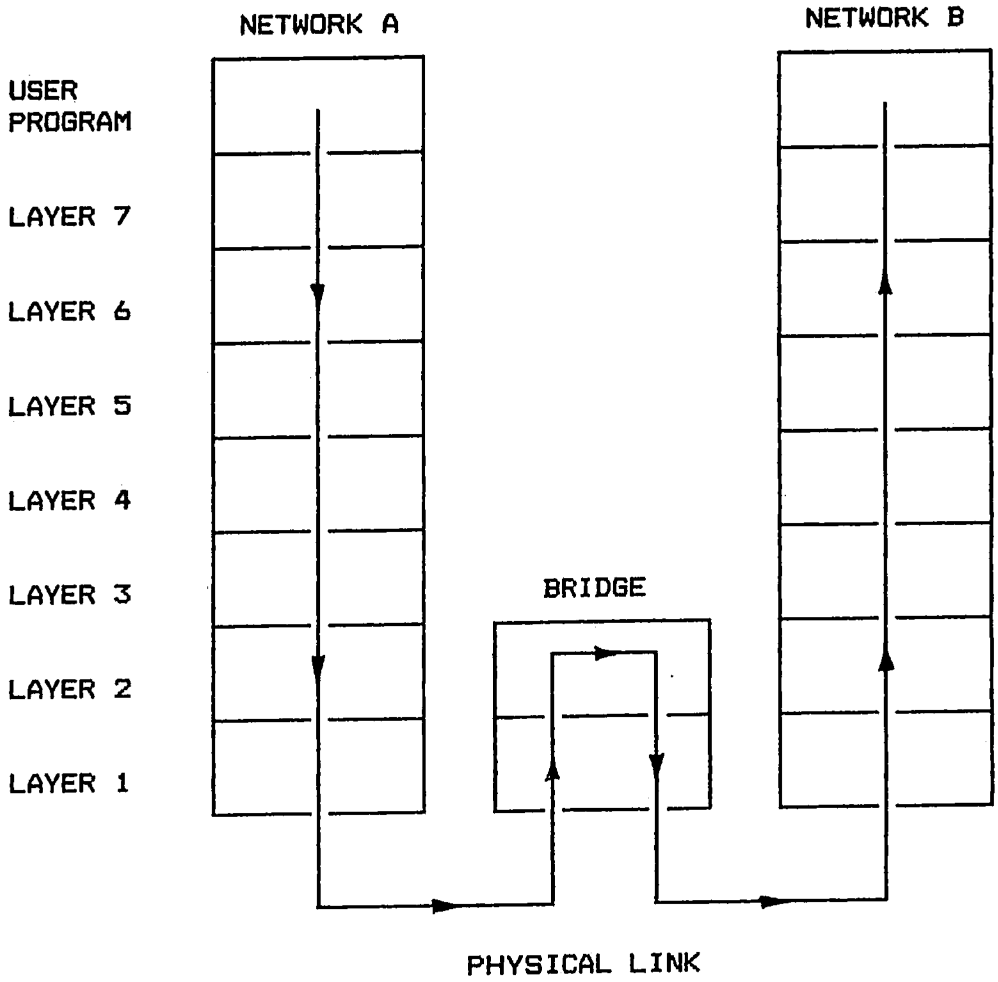


FIGURE 9 - BRIDGE ARCHITECTURE

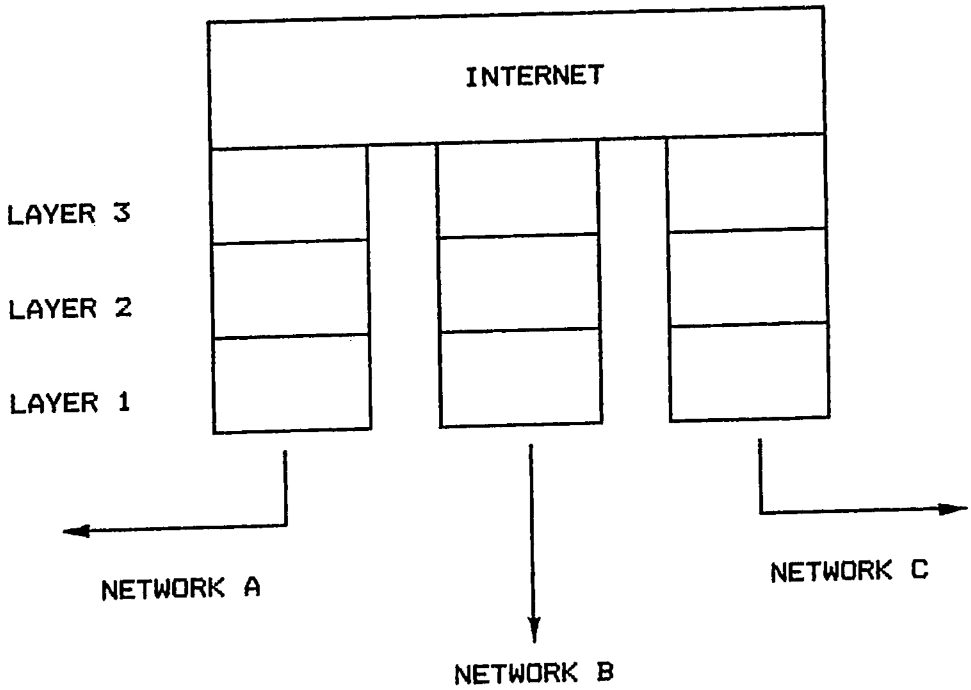


FIGURE 10 - ROUTER ARCHITECTURE

Network Management

Network Management is responsible for ensuring the correct operation of the MAP network. It consists of data and programs that are used by people and machines and the resulting control actions. At present, the Network Management operating system has not been developed. A few of the proposed characteristics of the Network Management are as follows: It will manage the network by exception. It will not intervene in the network operation unless the network specification has been violated or a data request has been issued. The Network Management will be able to operate independently of any physical location, and to operate in the presence of failures, so long as the failures are not in the physical or data link layers. The Network Management will be able to communicate with non-MAP network managers, through bridges, to allow for the exchange of information between non-MAP and MAP networks. The proposed functions of a Network Manager are as follows:(7)

1. Monitor the operational status of the network, and to collect and store information on the performance of the network.
2. Control the operation of the network including network recovery from a catastrophic failure.
3. Initial Program Load (IPL) of computers and

other program devices including network software, address tables, etc..

4. Coordinate network topology alteration and propagate this information to all affected nodes.

5. Problem determination and recovery; the recognition of a problem, identification of problem source, and the corrective procedures necessary for recovery.

Migration Path

The implementation of the MAP networking concept will not occur abruptly. Instead, the implementation process will occur gradually. Initially, the MAP network will consist of the IEEE 802.4 token bus, and gateways used for connecting application processors, terminals, and other program devices together. Gateways may also be used to connect vendor non-MAP subnetworks if appropriate gateways are available. As vendors of computers and other devices provide MAP interfaces, those computers and other devices will be attached to the MAP network directly as required. As the architecture becomes more mature, higher layer communication capabilities will be used. At the most advanced stage, application to application communication would take place using all seven layers of the open system.

PRESENT STATE OF MAP

At present, the overall MAP specification is still emerging, but layers 1, 2 and 4 have been determined. Since MAP is still incomplete, no one is presently using it. Pieces of MAP, however, are already in place or being planned. The following are examples of what is happening within General Motors:(31)

- General Motors has developed a MAP test bed in its Tech Center engineering labs in Warren, MI
- New assembly plants will use MAP protocols to interconnect various automated equipments such as conveyors, supervisory computers, robot painter, etc.
- A Steering Gear plant in Saginaw, MI has been selected to test the workability and availability of new MAP hardware.

Outside of General Motors, MAP compatible projects are also being planned. The following is a list of some of those projects:(31)

- The modernization of the shotgun factory of DuPont's Remington Arms unit in Ilium, NY is said to include MAP compatible hardware and software.

- Another similar project is taking place by Boeing in its Audurn, WA machine shop for airliner parts.
- Testing facilities are being planned at the National Bureau of Standards' Center for Computer Systems and Engineering, and at the Industrial Technology Institute.
- The Society of Manufacturing Engineers are planning to demonstrate the ability of MAP by connecting various vendor equipments together at the next AUTOFACT show late in 1985.

Although MAP faces many technical and political obstacles, the chance of MAP becoming a defacto standard is good. At present, there are over 100 companies are involved in MAP either in the helping to development standards, or by providing support to the effort. The purchasing power of General Motors, and the potential benefits of such a standard gives MAP a good chance for success. The success of MAP will enable virtually all programmable devices to communicate over LANs that employ the same technology as cable television systems.

PROTOCOL CONVERSION

While the standards bodies are addressing the compatibility problem, a temporary solution to the multivendor, multiprotocol problem is presently available. The solution is the use of protocol converters. Protocol converters are hardware or software devices that enable dissimilar programmable devices to communicate with each other. There are three basic types of converters: translators, extenders, and emulators.(21)

The main task of a translator is to convert the physical connection and transmission protocols to allow two different devices to exchange data. The translator performs three levels of conversion: data link control, transmission protocol processing and device characteristics conversion.

The data link control maintains the electrical connections and supports requirements for initiation and termination of connections. The transmission protocol processing provides data blocking, device identification, addressing and error detection and recovery. The translator and other protocol converter accomplish these translations through device characteristic conversions. The characteristics of each device attached to the protocol converter is stored in memory. The characteristics of each device is then mapped to the associated characteristic of the other devices. Based upon these device maps, the required conversions are processed.

As with the translator, a protocol extender carries out the necessary conversions at the data link control and transmission processing levels. Unlike the translator, however, the extender will actually manipulate the internal data formats of transmissions to ensure that the proper data format is being transmitted. An extender cannot, however, handle complex communications protocol conversions like a translator. Its major task is data reformatting.

The last type of protocol converters is the emulator. The emulator is simply a protocol converter with the combined capabilities of both the translator and extender. It is therefore, able to handle application where data formatting and complex protocol conversions are both required.

While the protocol converters are able to bridge the communications gap, they are a short term solution. Protocol converters are not universal interfacing devices. They are equipment designed to handle a specific task, and therefore, have limitations. Some of them are:

1. Can only handle a limited set of protocols
2. Generally, only popular protocols are supported
3. Converters can support only a small number of computers.

4. Cost - Using protocol converters to integrate a manufacturing facility can be too costly.

CHAPTER 5 - NETWORK CONTROL STRATEGIES

Computer integrated manufacturing requires that the various programmable devices within a manufacturing complex be integrated via some type of communications network. The establishment of such a network is only one segment of the overall integration process. A method of controlling the information flow within that network is another segment.

The vast amount of information which will be traveling on a manufacturing network requires that a network control system be designed into the integrated system. There are two basic functions that must be performed by any network control system. The first function is information flow control. The other, is information processing.

FLOW CONTROL

In any communications network in which shared resources are use, some type of network management or control system must be used. A specific algorithm must be implemented in the network to handle the distribution of data and to resolve any conflicts which may arise. The type of network communication control strategies used to manage data flow depends largely on the network topology. Three basic control architectures are used to control the various network topologies, there are host, distributed, and hierarchical.

Host Control Architecture

The host control architecture is one of the oldest control architecture being used today. It uses a single centrally located computer to handle the distribution of information. A common example of this control architecture is the star topology.

In this type of control architecture, communications between computers is always indirect. All information exchanged between computers must first be passed to the host or central computer. The host computer will then relay the information to the target computer.

This type of control architecture has the advantage of allowing the network manager full control over the entire communication link. Network security is greatly improved. The central computer knows every thing that goes on, and have full control over the flow of information within the network. This architecture also has good fault detection and correction abilities. The host can easily detect and isolate any malfunction within the network.

While the host architecture has some advantages, it also has disadvantages. One of the most disabling draw back of the centralized host scheme is reliability. If the host computer malfunctions, the entire network is disabled.

Distributed Control Architecture

The distributed control architecture is a system of multiple computers/processors which operates concurrently and communicate with each other via messages transmitted over a channel. Topologies which use a distributed control architecture are shared buses, rings and loops. In a distributed control architecture, there are two major flow control problems which must be addressed by the network management system. The first problem is contention, and the other is data distribution.

Contention occurs when two or more computers want to use the shared communication channel at the same time. In a distributed system, there are numerous ways of avoiding contention. The most common methods used are polling, token passing, and collision detection.

In the polling method, one computer within the network is designated as the network controller. The network controller asks each computer, on the network, in some predetermined sequence, if it wants to use the communications channel for transmitting data. If it does, the computer will reply with a RTS (Request To Send) signal. The polling computer will then issue a token bit to that specific computer. The computer will then send an address data block on the communication's channel, followed by data blocks, and an error detection block, commonly referred to as a checksum. Meanwhile, the other computers on the network is constantly checking the channel for their address bits. When the correct address bit is identified, the receiving computer will know that the following data bits are for it, and will proceed to copy the data off the channel. The receiving computer will then do a checksum on the data it received to identify the presence of any errors. If the transmission was received error free, the receiving computer will send an ACK (acknowledgment) bit back to the sender. Otherwise, it will either do nothing, or it will send a NAK (negative acknowledgment). The sending computer will wait a specific time after the transmission of data. If no ACK is received before the transmission timer expires, a duplicate copy of the data will be retransmitted. This process will continue until an ACK is received. Once the computer has completed its transmission, it will release the token bit to the network controller, and the polling process continues.

In a token passing system, the network controller will generate a token bit, and place it on the network. When a computer desires the use of the channel, it will remove the token from the channel, and proceed with data transmission. Data can be transmitted only by the computer possessing the token. Once the transmitting is completed, the token will be release, thereby allowing the other computers to use the communication channel. To prevent the network from being disabled by a lost or destroyed token, the network controller will monitor the communication channel continuously. If the controller does not detect a token after a specific time period has elapsed, a new token will be regenerated by the network controller and placed on the network.

The last, most commonly used, method is collision detection. All of the computers within the network listen for activities on the communication's channel. If there are no activity, any computer can begin to send data on the channel. If two computer try to send data at the same time, data collision occurs. This collision, when detected by the transmitting computers, will force the termination of all data transmission. The computers will then wait for a specific time before trying again. This type of protocol is very efficient in low traffic networks. In networks with high traffic flow, this protocol become unusable.

Distributed control system, as compared to host systems, has the advantage of better fault tolerance, and higher reliability. The network is not dependent upon a single central computer for network control. Should the network controller malfunction, other computers on the network can assume the network controller's responsibilities. Another advantage of distributed system is its higher throughput rate. Since transmitted data do not have to pass through a single point, there is no bottleneck. The data can also be multiplexed to achieve greater throughput.

Distributed control systems have their share of problems as well. One of the problems is with data security. Since data is sent on a common communication channel, all computers attached to the channel can have access to the data. Secondly, expansion on a distributed system will be more disrupting than for a host type control architecture.

Hierarchical Control Architecture

A hierarchical configuration, as its name implies, consists of a tree structure of computers. In general, the capability of the processors increases as the top of the pyramid is reached. Similar to corporate organizations, the base are generally application dependent, whereas the top of the pyramid has the general purpose of controlling and coordinating the entire system. In this type of configuration, information is passed vertically between the various levels in the hierarchy.

Like a host system, communication between computers on the same hierarchical level must go through an intermediary computer. In other words, in order for two computer, on the same hierarchical level, to exchange data, they must send their data up to the controlling or parent computer located on the next higher level. The controlling computer will then relay the data back down to the appropriate receiving computer.

A hierarchical control architecture have the advantages and disadvantages of both the distributed and host system. It has better fault tolerance than a host system, but not as good as a distributed system. If a malfunction occurs in a computer on the lower levels, the fault can be easily isolated and by-passed. If the malfunction occurs in the upper levels of the network, then serious degradation in performance may occur. All computers or nodes below the malfunction will be disabled.

Other advantages of a hierarchical architecture are flexibility, expandability, security, and higher level of network control.

INFORMATION PROCESSING

Control architecture affects not only how information are transmitted, but also how those information are to be processed and used. Some of the functions which manufacturing computer networks use to accomplish this task are:(25)

1. Monitor shop floor equipment status
2. Supervisory control - Process coordination and optimization
3. Operator communication
4. Information process
5. Management report generation

Like in flow control, there are three basic control architectures: Host, distributed, and hierarchical.

<u>Host Control Architecture</u>

The host system was the first architecture used in controlling and processing information. In the past, when computer power was very expensive, companies installed a single computer to handle all of the information

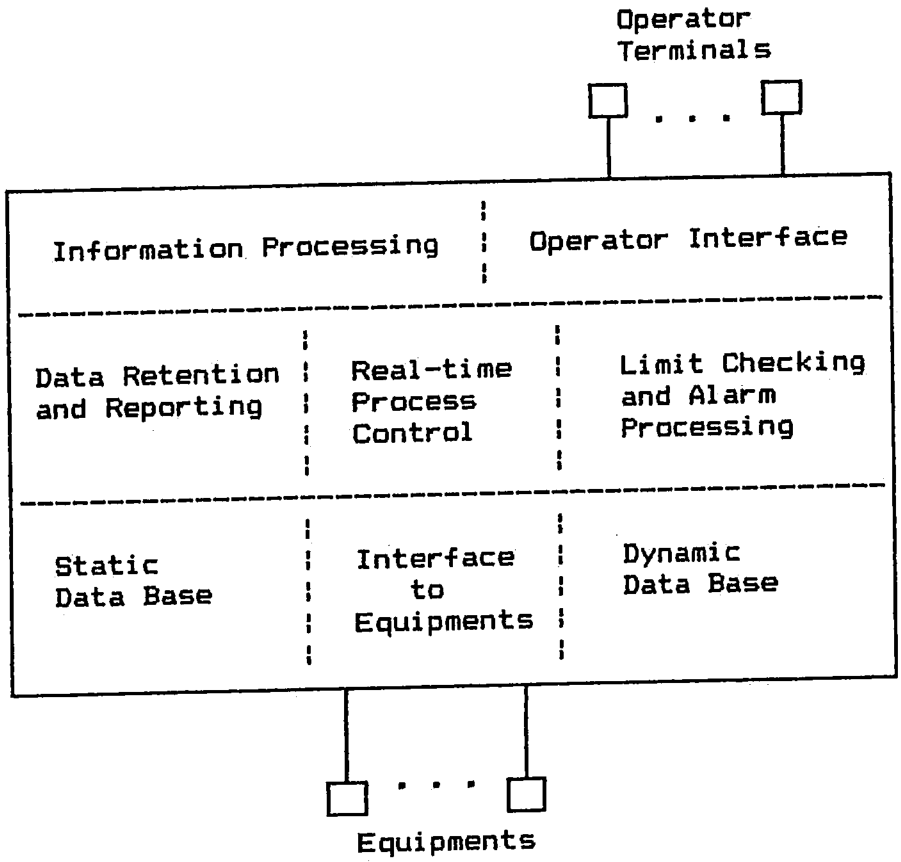


FIGURE 11 – HOST SYSTEM ARCHITECTURE

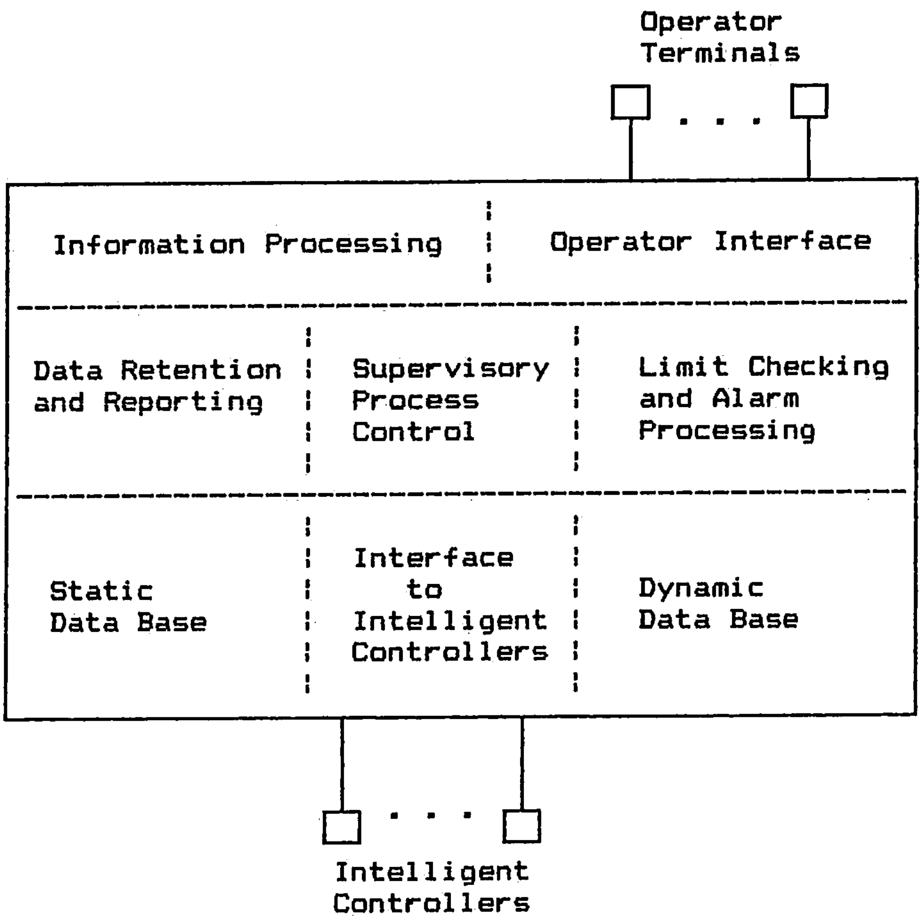


FIGURE 12 - SUPERVISORY HOST SYSTEM ARCHITECTURE

processing, and control functions. As computer cost decreased, programmable controllers were attached to the host computer. While the host was still responsible for information process, the programmable controllers were now responsible for real-time process control. The host computer, however, was still responsible for providing the process control algorithms. While the host type system increased productivity, it has some limitations:

1. Host processor provides a single point for system failures.

2. When all operations occur in one processor, the system has a limited bandwidth

3. All system software reside on host, thus, making software maintenance difficult.

Distributed Control Architecture

In a distributed control architecture, the various functions, necessary to run a manufacturing facility, are performed by many different computers or programmable devices. Computers are assigned specific tasks to perform such as data collection and storage, alarm monitoring and processing, supervisory control, operator interfaces, and special application processing.(8)

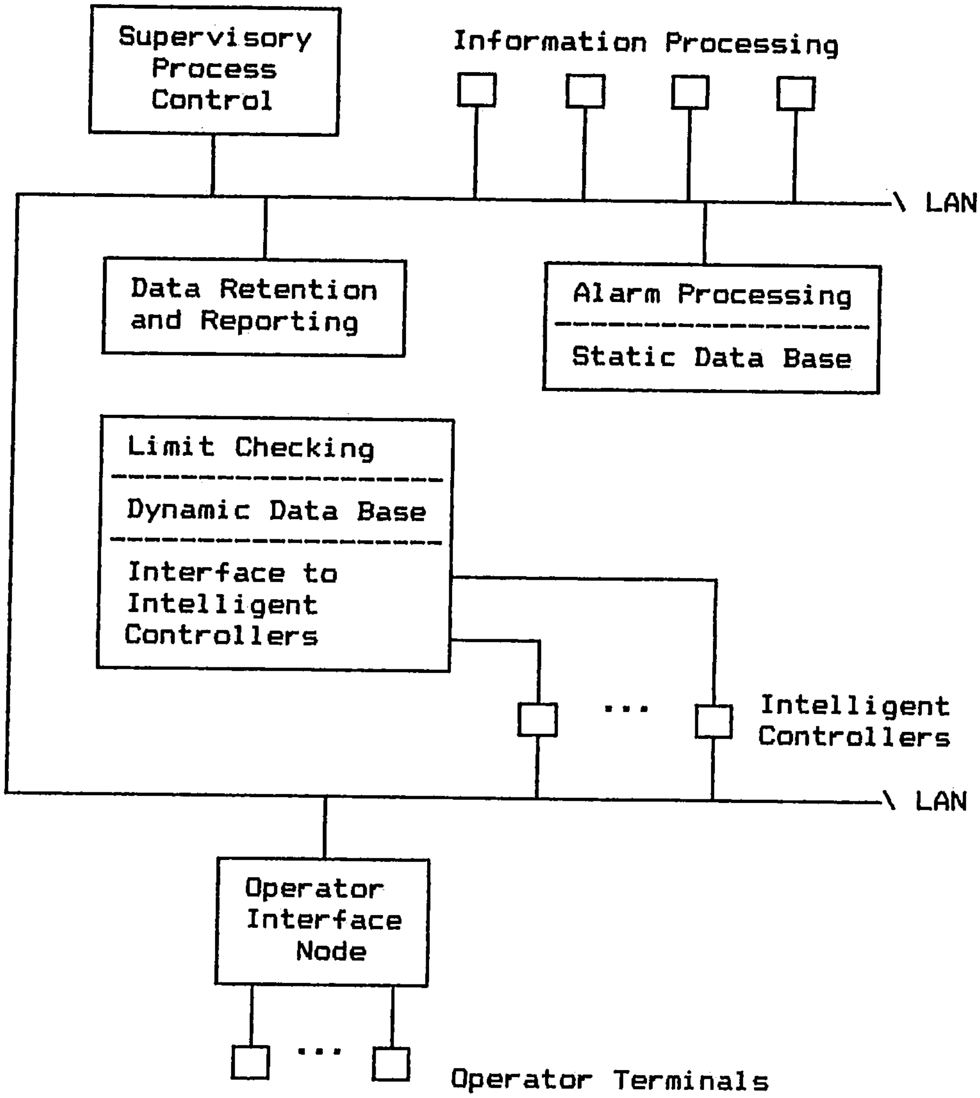


FIGURE 13 - DISTRIBUTED SYSTEM ARCHITECTURE

There are three basic advantages of a distributed system: Reliability, improved responsiveness, and flexibility.

A distributed system is more reliable than a host type system because, should an actual failure occur, only a small area will be affected. And, since critical operations reside in smaller processors, redundancy may be accomplished in a cost effective manner.

Responsiveness of the network is increased because no bottlenecks exists in the flow of information. Secondly, operators may communicate directly with the plant floor. Information handling system may gather data as needed from the source. Data, therefore, travels on an as-needed basis, thereby cutting down congestion.

Distributed systems are flexible because of the physical modularity of the distributed system dictates a functional modularity. Such systems are easier to configure to the specific needs of a facility and can be altered more easily. Modularity means that alterations of software and hardware of existing sub-systems are not required for expansion.

Despite the advantages of a distributed system, there are two potential difficulties with such an architecture. In a distributed system, the communication network is critical to its proper operation. Secondly, by its very nature, a distributed system has more equipments than does a host type system. To some extent, this may imply increased maintenance costs, but generally, the opposite is true. Smaller processors are generally easier to maintain than large computers. Furthermore, any node may be taken off line for maintenance without degrading system operation.

Hierarchical Control Architecture

While a distributed system may have many advantages over a host type control architecture, most network designers are in favor of implementing a hierarchical control architecture. The need for more processing power has force a new way of looking at manufacturing control.

The process of controlling a manufacturing system can be divided into seven hierarchical levels. Each level represents a distinct area of factory control:(25)

Level 1 - Actual equipment or process being controlled

Level 2 - Electromechanical devices used for control

Level 3 - Machine/equipment controllers

Level 4 - Real-time manufacturing, movement and storage control.

Level 5 - Control: Responsible for implementing the controlling and scheduling work planned by Level 6; including shop floor , purchase and distribution schedules.

Level 6 - Detailed planning: MRP, capacity, distribution requirements planning.

Level 7 - Corporate or factory master planning and control; long range planning results are passed down to Level 6

An control architecture which can perform the necessary tasks at the various levels have been suggested by the National Bureau of Standards.

<u>NBS Hierarchical Control Architecture</u>

The NBS hierarchical control concept consists of three parallel interconnected hierarchies. The first is called behavior-generating hierarchy which performs task decomposition. The second hierarchy is called sensory-processing. This module provides the hierarchy with information about its environment. It accomplishes this task by collecting, processing, and formatting sensory data. The last hierarchy is called world-model. This hierarchy generates expectations and predictions for the sensory-processing modules at each level.(1)

The control concept operates in the following manner: First, the input goal/task is entered into the behavior-generating module. This module will decompose the required goal/task into subtasks to be accomplished by the next level of behavior-generating module. The task decomposition is accomplished based upon the sensory data input provided by the sensory-processing module, and the status of the hierarchy at the lower level. Once the behavior-generating module outputs a command/goal for the next level, the command is also sent to the world-model module. The world-model module will take this command/goal and predict the expected sensory response. This prediction will be base upon past experience and previous programmed information/algorithms. This prediction will be passed to the sensory-processing module on the same hierarchy level. The sensory-processing module will then evaluate the sensory inputs based upon this prediction, thus reducing the sensory processing time.

The software system of these modules are base on state tables. Given a specific task, a set of states are defined. And, for each state, there is a corresponding action to be taken. Therefore, when a task is given to a module, the module's software goes to a state table library, where the proper state table is selected. Then, based upon the state of the operating environment, the proper command is determined and executed. Please note that, the state of the operation environment various from level to level, and contains the internal state of the processor (i.e. pointers, stacks, flags, etc.) and the external state relevant to that particular level (i.e. sensory data, lower level status, etc.).

Advantages and Disadvantages

Although the NBS hierarchical control concept was originally developed for real-time control of robot system, the concept can be applied to various other control needs as well, such as factory control. To determine the best area of application, the advantages and disadvantages of the concept must be understood. The following is a partial list of the advantages and disadvantages of the the NBS hierarchical control concept:

Advantages

1. Allows for real-time control.
2. Have a deterministic response time.
3. Allows for distributed processing.
4. Allows for concurrent processing.
5. Reduction of control effort through

task decomposition.

6. Ease of software modification, debug and expansion.
7. Ease of system modification and expansion.
8. Any computer system can be developed into a hierarchical system.
9. Geographical distribution is unlimited.

Disadvantages

1. Reliability is questionable.

   System operation is reduced with single point failure. The failures become more serious the higher up the it occurs. That is the computers or nodes below the failure points will be inoperative.
2. State tables are difficult to program
3. Data base interface and control are difficult
4. Real-time control limited by computer processing speed and the number of hierarchical levels
5. Implementation of system may be costly
6. Leading Edge Technology, no experience base available at present
7. State table programming requires that the identification of all possible conditions in which system may face.

CHAPTER 6 - DATA BASE SYSTEMS

The heart of Computer integrated Manufacturing is a sound data base. The data base must be capable of aggregating data independent of the order in which it is stored, the proximity of information, and even the physical location of the data. This capability will allow the different manufacturing operations to share product and process data readily. The process of sharing data is, of course, the main thrust of CIM. In order to make the correct decisions about data base design and implementation, some fundamental concepts should be understood. Since data base technology is one of the fastest growing area of computer and information science, only the CIM related concepts of data base technology will be covered.

WhAT IS A DATA BASE

A data base is simply a repository of related information. Software and hardware components are used to allow intelligent devices to store and retrieve information stored in the repository. Safety interlocks are installed to insure the integrity of the stored data.

In a typical enterprise, the various operational information are collected, transformed into binary format, and stored on magnetic media. The software and hardware used to perform the necessary storage and retrieval of data, is part of the data base system. The system is composed of four major components: Data, Hardware, Software, and User.

The data component is the pieces of information which is to be stored and retrieved. In some systems, the data are stored into one or more data bases. These data bases are then integrated into a single data base system.

The hardware component consists of the physical storage devices such as disks, tapes drives, drums, etc., along with the associated electronics necessary to control and operate the various storage devices.

The software component of a data base is the logic which performs the tasks necessary to interface the hardware devices with the user's requests and desires. The most common name given to the software component of the data base system is the Data Base Management System or DBMS. The main functions of the DBMS is to allow for easy storage and retrieval of information, while insuring the security and integrity of the stored data. The function of a DBMS system depends upon the physical data structure used, and the overall data base architecture.

The last component of a data base system is the user. The user is any person, device or system which interacts with the data base system for the purpose of either storing or retrieving data. How an user interacts with the DBMS to store or retrieve data is a very important issue in the design and implementation of a data base system. The DBMS is the only link users have to the data being stored in the system.

WHY USE A DATA BASE

Manufacturing is an information intensive operation. Information is both required and being generated at the various processes. Traditionally, the production manager was the repository of manufacturing knowledge. He knew exactly what was required to manufacture any part. The ability of the production manager to use his knowledge for decision making, however, was limited. When the conditions, in which his shop operated, changed, he will be at a loss. For example, if asked what are the impact of adding new products to his manufacturing line, or the impact of raw material delays, he may not be able to supply an adequate answer. If the knowledge of the production manager were in a data base, the answers to those questions are readily available.

A data base system provides a company with centralized control of its operational data. This control allows better decision making, through the use of simulation, or historical data analysis. Centralized control also provides a quick and easy mean for sharing data among different users, a prerequisite toward data driven automation and CIM. The ability to share data among the different manufacturing operations can provide many benefits, such as reduce manufacturing lead-times, scraps, and machine setup times, among other things. For example, reviews of previous product designs can improve design efficiency by eliminating design duplications.

DATA BASE REQUIREMENTS

The establishment of a data base can provide centralized control over a company's most valuable asset, the operational data base. How a data base is designed, however, is very important. A well design data base can help facilitate the exchange of information, while a poorly design system can make data exchange difficult. The following are the basic requirements for a well designed data base:(3)

1. Reduce the amount of redundant data.
2. Reduce the amount of inconsistent data.

3. Establishment of data standards.
4. Increase data security.
5. Maintain data integrity.
6. Allow for the sharing of data.
7. Data independence.

Reduction of Redundant Data

Data redundancy means that one or more copies of the same data exist. This duplication of data may cause a problem with maintaining data integrity.

In a CIM environment, uncontrolled duplication of data may cause a great deal of problems. Computer Integrated Manufacturing is an environment in which the data processing operation is distributed over a wide area. Many different devices may require access to the same piece of data for decision making or process control. Disastrous results may occur when one device access one set of data for process, while another device uses a different set. Computer Integrated Manufacturing rely heavy on the use of shared data to keep the system in synchronization, and under control. The following is an example of what can happen if redundant data is not controlled.

A product specification states that a hole should be drilled through the center of a part. Based on that part specification, manufacturing engineering developes a NC program. Meanwhile, the product engineering department decides to change the part specification. They decide to offset the hole to the right by one inch. The updated specification is stored in the engineering data base. Now, since manufacturing engineering maintains their own data base, their product specification remains unchanged. Since the mating piece to this part is being produced by an outside vendor, manufacturing engineering is unaware of the change. The vendor, however, receives the updated product specification, and produces a suitable mating part. The problem remains undetected until final assembly when the two parts does not fit. By this time, a great deal of time and money have been spent.

The above example was given to illustrate the potential problems of uncontrolled redundant data. Data consistence and integrity are crucial to the proper operation of CIM. The existence of uncontrolled redundant data is unacceptable in a CIM environment.

Uncontrolled data redundancy can be eliminated through the use of centralized control. This means the elimination of locally maintained data bases. The elimination or reduction in the amount of redundant data would increase the overall data storage capacity of the organization, and improve data integrity.

The elimination of redundant data in a CIM environment is very difficult. In many manufacturing operations, quick access to certain information may be crucial to the process. This response time requirement may require that a copy of the data be stored locally. Maintenance of the local data now becomes a problem. The problem, however, is not insolvable. For example, the local data base can be used as temporary storage area. All data residing in the local data base are downloaded during the start-up procedure of the operation, thereby insuring that the most up-to-data information is constantly being used. Also, all updates are downloaded to the local data base immediately after being received.

Reduction of Inconsistent Data

The elimination of uncontrolled redundant data will greatly reduce the occurrence of data inconsistencies. Since there is now only one copy of the information, most users can be assured that the data they receive are consistent with what their counterparts are receiving.

Since the elimination of redundant data is very difficult, the possibility of inconsistent data exists. The occurrence of data inconsistency will most likely occur during data updates. For instance, if the central data base is in the process of updating the local data files, while data is being accessed, two or more users may receive different versions of the same data. This is particularly true if the central data base has already updated a portion of the local data bases.

The above situation can be eliminated by locking out all requests for data while updating is in progress. This solution, however, may be unacceptable. Time critical process requiring access to important data may not be able to wait for the completion of the update process.

Establishment of Data Base Standards

The problem of needing an established standard, described in Chapter 1, applies for data base systems also. Standardizing data storage formats is particularly desirable as an aid to data interchange. The establishment of data format standards will allow different applications to both access and understand the retrieved data. Without the use of standards, different application programs may have access to the data, but will be unable to use it because the data format is foreign to the application program.

At present, many organizations are working on establishing a standard for data bases. The standardization activity can be associated with six classes of organizations:(22)

1. Data Processing professional associations (ACM, DPMA, BCS, CIPS).
2. Professional associations with strong data processing aspects (AICPA, IIA).
3. Developmental and user groups (CODASYL, SHARE, GUIDE, JUG).
4. Groups specifically developing and approving computer standards (ECMA, ANSI X3 (CBEMA)).
5. National government bodies (National Bureau of Standards).
6. International government bodies (CCITT, ICA, etc.)

With the lack of national or international data base standards, the enterprise should take the initiative and develop a company standard. A company data format standard will allow different divisions to exchange data readily.

Data Security

The ability to control access to sensitive information is a very important consideration in data base design. An adequate data security system should be designed into all data base systems. The security system should be able to control both access to and modification of sensitive information.

The need for a good security system is very important, especially in a CIM environment. The distributed data processing environment of CIM makes data security much more difficult.

Data security can be implemented in three ways. The first is to install a password and/or a data encryption algorithm in the DBMS, since the DBMS must process all data requests. The second method involves the use of a hardware key. Whenever the DBMS receives a request for accessing sensitive information, it checks to see if the requesting device possess the necessary hardware key. If it does, then the request is processed. If not, a security violation is logged, and the request is denied. The third security system involves the combined use of hardware and software. For example, the sensitive data may be stored in an encrypted format and the only way to decipher the code is through the use of a decoding circuit installed in specially designated devices.

Data Independence

Data Base Management Systems allow users to access information without having to know the location and format of the data in question. DBMS accomplish this task by separating the logical and storage structures of data. As a result, the way in which data is physically stored is totally independent from accessing programs. The same data can, therefore, be shared by different programs. This characteristic is called data independence.(22)

DBMS accomplish this interfacing task through the use of schemas. There are three major schemas levels presently defined by the ANSI/SPARC committee on DBMSs. The schemas are external, conceptual, and internal.(14) The external schema describes the user point of view. The conceptual schema describes the organizational or enterprise point of view. And, the internal schema describes the access paths to the data. When a data request is received by the DBMS, it is passed through the different schema levels. By mapping the external schema to the conceptual schema, which in turn, is mapped to the internal schema, an access path to the data can be determined.

The concept of DBMS and schemas are much too complex to be covered in this thesis. The reader is therefore, referred to the suggested reading section for additional readings on the subject.

The development of a data base system, to meet the above criteria, requires the understanding of both the data system architecture and data structures.

DATA BASE ARCHITECUTRE

There are two common approach to organizing a data base: Centralized data storage, and distributed data storage.

Centralized data storage implies that all of the data bases are placed in a central location. Access to the data bases must go through a central data base management system.

Distributed data base systems may be achieved in two ways. This first is to have a central data base administrator with the physical data base hardware distributed throughout the plant. In this type of system, all requests for retrieving or storing data must pass through the central data base administrator. The administrator will then route the request to the appropriate data base.

The second type of distributed data base is to have a data base administrator for each data base system. Requests for data retrieval or storage goes to the local

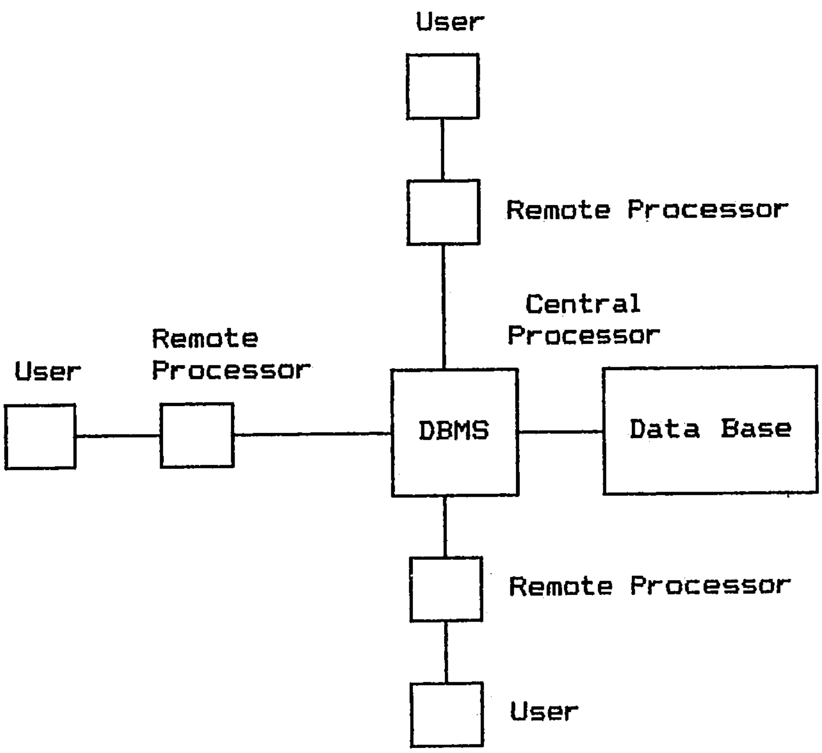


FIGURE 14 - CENTRALIZED DATA BASE SYSTEM ARCHITECTURE

data administrator. The local administrator will first search its data base. If the requested data is not found, it begins a search routine throughout the network, contacting the other local data administrators for the desired data until it is found.

Whether a company should implement a centralized or a distributed data system depends largely upon the type of data stored, and the application requirements of the different users or systems. For most Computer Integrated Manufacturing systems, a distributed data base would be the most suitable.

CIM is a distributed data processing environment, in which large quantities of information are processed, shared, and stored. The distributed nature of CIM tends to favor the implementation of a distributed data base. It is often desirable to store data where it is required, than to store the data in a central location. Centralized data base in a distributed system means that communication costs will be greater, and the response time slower.

Another factor of CIM which makes distributed data bases more favorable is the amount of information flowing through a CIM system. According to one estimate, the disk space required to store the information used in an average sized manufacturing plant is around 100 trillion bytes. In other words, the amount of disk packs required is large

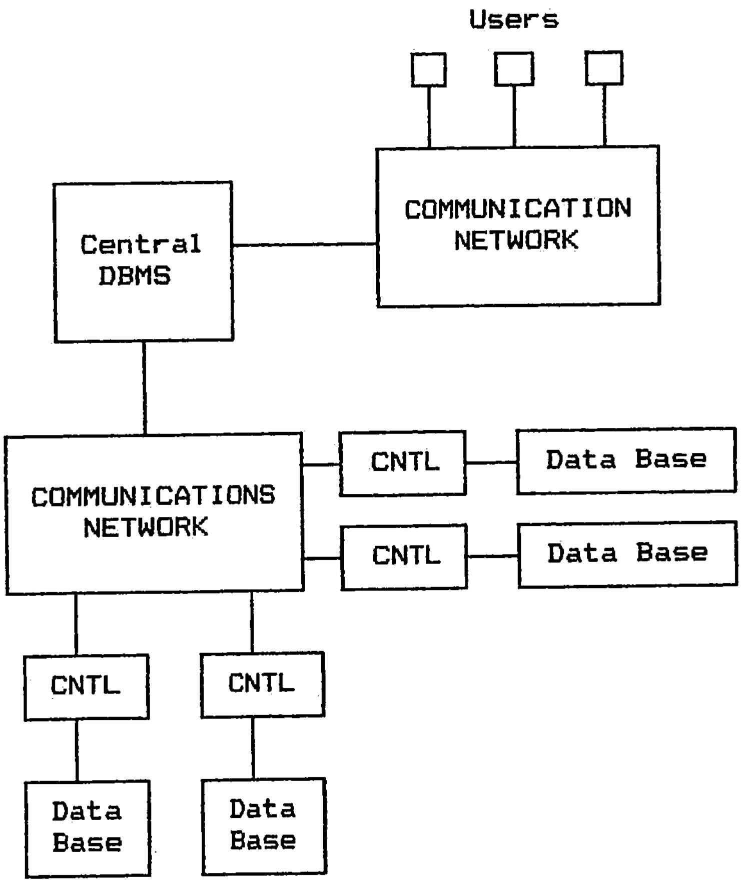


FIGURE 15 - DISTRIBUTED DATA BASE SYSTEM ARCHITECTURE WITH A CENTRALIZED DBMS

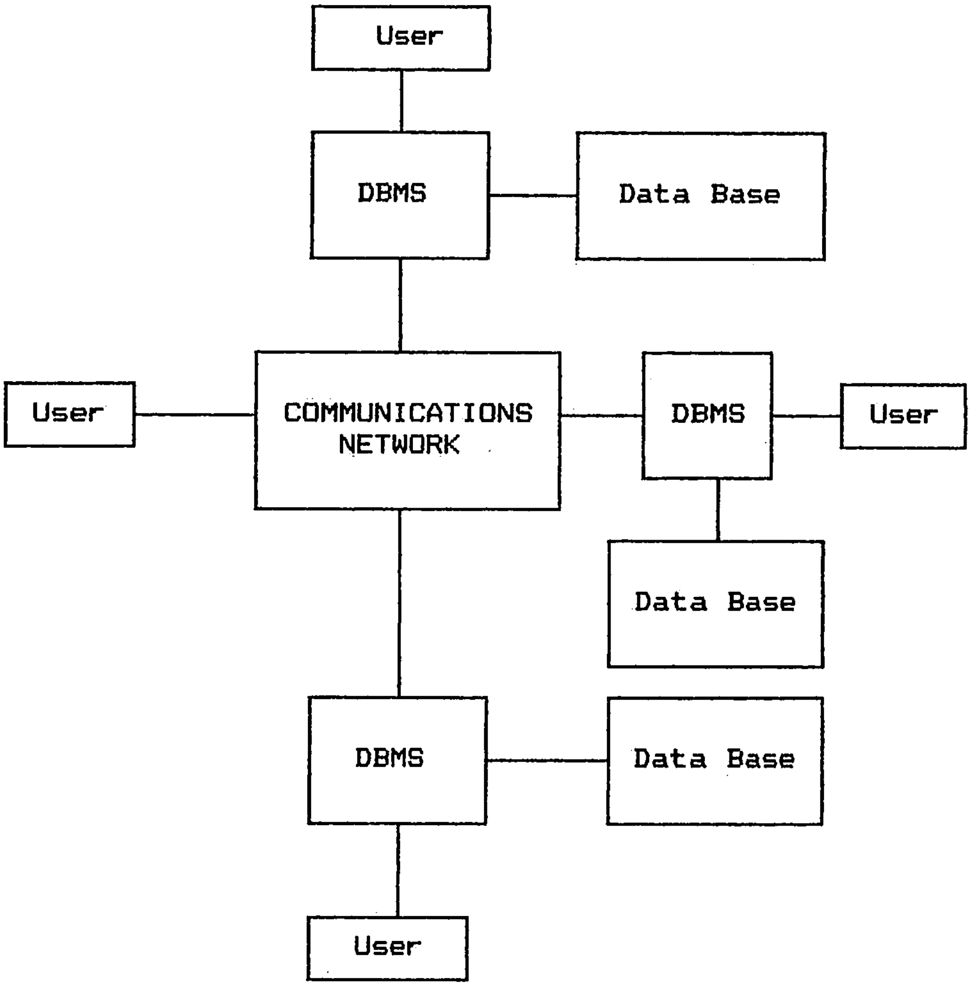


FIGURE 16 - DISTRIBUTED DATA BASE SYSTEM ARCHITECTURE

enough to cover a football field to a height of 40 feet.(13) It is, therefore, inconceivable to believe that any organization would dedicate all of the necessary floor space for the sole purpose of data storage. Most likely, the data base would be distributed over a wide geographically area. Some of the reasons for using centralized and distributed data base are given below.

<u>Reasons for Centralizing Data</u>

A property of data that argues strongly for centralization is that the data are being constantly updated and referred to by multiple users in different geographical locations.(16)

Other properties of data that favor centralization is bulk. If the data occupy a sufficiently large volume such that the economies of scale favor the use of large storage units, then the data should be centralized. This argument is valid up to a certain point. Floor space is a company asset and should therefore, be included in the overall data base system cost. Another reason for centralization is security. Highly protective measures can be more readily and economically be used to control a centralized data base.

Another strong argument for centralization is if the data have to be searched as a whole. The process of search all of the distributed data bases may be too time consuming to be practical. Again, this argument is valid up to a point. To determine the overall response time savings of a centralized data base over a distributed data base, the communication time must be included in the calculations. It may be possible that the data search time is much lower in a centralized data base, but the communication time will bring the overall response time to such a high level, that the distributed data base was faster. The reduction in storage overhead, and thus increase storage capacity is another reason for centralized data storage.

Reasons for Distributed Data

In most cases, it often better to store the data where it will be used. There are some properties inherent in certain types of data which lead naturally to distribution.(16)

The main property for distribution is that the data will be used mainly at one location. Another reason for distribution is that the data is required for critical operations requiring immediate access to the data. The time required for data request to and transmission from the central data base may be too long for the real-time application. The use of distributed data bases will also reduce the impact of equipment failure at the central data base. In a central data base system, if the data base administrator malfunctions, the entire data base system is out of commission. In a distributed data base system, if one of the local data administrator fails, the other data bases and their associated DBMS can still continue to function.

Distributed data base systems have a number of serious problems associated with them. While these problems have solutions, it is often desirable not to have unconstrained distribution and replication of data. The problems are:(16)

1. Interference between updating transactions
   Two transactions may be updating the same data item on a remote storage unit and can interfere with one another giving incorrect data. This may be prevented by appropriate locks or protocols.

2. Inconsistent reads
   With more than one copy of data, inconsistent information can be obtained when reading the data. Sometimes, due to timing problems, the data read can be invalid. The copies of data

may be at different version level due to recent updates.

3. Dead lock

   The locking of distributed data to prevent update interference could cause deadlocks unless appropriate, and fairly complex protocols are used.

4. Protocol overhead

   Unless carefully thought out, the protocols used to prevent invalid updates, inconsistent reads, and deadlocks can incur excessive overhead, especially when multiple copies of data are used.

5. Recovery

   Recovery after a failure needs to be controlled so that updates are not accidentally lost or double processed.

6. Recovery of multiple copies

   When multiple copies of data exist, they may be at different states of update after the period of failure. They have to be brought back to the same state, but it may be complex to do this while the data bases are on-line. Taking the data bases off-line may be too disruptive.

7. Different data representation
   Because of lack of data administration or firm management control, the same data are represented differently in different locations.

8. Auditing
   It is difficult on some distributed systems to find out who did what to the data. Appropriate design for auditability is needed.

9. Security and privacy protection
   Security controls and privacy protection are sometimes poor on distributed systems and need to be built into the basic design.

At present, research is being conducted to determine a method of overcoming some of the major problems with distributed data bases. One key area of research is in DBMS design. The use of different types of schemas are presently being investigated. Again, please refer to the suggested readings section for further details.

DATA STRUCTURES

How data is stored in a data base is referred to as the data structure. The way data is structured can have great impact on the overall performance of a data base system. There are many ways in which data are stored in a data base. Only the three most commonly used data structures will be discussed.

Relational Data Structure

A relational data base is one in which the data is arranged in the form of a matrix, with the rows of the matrix forming each individual record in the data base, and the columns of the matrix forming the individual fields of information, across all records.(5)

The relational data structure, as the name implies, represents a relational view of the data. The approached used in relational data structure is based on the realization that data files obey certain constraints. By considering these constraints as mathematical relations, the elementary relations theory can be brought to bear on the various problems data management problems.

One of the major advantages of the relational approach is its simplicity. The end user do not have to be concerned about the physical storage structure. Instead, the users can concentrate on the information content of their data and not worry about the physical storage details. The ability to use the data base without knowing the about how the data is physically stored is called data independence. Because there is no positional dependency between the relations, request do not have to reflect any preferred structure and therefore, can be nonprocedural. In other words, data independence means that changes to the way data is physically stored will not affect the ability of different application programs to access and use the stored data. If data independence does not exist, then changes to the way data is physical storage will affect how the data is to be accessed. Application programs must, therefore, be modified before they can access the data in its new physical state.

At the present time, only a few data base management systems based on the relational data model are commercially available today. As a result, detail studies on the performance of relational data base system have not been conducted to the same degrees as for systems based on the other data structures. As more relational data base systems are used, the amount of performance data will increase. When sufficient performance data have been accumulated, the performance of DBMS based on relational and other data structures can be compared. Presently, however, the question of whether relational data bases can operate efficiently on a large scale remains unanswered.

Hierarchical Data Structure

A data base using a hierarchical data structure organizes data in a hierarchical tree structure. A hierarchical tree structure is made up of nodes and branches. A node is a collection of data attributes describing the entity at that particular node. The highest node of a hierarchical tree structure is called the root.(3)

In a hierarchical data structure, the level of the nodes depends on their distance from the root node. A node at a higher level is called the parent of all the nodes one level beneath it. The nodes, one level beneath the parent node are called the children.

Every node except the root has to be accessed through its parent node. In order for nodes at the same hierarchical level with the same parent to exchange data require the nodes to first pass the information up to the parent before it is passed to the designated node. Since nodes can only be accessed through its parent, the deletion of the parent will subsequently, result in the deletion of the associated children.

The major advantage of the hierarchical data base structure is the existence of proven data base management systems that use the hierarchical data model as the basic structure. The relative simplicity and ease of use of the hierarchical data model and the familiarity of most data processing users with a hierarchical data structure is another advantage. Data base performance can be determined through the examination of the predefined relationships. That is, by knowing the path in which a specific data request will have to take, the total access time can be accurately estimated.

The disadvantages of a hierarchical data base are a result of its strict hierarchical ordering. Since accesses to children nodes can only be achieved through its parent, redundant data are stored. Also, as a result of the strict hierarchical ordering, the operations of insertion and deletion become unduly complex. Deletion of parents results in the deletion of children. As a result, users have to be careful in performing deletion functions.

Network Data Structure

In a network data structure, data is represented by records and links. Like the hierarchical data structure, a record has a parent or superior. But unlike the hierarchical data structure, a record may have any number of immediate superiors or dependents. It is not limited to just one superior as in a hierarchical data structure. The network approach thus allows the user to model a many-to-many correspondence more directly than does the hierarchical approach.(3) The network approach also make use of a new record type called a connector. The connector record provides the association between the various record entities. The relationship between the various records are therefore, chained together by the connector.

The network data model has been in use since the early 1960s. It is therefore, a very well established and developed technology. Data base systems based on this data model have the benefits of past experience. The network data model is a variation of the hierarchical data model and as such, possess some of the same advantages and disadvantages of hierarchical data bases.

A major difference between the two data models is the ability of the network data model to have an infinite number of superior and dependent records. This difference increases the network data model's ability to model the many-to-many relationships more effectively.

This modeling ability is also the source of the prime disadvantage of the network approach, its complexity.

Another complication with this data structure occurs when the data base is reorganized. If improperly implemented, reorganization of the data base may cause the loss of data independence. A very serious problem. The main cause of this potential problem is related to the complexity of the data structure. To avoid this potential problem requires that great care be taken during the reorganization process.

CHAPTER 7 - CIM IMPLEMENTATION ISSUES

In the previous chapters, the reasons for implementing CIM, along with some of the basic CIM technologies and concepts were introduced. In this chapter, the specifics of how CIM can be implemented will be addressed.

The chapter is divided into two sections. The first section provides a general overview of the steps necessary for the proper implementation of CIM. The second section identifies the technical details which must be addressed during the implementation process.

Implementation Basics

The process of implementing computer integrated manufacturing (CIM) is a very complex and resource intensive operation. To undertake and manage a project of this scope requires that a well structured formal approach be followed. One such approach is listed in the Implementation Steps section.

The first step in the process of implementing CIM is to examine and model the present manufacturing operation. This initial examination is done for three very important reasons. The first reason is to determine whether CIM should be implemented. In most cases, the answer will be an unreserved "YES". The second is to establish a basis for comparison and progress measurements. The last reason is to identify the problem areas.

In today's competitive market place, most company executives are unaware of how the manufacturing facility is operating. A detail study of the present operations will improve the top executives' understanding of the capabilities and limitation of their manufacturing plant. This understanding will enable the executive to determine if the company's manufacturing facility is capable of achieving the strategic objectives being set. A honest assessment of the company's competitiveness, in both the present and in the future, can determine whether CIM is needed or not. Top management must understand that, while a company may be in a highly competitive position at present, the competition will not stand still. The competition is always working to improve their position. Therefore, any company that stands still will be at a disadvantage in the future.

The understanding of the present operation will not only benefit top executives. It will benefit the line managers as well. The fact that line managers are in constant contact with the present operation, can make the managers less sensitive to what is happening around them. They get into the habit of doing everything the same old way, they lose their ability to question. In fact, the prospect of change may become more disturbing to the line manager than to the top executives. The line managers may therefore, become an unwilling obstacle to innovation.

An initial investigation of the present operation also serves another important function. It can identify the weak points and trouble spot of the present operation. Once the weak points and trouble spots have been identified and ranked according to severity, an action plan can be developed. Based upon this plan, the order of CIM implementation should be established.

The final reason for doing the study is to establish a base for comparing the implementation progress to. The establishment of a base on which to look back upon serves two basic purpose. First, it provides feedback to everyone involved with CIM implementation. This feedback will show the people involved with CIM how much they have accomplished. Studies have shown that feedback is very important to keep employee moral high. The second purpose of establishing a base is to allow top management to evaluate the true benefits of CIM. Comparing the present capabilities and limitations with the past allows management to truly determine both the tangible and intangible benefits.

IMPLEMENTATION STEPS

After a company has decided to go ahead with CIM, the next step in the process of implementing CIM is to develop a plan of action. The following are the basic steps which should be included into that action plan:

1. Project Definition
   - Define the boundaries in which the project will be covering.
2. Investigation
   - Identify what are the present and projected future function of this area.
   - How are the functions presently being accomplished and why.
   - What type of information is required for the performance of this function, and in what format and frequency.
   - What type of information is generated during the performance of this function, and in what format and frequency.
3. Analysis
   - Does this area meet it objectives?
   - How can this area be improved?

- What are the trouble spots?
- How does the information flow?
- What are the security requirements?
- What are the communication requirements?

4. System Specifications
   - Specify the information requirements of the system.
   - Develop a information flow diagram.
   - Select the most appropriate network architecture, control strategy, and data base scheme for the system consistent with the factory network specifications defined in the strategic plan.
   - Identify the future requirements of the system, and migration paths to meet those requirements.
   - Identify the security requirements of the system.
   - Identify the system maintenance and support requirements of the communications network.

5. Management Review and Approval
   - Inform management about, and obtain their approval for the system specifications obtained in step 4.

6. Preliminary Design

7. Feasibility Study

8. Management Review and Approval

   - The final management review before starting on the detail design of the system.

9. Detail System Design

   - Contingencies should be designed into the system initially to overcome any potential problems.
   - A method of increasing communication network throughput should be developed to handle the any future capacity requirements.

10. System Build and Installation

11. System Debug and Evaluation

   - Evaluate the initial performance of the system as compared with the expected system performance. The sources of any discrepancies should be found to prevent any future problems.

12. Operation, Maintenance, and System Performance Monitoring

In the process of achieving the various tasks outlined above, consideration must be given to both technical and organizational issues.

TECHNICAL CONSIDERATIONS

In the process of implementing CIM, certain technical issues must be addressed. These issues, if not addressed initially, will have to be addressed during design. The following are some of those issues.

DATA BASE SYSTEMS

How will data be stored and controlled throughout the entire factory is an important and difficult issue to resolve. The type of data base strategy selected for the factory will determine how the various subnets or LANs should be connected, and how much data transfer will be necessary for the operation of the factory. As previous discussed in Chapter 6 of this thesis, each of the various data base strategies have their advantages and disadvantages. The selection process, therefore, must be done based on the present and projected data requirements.

The selection of a data base structure should begin with an examination of the present data base structure, and the various application software being used. Remember, the ultimate goal of a CIM data base structure is data independence. That is, changes in the data format will not effect the operation of application software accessing the data.

One step toward data independence is the establishment, and strict enforcement of a corporate standard for data storage. The standard should identify how various types of data should be stored. The use of this type of standard will allow various application programs, and computers to share data.

The development of information flow diagrams can help in the understanding the overall data requirements of the factory. The establishment of an appropriated data base strategy requires the understanding of the different types of information generated, and required by the various manufacturing operations.

In the initial study of the present manufacturing operations, the data requirements of each operation should be noted. The type of information, where it came from, and in what form (computer print outs, paper tape, hand generated notes, etc.). The type of information generated at each operation should also be identified. Again, the type of information, where is it going, and in what format should also be noted. From these information, and the overall information flow diagram, a data base strategy can be developed. The use of a centralized or distributed data base system does not automatically exclude the use of the other. A hybrid data system can be used, and should always be considered. In all organizations, some of the data generated and used will have characteristics which gravitate toward centralization, while other will migrate toward decentralization.

NETWORK TOPOLOGY

Identification of the factory network architecture will provide the required factory network specification for the subnet or LAN designs.

The specifications of the factory network architecture will allow for the design of subnet or LAN gateways or bridges to the main factory network. It will also allow for response time calculations of data request outside of the subnet or LAN.

Issues which effect the selection of network are reliability and availability, performance, migration and growth potential, and overall system cost.

Network reliability is an index of the failure rate of the total network. And, network availability is an index of the percent of time the network is operational. Both of those indexes are influenced by some important network capabilities:

1. The ability to detect, isolate, bypass inoperative, failed or intermittently failing

device.

2. The ability to protect the transmission path from external electrical interference and noise.
3. The ability to detect and bypass a break in the transmission channel or path.

A networks migration and growth potential is a measure of how well an existing system can be converted into the desired network configuration. It is also a measure of the capabilities of the network to meet the long term communication needs of a company. The technology of the network must be flexible enough to provide for as yet unknown changes in communication technology.

The overall cost of a network is dependent upon the cost for material, initial installation, connection techniques, on going maintenance, and modifications. The cost of a network is also dependent upon whether a system can be developed using off-the-shelf hardware and/or software. The number of computers and/or programmable devices to be used in the system, the amount of memory required in each node of the system, and the bandwidth of the communications link.

The overall performance of a network is a function of the overall throughput, response time, and network reliability. Other specific measures of network performance are application specific, and thus, are not mentioned. A critical factor in establishing the overall throughput of a network is the type of transmission technology being used.

TRANSMISSION TECHNOLOGY

What type of transmission technology should a factory use? Broadband (Analogy) or Baseband (Digital) or may be a combination of the two? To answer these question, an examination of the response rate and throughput requirements for each project should be undertaken. Comparison of the requirements with the capabilities of the various transmission technologies should provide the answer.

In order to make the proper decisions as to which transmission technology should be used, some basic factors effecting the performance of broadband and baseband systems should be known. The following are some of those factors:

Analog or Broadband

Analogy or broadband transmission technology requires the use of an analog radio frequency modulator/demodulator (RF modem) to allow the attached devices to receive and send data on its assigned frequency. By means of a switchable or multifrequency RF modem, devices on different frequencies can communicate. Control logic, however, must be incorporated into the modem to control the switching from one frequency to another. Devices on different assigned frequencies cannot communicate with each other without the additional frequency translation equipment.

The throughput on a broadband system is determined by the bandwidth capability of the transmission medium. The broader the bandwidth, the higher the throughput. Broader bandwidth will also require a higher quality of cable, which will increase the overall cost of the network. Increasing the bandwidth, will also increases the total amount of devices and/or communication channel that can be accommodated by the network.

Communication on a broadband system will require the use of analog amplifiers, placed at strategic points along the network, to force the signal down the length of the network. The broader the frequency used, the more expensive the amplifiers.

Digital or Baseband

In a digital or baseband system, many types of transmission media can be used. And since the data are transmitted in digital form, no modems are required. Transmission across long distances are not amplified, but regenerated. Regeneration can reduce transmission errors.

Data transmission on a baseband system are multiplex through the use of time division. That is, each device is given a specific time slot in which to send data on the communication channel. The use of this type of protocol, can accomindate a number of devices can be use for transmission or reception of data without the need for additional equipment. The total number of devices supported will depend on the number of time slots available.

<u>Comparison of Technologies</u>

Both of the transmission technologies are well known and developed. Selection, therefore, must be based upon the merits of each technology. The following is a list of the advantages and disadvantages of both technologies:(10)

<u>Advantages</u>

BROADBAND

1. High throughput capacity
2. Supports communications over a wide range of frequencies. That is, it can support

the transmission of video and digital data over the same transmission medium.

3. Able to connect large number of equipment on the a single communication channel.
4. The development of semiconductor modems have greatly reduced the cost of modems.
5. More resistant to transmission noise.

BASEBAND

1. Computers operate on digital signals. Therefore, no additional equipment is necessary for communications.
2. Recent advances in digital transmission technology, namely fiber optics, have reduced the throughput advantage of broadband circuits.
3. Are able to use a wide range of transmission media.
4. Installation, device connection, and control of communication traffic are all less expensive for digital networks than for analog.
5. Use of signal regeneration, instead of amplification, reduces the amount of transmission error rate.

Disadvantages

BROADBAND

1. Modems are required for each device on the network.
2. Requires the use of additional equipment for devices on different assigned frequencies to communicate.
3. The bandwidth is highly dependent upon the quality of the transmission medium used, thereby limiting the selection of suitable cables.
4. Transmission speed is slower than that of baseband systems.

BASEBAND

1. Prone to transmission noise
2. Time division multiplexing limits the amount of devices which can be attached to the network to a smaller number than with broadband.
3. Communication is typically unidirectional.
4. Distance between regeneration stations is shorter than the distance between amplifier for broadband systems.

The selection of a transmission technology will depend upon on how well the advantages and disadvantages of the two technologies fit within the overall CIM plan. Other factors which will effect this selection are network topology, and transmission media.

Transmission Media

The types of transmission media offered today are: (10)

1. Twisted pair
2. Shielded multiple twisted pair
3. Coaxial cable
4. Twinaxial cable
5. Mixed media
6. Broadband cable (CATV)
7. Fiber optic link

TWISTED PAIR

Unshielded twisted pair is the most widely used form of copper wire cable. It is suitable for voice frequency and low frequency data communications. The transmission rate of this medium is between 64Kbps to 512Kbps (thousands bits per second).

Advantages

1. Mature, well understood technology
2. Skill levels required for connection are

readily available.

3. Installation is quick and easy.
4. It is the lease expensive transmission medium used today.

Disadvantages

1. Medium is subject to external electromagnetic interference.
2. Medium is only capable of low data rate transmissions.
3. Crosstalk between adjacent wires can produce transmission errors.
4. Medium is subject to external electromagnetic interference.

SHIELDED COPPER WIRE

There are several variations of this type of transmission medium. They are shielded twisted pairs, twinaxial cable, coaxial cable, broadband cable (CATV). Of these different variations, the most common are the shielded twisted pair and the coaxial cable. The transmission rate for the group range up to 10 Mbps (Million bits per second).

Advantages

1. Mature technology
2. Skill levels required for device connection are readily available.
3. All are quick and easy to install, with the exception of CATV cables.
4. Media are immune to most electrical interference and crosstalks.

Disadvantages

1. High grade coaxial, twinaxial, and CATV cables are relatively expensive.
2. CATV cables are thick and rigid, requiring special tools for installation around curves.

FIBER OPTICS

Fiber optic cables are typically selected for their very high transmission speeds. The cables are made from two different types of glass; one making the inner core, and the other the outer layer. Since each type of glass have a different index of refractance, light entering is prevented from escaping from the side of the cable. Fiber optic cables are encased in protective sheaths, which also provide structural integrity.

Advantages

1. Capable of high transmission speed, around one trillion bits per second.
2. Immune to electrical interference, crosstalk, or corrosion.
3. Can propagate transmission signals over long distances without the need for boosting.

Disadvantages

1. State of the art technology.
2. Skill levels required to connect devices are not widely available.
3. Connection to devices is more expensive than for conventional transmission media.
4. Communication path is unidirectional. Bidirectional communication, therefore, requires two lines.
5. Fiber optic cables cannot be tapped. It is, therefore, useful only in point-to-point topologies.

The specific transmission medium most suitable for a network will depend upon whether the network uses digital or analogy transmission techniques, and the specific bandwidth requirements. Analog transmission technology requires a medium capable of handling wide bandwidths. Typically a coaxial or CATV type cable. Digital transmission technology has a wider selection of suitable media. Shielded twisted pair should be satisfactory for most communication across short distances. For long cable runs, the coaxial medium provides increased transmission speed and reduced line loss. For applications requiring very high transmission speeds, the clear choice is fiber optics.

Because of the amount of cable used in a communication network, the cost of cables is a very important factor. Cost, however, should not be the dominant factor in media selection. Selection should be based upon the performance requirement of the overall network.

Beside selecting the proper transmission technology and media, the topology of a network is very important. The following is a comparison of the advantages and disadvantages of the most common topology types: (Please review Chapter 3 on topology for the descriptions)

STAR TOPOLOGY

Advantages

1. Cabling is easily modified to accommodate changes and moves.
2. Defective nodes are easily detected and isolated.

Disadvantages

1. Uses the most amount of cable.
2. Failure of the central controller disables the entire network.

BUS TOPOLOGY

Advantages

- Uses the least amount of cable for interconnection. This is because it provides the most direct route between devices.

Disadvantages

1. Requires a means of bidirectional traffic control along the bus to prevent collisions of simultaneous transmission.
2. A break in the cable cannot be easily detected.

RING TOPOLOGY

Advantages

1. A break in the cabling can be readily detected.
2. Communication control is simplified because the ring is unidirectional, and is a closed circuit.
3. Distance covered by the network can be greater because each node regenerates the signal to full strength.
4. Topology lends itself to the use of fiber optics because of it unidirectional nature.

Disadvantages

1. Modifying the ring layout to accommodate changes may be difficult.
2. Uses more cable than bus topology, but less than the star topology.

STAR - RING TOPOLOGY

Advantages

1. A break in the cabling can be readily detected and by-passed.
2. Cabling is easily modified to accommodate changes and moves.
3. Defective nodes are easily detected and isolated.

4. Communication control is simplified because the ring is unidirectional, and is a closed circuit.
5. Distance covered by the network can be greater because each node regenerates the signal to full strength.
6. Topology lends itself to the use of fiber optics because of it unidirectional nature.

Disadvantages

1. Uses more cable than bus topology, but less than the star topology.

Depending on how the various design attributes are weighted, one or more of the network topologies can be selected. Generally, it is not necessary to consider all of the various possible architectures. The pros and cons of the transfer strategy, control method, and path structure will usually provide a clear indication of the most attractive solutions.

The complexity of network design has stimulated computer manufacturers and software vendors to provide computer assisted network design software tools. The capability of these design packages range from simple systems that store and compile network statistics to complex traffic simulators, design configurators, and software for data distribution modeling. The purchase price of these software packages also vary widely; from free use to corporate customers, up to $50,000.

The following is a list of some commercially available network design packages:(26)

AT&T	INOS	- Interactive voice & data design tool
	NERCE	- Network response time & configurator evaluator
	CIRGEN	- Circuit Generation
	GRINDER	- Graphical Interactive Network Designer.
	Note:	Use of the above network design software are free of charge to corporate customers on a limited basis.
CONNECTIONS	NDS	- Network Design System. Works on an IBM personal computer. Approximate cost: $4,000.00
IBM	CNDP	- Topology analysis
	3270FIVE	- Network performance analysis and simulation.

Note: Use of the above network design software are free of charge to corporate customers on a limited basis.

TECO RESEARCH Data Network Optimizer

While there are lots of network design software on the market today, most of them were designed to analyze wide area networks, ie telecommunications. Most of these packages, however, can be modified to deal with local area networks. As local area network systems become more common place, more and more software design tools will be available.

Never the less, before selecting a software design package, network planners should consider the following factors:

1. Ease of use, and the amount of training required.
2. Software operation interactive or batch.
3. Types and number of design models supported.
4. Readability of output.
5. Amount of vendor support and consulting.
6. Ease of updates, for network changes.
7. Ease of usage, parameter inputs, help menus, etc.
8. Protocols supported.

9. Modifications available to support customer requirements.

NETWORK CONTROL

After all of the various components of CIM are installed, a method of controlling and monitoring the function of the integrated network must be established. But since a network control strategy will inadvertently, have an impact on how the various subnets and LANs will operate, the control strategy should be establish as soon as possible.

The hierarchical control concept is an excellent control architecture for real-time control of process equipments, test equipments, and certain manufacturing processes. Therefore, the hierarchical control concept suggested by the National Bureau of Standards should be examined closely. At the present time, however, the application of hierarchical process control should be not exceed the cell control level for the following reasons:

At this level, the processing power required by the hierarchical control concept can be furnished by microprocessors. And, since the cost of microprocessors are falling rapidly, the implementation cost of such a system will be practical and cost effective. At this level, the disadvantages associated with this control concept can be addressed with minimal effort. The complexity of implementing this control strategy decreases as the level of implementation decreases. For example, the problem of data base interface and control can be localized to the cell computer, thus reducing the data base control over head. The number of interconnection and relationships is also proportional to the number of levels in a hierarchy. And, when dealing with Leading Edge technologies, it is best to minimize the complexity of implementation to ensure success. The response time of the control system will also be increased by reducing the number of levels in the hierarchy. Similarly, the amount of effort required for state table programming will also be reduced. It is important to note that while the complexity of implementation will typically be reduced with the level at which the concept is implemented, there are exceptions. The actual process will dictate the amount of complexity associated with implementation. It is also important to note that this control concept is Leading Edge technology and, as such, is un-tested. There are still a lot of unanswered questions. For example: How should the various modules be designed and programmed. How should/can the system cope with failures.

The NBS hierarchical control concept has progressed far enough, however, to be seriously considered for real-time control of certain process which requires a great deal of real-time sensory data processing. Present implementation of the control strategy will, most likely, take a lot of effort and time. The end result may be similar but not necessary the same as the NBS's.

ADDITIONAL CONSIDERATIONS FOR TECHNOLOGY SELECTION.

In selecting of a network architecture, a transmission technology, a control strategy, and data base strategy, the following item must be considered: (10)

- The network to be installed will have an useful life of 10 to 30 years.
- The network must be responsive to both current and future communication requirements.
- The network must be able to provide an economical and orderly migration path from existing systems.
- The present state of communications technology.

CONCLUSION

As foreign competition increase, U.S. manufacturers will have to look toward new manufacturing technologies for assistance. The premier manufacturing technology is Computer Integrated Manufacturing, or CIM.

While CIM has become a industrial buzzword, its meaning is often misunderstood. To assist in the understanding and implementation of CIM, the concepts, technologies, and implementation basics were introduced.

The magnitude of the topic, CIM, necessitated that only the basic supporting technologies be covered in this thesis. The supporting technologies covered were Network topology, Communication protocols, Network control, and Data base systems. To help in understanding of how the various components and technologies of CIM interrelate, the structure of CIM was discussed in Chapter 2. While this thesis has presented the basics of CIM, much more remains to be done by those who follows.

The concepts, technologies, and implementation issues of associated CIM technologies should also be examined in detail. Associated CIM technologies have an impact on the overall success of CIM systems. One associated technology, which has a great impact on CIM, is Group Technology.

Group technology, or GT, is a very integral part of CIM. Presently, GT is used either for CAD drawing retrieval, or for machine cell layout design. Group Technology should be applied as a means of describing parts in a form that can be integrated readily into a computer data base structure thereby linking design and production. This approach will create both a compatible and economic basis for evolution of computer automation in batch type manufacturing.

As future developments in manufacturing technology progress, more generative and evolutionary systems of GT should be studied and implemented in all areas of manufacturing.

In an attempt to provide some coverage of the associated CIM technologies, Appendix B was included. Appendix B briefly examines the basic concepts of group technology, computer aided process planning, and expert systems. Other, equally important, associated CIM technologies are Flexible Manufacturing Systems (FMS), Continuous Flow Manufacturing (CFM), Material Requirements Planning (MRP II), simulation, robotics, material handling systems, etc..

Aside from the technical issues previously described, CIM related organizational issues should also be examined in detail.

The importance of organizational support to the overall success of CIM can not be under estimated. It is the foundation on which successful CIM systems are built. The interaction between the traditional organizational structures and CIM needs to be examined in detail. Implementation of CIM requires that the traditional organizational structures be modified. Departmental ownership and control over the different manufacturing activities will be totally eliminated by CIM. As Computer Integrated Manufacturing is installed, the departmental boundaries will begin to blur-or-vanish. While this is good for the overall efficiency of the company, it can cause a great deal of resistance and resentment.

An investigation into how a company should be organized to carry out the implementation process should also be done. The complexity of the task requires that some sort of organizational structure be established. The organizational structure must allow for control and coordination of the different CIM activities. At the same time, it must be flexible to changes, and be conducive to creativity. The organization must also allow, and encourage end user participation. The end user must be made to feel and believe that the completed CIM system is theirs. For without the support of the end user, the system will ultimately fail.

Once CIM has been installed, the question of how to manage the system arises. How should the various activities within the system be monitored, coordinated, maintained, and controlled? Who should have ultimate responsibility over CIM? Should a single person or a committee be responsible for the system? How will future projects be implemented? These are just some of the questions still left unanswered.

Besides the organizational issues, the question of how should CIM and related project be financially justified still has to be answered. Despite the inappropriateness of using ROI for measuring economical feasibility of new technology investments, no other measuring method has been proposed. Companies will, therefore, continue to use ROI. This lack of other suitable financial measurement tool will cause many companies to turn away from implementing CIM. A new financial measurement technique is, therefore, desperately needed.

At present, CIM is still in its infancy with many technical, organizational, and financial issues still needing to be resolved. As it progress, the benefits and capabilities will surpass present expectations. CIM will, in the future, be the main stay of U.S. manufacturing companies. It will allow the United States to become competitive, once more, in both the national and international market place.

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APPENDIX A - ORGANIZATIONAL ISSUES

Aside from the technical issues discussed in Chapter 7, there are organizational issues which must be addressed for CIM implementation. The following are some of those issues.

TASK FORCE ORGANIZATION

After the decision to implement CIM is approved, the next step should be the development of a formal organization responsible for the task. The reasons for the creation a formal organization are as follows:

1. To establish accountability and responsibility.
2. To provide a method for the allocation of tasks, responsibilities, and authorities.
3. To provide a method for coordinating and controlling project efforts.
4. To provide a method of communicating within the project group.
5. To define and assemble the required skills at the right time.
6. To provide for end user representation and participation in planning and implementation.

7. To provide a method of communicating between the end users and management.
8. To provide a clear separation of the technical and administrative skills needed in the project

The CIM task force organization should be structured into three hierarchical levels. The top level is the Planning Committee, which has overall responsibility for the entire planning and implementation effort. The next level is the Project Management Group. This group will be responsible for the daily management of the entire CIM effort. The last level is the Project Team Members. These are the people who are performing the required tasks for CIM implementation.

To understand how the organization will operate, the responsibilities of each group will be explained.

Planning Committee

The Planning committee is the main governing body of the CIM implementation project. It is responsible for:

1. Establishment of a master CIM plan
2. Development of short and long range plans.
3. Resource allocation.
4. Definition and recruitment of the required skills.

5. Initiation of feasibility studies.

6. Project status monitoring.

7. Management reports and interface.

The Planning Committee should be composed of technical experts, members of management, and end user representatives from the projected impact areas. The inclusion of end users serves two purposes. One, the users will be able to provide valuable insight on how the present operation actually works, and ways of improving the present operation. Secondly, inclusion of end users into the planning process provides the users with a sense of ownership. No automation project can succeed without the backing of the end user. The inclusion of end users on the planning committee will improve user acceptance, and therefore, improve the chances for success.

Once the members of the committee have be established, upper management should appoint a committee chairman, who will have overall responsibility for the project. Next, the ground rules of committee operation should be establish. The ground rules of the committee must be specific enough to define the tasks, responsibilities, and authorities of each committee member. A description of the committee decision making procedure should also be included. The use of group consensus to make important decisions will insuring that all of the relevant issues will be discussed. Secondly, group consensus will show the people with the minority viewpoint the group's viewpoint, and thus, embark a sense of fair play. Research in the area of group dynamics have shown that best results were obtained if a group consensus was defined as the agreement of at least 75% of the total membership. In cases where no group consensus can be obtained, the committee chairman will make the final decision.

To accomplish the tasks for which the committee is responsible for in an effective manner, the committee should be divided into sub-committees each responsible for a specific task. To manage the sub-committees, sub-committee chairmen will be appointed. At periodic intervals, each sub-committee chairman will provide progress reports to the entire committee, along with sub-committee recommendations. Differences and decisions should then be resolved and made at those meetings.

Project Management Group

The Project Management group are comprised of project manager, and team leaders. This group is responsible for the daily administration of the various project tasks.

The project manager is the person responsible for the daily operation of the project. Some responsibilities of the project manager are tasks such as resource allocation, budget preparation, and team member performance evaluation.

The team leaders have the overall technical responsibility for the project. Some responsibilities of a team leader are technical leadership, design and specification reviews, development of design approach, and advising the project leaders on technical issues.

Project Team Members

The last part of the task force organization is the project team members. These individuals are the technical experts necessary for the actual planning, design, and implementation of the CIM systems. Since the required implementation task will vary from phase to phase, along with the skill requirements, the team members will vary from phase to phase. Selection of the individual team members should be based on their technical skills and experiences. The selection process is the responsibility of the Planning Committee. One important thing to remember is that all task force members should be held accountable only to the task force. All previous reponsibilities must be terminated (with exceptions given to true emergencies).

PLANNING

The key to a successful CIM implementation, as with any complex operation, is a good plan. The formulation of a plan for a large and complex operation as CIM implementation, requires that the plan be developed in two sections. The first section is strategic planning, and the other is tactical planning. The steps necessary for the development of either a strategic or tactical plan is basically the same. The difference is in the amount of detail analysis required.

The purpose of the strategic or master plan is to provide a set of objectives for CIM. It should be detailed enough to describe what the factory will look like, but flexible enough to accommodate to changes in technology, and business. The strategic plan should also define how the system will evolve from its present state to the final state of CIM, as specified in the master plan.

The tactical plan on the other hand, must be a very detailed implementation plan. The development of operational budgets, determination of skill requirements, resource allocations, establishment of project schedules, technical approaches and problem solving, etc. will all be based upon the tactical plan.

Strategic Planning

The development of a strategic plan requires that the following steps be taken:

1. Business Considerations

   The development of a strategic CIM plan must take into account the needs of the business. That is, the CIM plan should be integrated into the overall business plan. Listed below are some of the questions which must be answered before a sound strategic plan can be developed.

   a. What are the corporation's strategic business objectives?

      Determining the direction of the corporation will allow CIM implementation to take place so that it is both compatible and complementary to the anticipated change. As the progress of CIM implementation continues, this process should be iterated.

   b. What factors will be key to the success of the corporation in the future?

This question may define the minimal requirements of your CIM system. It can also provide a direction for future design considerations. For example, if the labor cost of a company is growing so rapidly, that it might reduce the competitiveness of the company in the future, the company knows that it must cut back on its labor costs. One way to do this is through automation. This would mean that work cell controllers, and their requirements must be considered in the overall CIM plan.

c. What is the evolutionary path of the company's product line?

The purpose of this question is to ensure that the CIM system will be compatible with the possible future products of the corporation. Due to the length of implementation, and the long useful life of CIM systems, this question can identify how, and where flexibility needs to be built into the system.

2. Organizational Considerations

a. What is the short term and long term

impacts of CIM on the organization?

This question has two purposes. The first is to identify any need for additional manpower. For example, the present organization skill base and projected workload need to be examined to determine if new employees are required for CIM. The second purpose is to determine if the present organizational structure can accommodate a CIM system (typically, the answer will be "no"). If the answer is no. Then, it is time begin to think about restructuring the organization gradually, so that when CIM is fully implemented, the organization is able to handle it effectively.

b. What additional training is required? For whom and How soon?

The immediate benefit of this question is the identification of the present skill level pool from which to draw the CIM implementation task force members. It can also identify the areas in which outside consultants may be required. The questions also identifies the training requirements for all of the employees which will be eventually effected by CIM. By understanding the training requirements, a suitable CIM implementation plan can be developed.

Beside building up the skill base of the company, the training program should also be used to inform the employees as to what CIM is and how it will affect them. Used for this purpose, training should be given to every company employee. The purpose of the orientation is to gather the support of the employees, without which, the project may be doomed to fail.

c. Are the current physical facilities adequate?

Can the present facility accommodate CIM? If not, what is required. If yes, what are the design restriction?

3. Information Gathering and Analysis

The purpose of this step is to gather as much information as possible about how you present organization function. For the strategic planning phase, the information you collect need not be in great detail. You will be repeating this process for each of the various implementation phases, but at a much more detailed level.

Here is a non-inclusive list of type of information you want to obtain:

- Identify factory functions
- Define the purposes/goals of each function
- Identify the information necessary for each function.
  - -- Identify the sources of the required informations.
  - -- Identify the information outputs of the function, and the targets of those information.
- Identify the timing requirements of each.
- Identify the cost associated with the operation of each function.
- Identify the storage requirements of each piece of information. (Daily vs Achieves)

4. Develop goals and objectives for CIM

Once you have determined the basic technical approach to CIM, you are now ready to develop a list of the goals and objectives for your CIM system.

The purpose of this step is to develop a set of generalized CIM specifications, which will meet your goals and objectives. From those generalized CIM specifications, a factory network description can be developed. It is from this description and the generalized CIM specifications, that a CIM implementation plan can be developed. The CIM specifications and the factory description will be used to identify the communication network requirements of each area, and how the various areas will relate to the rest of the factory.

5. Development of an implementation time table

   Once the above step have be accomplished, you should be ready to develop a CIM implementation time table. Since CIM implementation is such a large and complex task, the implementation time table should be limited only to the identification of the projected start and end time of each implementation phase.

CONTROL

Once the strategic and tactical planning have been completed, the next area of concern is project control. How should the implementation projects be controlled?

The two major activities in project control are the collection of project information, and the interpretation of that information. In the proposed project organization, the flow of project information will be from the bottom up. The collection of project information, therefore, will be gain at the task members level and move upwards. With each level summarizing the previous level's reports, while adding its own status information.

The task member should provide periodic status reports to the project management groups. The project management group should then summarize the status reports into phase status reports, including the various financial data required by the planning committee. This information then should be presented to both the Planning Committee and the Project Advisory Board. The Planning Committee will then present upper management with the necessary project status reports on a regular basis.

APPENDIX B - ASSOCIATED CIM TECHNOLOGY

Computer Integrated Manufacturing is composed of two major areas. The first is the technologies necessary for the achievement of CIM. An introduction to those technologies were given in the previous chapters. The other area is the associated CIM technologies. In this area, the technologies deal with how the information are processed and used to maximize the potential benefits of integration. Some technologies in this area are Group Technology (GT), Expert Systems, Computer Aided Process Planning (CAPP), Simulation, etc.

Due to the large number of associated CIM technologies, only Group Technology, Computer Aided Process Planning,and Expert Systems will be reviewed.

GROUP TECHNOLOGY

Group technology or GT is the technique of identifying and classifying parts according to similarity in operation process or geometrical shape in order to take advantage of their shared attributes. It is, in effect, a coding and classification system.

Group technology is not a new concept. It has been practiced in various forms and degrees for many years around the world. GT implementations, in many instances however, were primarily limited to certain segments of manufacturing. It has been used for designing machine cells and for the retrieval of designs from CAD systems. The limited use of GT reduced the overall potential benefits of this technology. Recently, with the emphasis on manufacturing systems, companies are applying GT concepts as a part of the total manufacturing system, from design to production.

The reason for implementing GT is simple. It provides some very good benefits. A study, done by Subodh Chandra Sharma, on the different types of coding and classification systems indicated that substantial benefits can be derived from implementing Group Technology. In general, the benefits which can be realized by companies that implement GT are as follows: (27)

- Productivity	25% to 80% increase
- Average manufacturing time	9% to 33% reduction
- Man Power	16% to 30% reduction
- Design duplication	3% to 9% reduction
- Drawing release time	70% reduction
- Number of drawings required	3% to 8% reduction
- Set-up time	30% to 70% reduction

- Jigs and fixtures	up to 25% reduction
- Scrap	up to 40% reduction
- WIP inventory	up to 36% reduction

The study also concluded that the amount of benefits which can be achieved depends largely upon how GT was implemented, and the type of coding and classification system used. Understanding the requirements of a suitable coding and classification system, as well as, knowing how to implement GT is very important to the overall success.

Coding and Classification

The main purpose of GT is to collect and group different parts into part families. A part family is simply a collection of related parts which are similar because of geometry, shape, size, function, or because they share similar processing requirements. Parts are considered similar, with respect to processing, when the sequence of operations, machines, and tooling required to produce the parts are similar.

Formulating part families or groups is often the most difficult step in implementing GT systems. There are three basic methods for forming part families:(34)

1. Visual inspection

Although it is very simple, it has the obvious draw backs when considering the large number of parts.

2. Production flow analysis
   This process involves the formation of part families based upon the examination of routings or operation sheets. The primary drawback of this method is its heavy dependence on the accuracy of the routing or operation sheets.

3. Classification and coding
   This method groups items by their similarities and separates them by their differences. Afterwards, a significant number or code is assigned to each item or family of items. The scheme is to divide the population into manageable sized families of items with attributes in common. This method is ideally suited for computerization.

The development of a classification and coding system is not easy or intuitive. To facilitate the development process, some type of guideline should be developed and followed. While the guideline should be tailored to the specific needs of a company, the following items should be considered: (12)

1. Determine the purpose of the classification.
2. Define the scope, i.e. the population of data to be covered.
3. Analyze the parts to identify the potential attributes.
4. Statistically analyze the part population to determine the desirable family size.
5. Synthesize the classification structure.
6. Analyze the classification and coding system to determine if the basic requirements are met.
7. Repeat the process if necessary.

Aside from the basic requirement of a company, the coding and classification system should also meet the following basic requirements:(12)

1. The coding and classification system should be designed from the user's point of view.
2. It must accommodate all part members and their pertinent attributes.
3. It must be based on easily identifiable and permanent attributes.
4. It must have a mutually exclusive structure.
5. It should be compatible with other systems.
6. It should have properly documented procedures and

glossary of terms and definitions.

Types of Codes

Aside from developing a classification scheme, a coding system must also be developed. Experience with the different types of codes used in the past indicate that there are three fundamental coding principles which should be followed:

1. All numeric codes give fewer errors.
2. Shorter codes give fewer errors.
3. No code should exceed five digits without a break in the string.

The types of codes being used today are monocodes, polycodes, and multicodes.(34)

Monocodes

Monocodes or hierarchical codes are codes where each digit in the coding structure is dependent on the prior digit. A hierarchical code is logically thought of as a tree structure. A hierarchical coding system provides an extensive analysis of the items classified since its code structure is very compact but can contain an enormous amount of information with a rather limited number of digits.

This type of coding system is very effective for data retrieval based on geometrical shape, size/dimensions, etc.

Polycodes

Polycodes are also known as fixed-digit codes and chain codes. In this code structure, each digit position represents independent information and is not directly related to any other digit. Polycodes are less compact than hierarchical or monocodes. Polycodes are said to be more adaptable for production oriented applications in classifying machine tools, tooling, and other process operations.

Multicodes

Most classification and coding systems use codes which are a combination of both. These hybrid codes are called multicodes.

Appropriate and successful implementation of Group Technology will lead to improvements and thus, improve a company's competitive edge. Like all new technologies, however, the economic gains through successful implementation will be achieve slowly. As Group

Technology becomes more accepted, the efficiencies and economic benefits obtained through GT will increase.

PROCESS PLANNING

After a product is designed, an intermediate step is required before it can be manufactured. The production process must be defined. Traditionally, production decisions have been made on the factory floor based on trail-and-error experience, but in today's computer age, a strong movement is under way to let the computer decide.

Computer aided process planning systems use design data, process data, and manufacturing resource data to automatically develop process plans. There are three basic reasons for using CAPP:(34)

1. Lack of experienced process planners.
2. No retention of process logic
3. Inconsistent plans, due to human subjectivity.

Types of Process Planning

There are two basic levels of process plan development: macroplanning and microplanning. In macroplanning, a specific sequence of operations is selected. In microplanning, the details of each process operation is selected. To achieve these different levels of planning, computer aided process planning system utilize either a variant process or a generative process to produce the desired operations plan.

Variant Process Planning

This method creates a new process plan by either modifying a standard plan or an existing plan for a similar part. Standard plans are pre-planned for similar parts and include:

- Major fabrication operations in sequence
- Machine and tool information
- Shop routing
- Work content indication
- Standard plan code

The objective of the variant process planning method are:

- Consistent plans
- Minimum revisions required by planners
- Allow use of lower grade planners
- Grouping of orders for release

Generative Process Planning

This method automatically generate a process plan from design and production data. The generated plan includes all the processes needed to complete a part in sequence and requires only minimal input of specific information from the engineering drawing by the planner. The generative process planning method allows for the following:

- Automatic generation of a process plan using only the data available on the drawings.
- Eliminates all subjective judgmental choices.
- Allows for manual intervention for complex parts.
- Simple to incorporate new process in existing and subsequent plans.
- Provides an interface with other system databases.

At present computer aided process planning systems are still in their infancy. As the technology matures, the potential of CAPP will be tremendous.

EXPERT SYSTEMS

The ultimate goal of manufacturing companies is the development of a totally automated factory in which no humans are required. To approach the goal of totally automated factory requires that computer make decisions presently being done by humans. Any system which is capable of emulating the human thought process is referred to as an expert system. In other words, expert systems are a class of computer programs which uses knowledge and programmed heuristics to solve problems.

Expert systems are developed with the help of human experts who solve specific problems and reveal their thought processes as they proceed. If this process of protocol analysis is successful, the computer programs, based on this analysis, will be able to solve the narrowly defined problems as well as an expert.

Basic Structure

An expert system is composed of three major components:(23)

1. Knowledge base
2. Inference procedure
3. Global data base

Knowledge Base

The knowledge base is source of expert knowledge. It contains the domain facts and heuristics associated with the problem. The most common approach to representing the domain facts needed by an expert system is in the form of situation-action rules. The rules are usually obtained by interviewing experts. The power of an expert system, therefore, is determined largely by the number of rules contained within a system. As the rules are connected together, by association links, to form rule networks, the amount of knowledge increases.

Inference Procedure

The inference procedure describes how the situation-action rules are to be chained together to form a line of reasoning. If the chaining starts from a set of conditions and moves toward some conclusion, the method is called forward chaining.(30) If the chaining starts from the conclusion, and moves towards determine the conditions, and process that lead to the conclusion, this method is called backward chaining.

In a forward chaining systems, the program scans the antecedents of the problem, and determines all rules with antecedents that are satisfied by the contents of the data base. If there is more than one such rule, selection is done by means of a conflict-resolution strategy. Once a rule has been selected, all actions associated with the rule are performed, and the data base changed.

The main difference between the operation of forward and backward chaining is a top-down versus bottom-up style of linking rules together. Although these are the most common control structures for rule-based systems, they are not the only control structures used.

Global Data Base

The last component of an expert system is the global data base in which the problem status, the input data for the particular problem, and the relevant history of what has happened are stored.

Present State

At present, expert systems are still in the development stage. Expert systems, primary in the medical and chemical domains, have been developed. The capability of these systems are, however, still limited. The most knowledge of the existing experts systems is the INTERNIST.(23) INTERNIST is a medical diagnosis system which can diagnosis almost 500 diseases, and contains over 100,000 pieces of knowledge.

In the area of manufacturing, expert systems have been developed in the domain of job shop scheduling, and logistic management.

Current Problems With Expert Systems

While expert systems may be the key to improved productivity, at present, major problems exits. The following are some of those problems:(23)

1. Knowledge base
   The operation of expert systems relies on knowledge data bases which must be created tediously with sometimes millions of specific facts.
2. Program validation
   Methods of validating the complex computer programs have not been developed.
3. Shortage of knowledge engineers
   The field is relatively new, and few knowledge engineers are available for the huge number of potential applications.

APPENDIX C - SUGGESTED READING LIST

Below are some suggestions for supplementary reading, keyed to the chapters of this thesis.

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VISTA

The author was born in the Republic of China on October 8, 1957 to Ren Jen and Chai Yung Sun. In 1964, the author and his family moved to the United States.

The author graduated from Northwood High School in Silver Spring, Maryland in 1975. Upon graduation, he attended the University of Maryland where he earned a Bachelor's Degree in Mechanical Engineering. While at the University of Maryland, the author joined Tau Beta Pi, the national engineering honor society, and Pi Tau Sigma, the mechanical engineering honor society. He was also enrolled in the Federal Junior Fellowship program. The fellowship allowed the author to work at the Naval Research Laboratory during semister breaks as an engineer-in-training.

Upon graduation, the author accepted a position with IBM in Rochester, Minnesota where his most recent assignment was designing a manufacturing process for the automated production of a new computer system.

The author is currently working towards completing the requirements for a Masters of Science Degree in Manufacturing Systems Engineering at Lehigh Universty from the Industrial Engineering Department.