COMPUTER INTEGRATED MANUFACTURING MARKETS

1986 - 1991

INPUT

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Computer Integrated Manufacturing Markets, 1986-1991

COMPUTER INTEGRATED MANUFACTURING MARKETS, 1986-1991

ABSTRACT

Computer Integrated Manufacturing (CIM) as a concept means different things to different people but basically refers to the goal of moving manufacturing from a series of uncoordinated batch processes to a continuum of interrelated, synchronized, real time processes. Many U.S. manufacturers have made the mistake of emphasizing technology and the visible components of automation as opposed to a strategy based on market conditions and a clear vision of the human elements critical to the harmonious and efficient production of quality products.

This report, Computer Integrated Manufacturing Markets, 1986-1991, was designed to provide a status report on the CIM market from both the end user and vendor standpoints. It concentrates on the real opportunities that CIM offers and details market structure. The 1980s have been a period of intense competition, excess capacity, and ferocious price erosion for many. CIM represents an opportunity to regain or increase market share, improve quality, reduce costs, and augment profitability.

This report contains 203 pages, including 49 exhibits.

M-SS1-383

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COMPUTER INTEGRATED MANUFACTURING MARKETS
1986-1991

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COMPUTER INTEGRATED MANUFACTURING MARKETS
1986-1991

EXHIBITS

I INTRODUCTION

I INTRODUCTION

A. CIM DEFINED

- Computer Integrated Manufacturing (CIM) is a misnomer--it refers to the market for integrated manufacturing (which may or may not use one or more computers, but usually does). As a concept it means different things to different people, but generally refers to the goal of moving manufacturing from a series of uncoordinated batch processes to a continuum of interrelated, synchronized, real time processes.

- Earlier market studies on CIM have fallen into the trap of emphasizing technology and the visible components of automation. Unfortunately, U.S. manufacturers have made the same mistake, believing that automation can be a catch-all panacea substituting for good management decisions, a game plan that responds to market conditions, and a clear vision of the human elements critical to the harmonious and efficient production of quality products.

- This is understandable since it is easier to make short-term decisions concerning the purchase of CAD/CAE equipment, MRP II software, or robots than it is to grapple with the redesign of manufacturing processes (and their impact on the people executing them), job content, process interfaces, etc.--all of which have far-reaching, long-term effects and are far more difficult to evaluate in terms of benefits, particularly in the short term.

- There are concrete examples of at least partial successes in obtaining benefit from the automation of nearly every aspect of the manufacturing process. Selective automation is a reality in today's market with today's technology, but CIM and automation are not synonymous and the automation of a poorly designed process has limited value. To obtain significant and lasting improvements in quality, productivity, and manufacturing costs it is necessary to have a long-term vision and strategy for the company.

- This approach allows the company to express its goals in terms of strategic targets such as market share which, in turn, can be articulated in medium-term goals (such as "95% on-time performance to master schedule") and in short-term goals (such as "reduction of manufacturing costs by 30%"). Unfortunately, many prospective users of CIM tend to focus on one aspect of the benefits only (e.g., reduction of labor costs) and try to use conventional parameters such as ROI to determine the validity of the proposed step. It is not uncommon to find that the data required to accurately assess the impact of a CIM implementation are not available; this should not mean that the proposed step should not be taken, although this tends to be the outcome.

- The goal of CIM should be to integrate sales data and forecasts with the process of making business decisions and with the manufacturing processes themselves. The difficulty faced by most users is that without a game plan (strategy) there can be no vision as to what steps need to be taken or what the alternatives are, let alone the order in which those steps should be implemented.

B. SCOPE OF THE STUDY

- This study is designed to provide a status report on the CIM market, from the standpoints of both the end user and the information services vendor who wishes to target the market. The study concentrates on the real opportunities for CIM and details the market structure, size, and growth of each of the main applications areas. In addition, the competitive environment is examined along with case studies of real end-user experiences of CIM implementation compared to real needs. Forecasts for each CIM segment through 1991 are included.

- The study has been conducted at a time when the CIM market is entering its take-off phase both in the U.S. and in Europe. For many industries the late 1980s have been a period of intense competition, excess capacity, and ferocious price erosion. CIM, for most, represents an opportunity to either regain or increase market share, improve quality, reduce costs, and augment profitability. For others, it represents a far starker choice between survival and gradual extinction.

C. METHODOLOGY EMPLOYED

- INPUT interviewed over 120 end users, equipment and software manufacturers, and CIM/manufacturing experts during the period July 1986-October 1986. Their respective roles were :

  - End users: provide case studies of actual CIM implementations, where possible mixing early-stage and late-stage implementations.

  - Equipment/software vendors: provide progress to date in the CIM markets and strategy pursued; forecasts; and competitive views.

  - CIM/manufacturing experts: provide overview/consensus as to the issues faced by vendors and users alike in implementing CIM; market trends; and likely developments in technology.

- INPUT is also conducting a companion study in Europe which compliments the U.S. study. It covers six major geographic markets:

  - West Germany.
  - France.
  - United Kingdom.
  - Italy.
  - Benelux.
  - Nordic countries.

- INPUT welcomes readers comments and queries. These should be addressed to Graham Kemp, Vice President, INPUT, 1943 Landings Drive, Mountain View, CA 94043 or call (415) 960-3990.

II EXECUTIVE SUMMARY

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- This Executive Summary is designed to help the busy reader to quickly review the research findings of this report without having to delve into each section. Each of the key points is summarized as an exhibit with an accompanying script on the left-hand page. This format can also facilitate the use of the Executive Summary as an in-house presentation by using the exhibits as originals for the production of overheads.

- To fully exploit the CIM market, information services vendors need to follow the lead of the manufacturing companies they wish to serve; i.e., obtain their own top management's commitment to CIM and determine the role that the company intends to play in the market (e.g., systems integrator, software house, etc.), and if partnerships with equipment suppliers or other vendors are necessary to penetrate the market, identify the products and services that make up a state-of-the-art CIM system as well as sources for those components that cannot be supplied from internal sources.

- CIM is a single, integrated systems philosophy that does not allow vendors or users to ignore parts of the system (although either may choose to implement only part of the total solution at any given time). The key is to bear in mind the total requirement/solution at all times and to know how what is done today fits that total need.

A. CIM: WHO NEEDS IT?

- There are 268,000 manufacturing plants in the U.S. that ostensibly represent targets for CIM, partial or complete. All of these would benefit from the systems philosophy and unifying thrust that CIM represents. However, the vast majority are small companies that have very small manufacturing lot sizes which are not suitable for the kinds of tools that are offered on the market today.

- The majority of these establishments are discrete manufacturers, and the diversity of their operations is enormous (see Exhibit II-1). They range from very low-volume job shops to very high-volume, repetitive-style assembly plants. The product variety in these plants also varies, from simple to complex. Examples of all of the four extremes are presented in the exhibit.

- The flexibity of these manufacturing operations ranges from high (at the right-hand side of the graphic where volume is high and the diversity of the manufactured product is low) to low (at the left-hand side of the graphic where the volume is low and the complexity of the manufactured product is high). Unfortunately, most plants are on the left-hand side of the chart, whereas most of the software and hardware tools for improving manufacturing control and efficiency are on the right side.

- The number of plants that have more than 200 employees is only 15,000, and since there are 10,000 MRP II installations, the MRP II market is approaching saturation and will become an upgrade/replacement market shortly.

- Thus, while many of the small- to medium-sized plants (representing the vast majority of U.S.-based manufacturing) could benefit from CIM and/or partial automation--and could definitely benefit from improved information handling and flow--the efforts of most of the hardware and software vendors are directed toward the needs of the smaller number of larger plants.

EXHIBIT II-1

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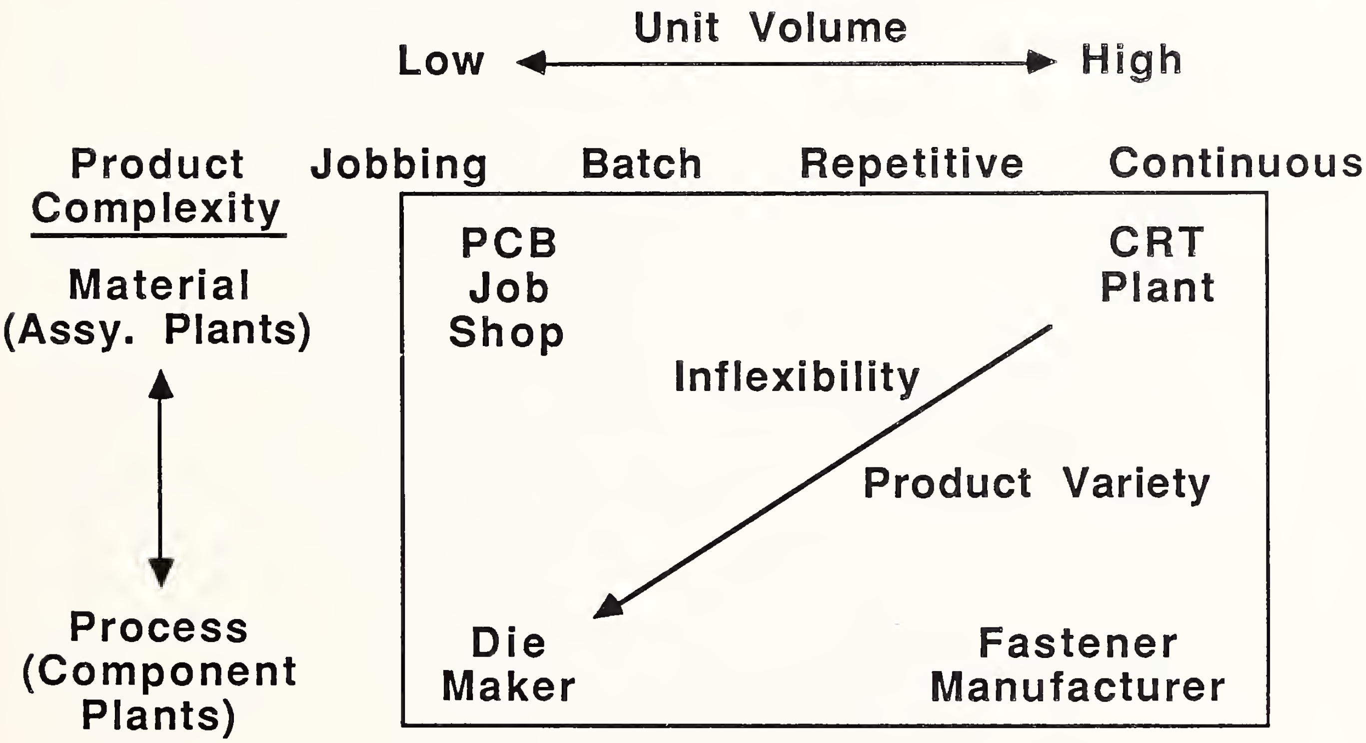
CIM: WHO NEEDS IT?

DISCRETE MANUFACTURING



Source: Anvil Corp.

B. CIM: SYSTEMS INTEGRATION IN MANUFACTURING

- U.S. industry regularly becomes infatuated with new concepts which are initially embraced enthusiastically and then abandoned. In the recent past we have had office automation, banking integration--and now CIM. Most of these concepts are extremely valid and have a role to play in maintaining high levels of productivity as well as improved communications and information flow. But the performance of some of these concepts in the marketplace has not always been acceptable when measured against the short-term goals of most managers.

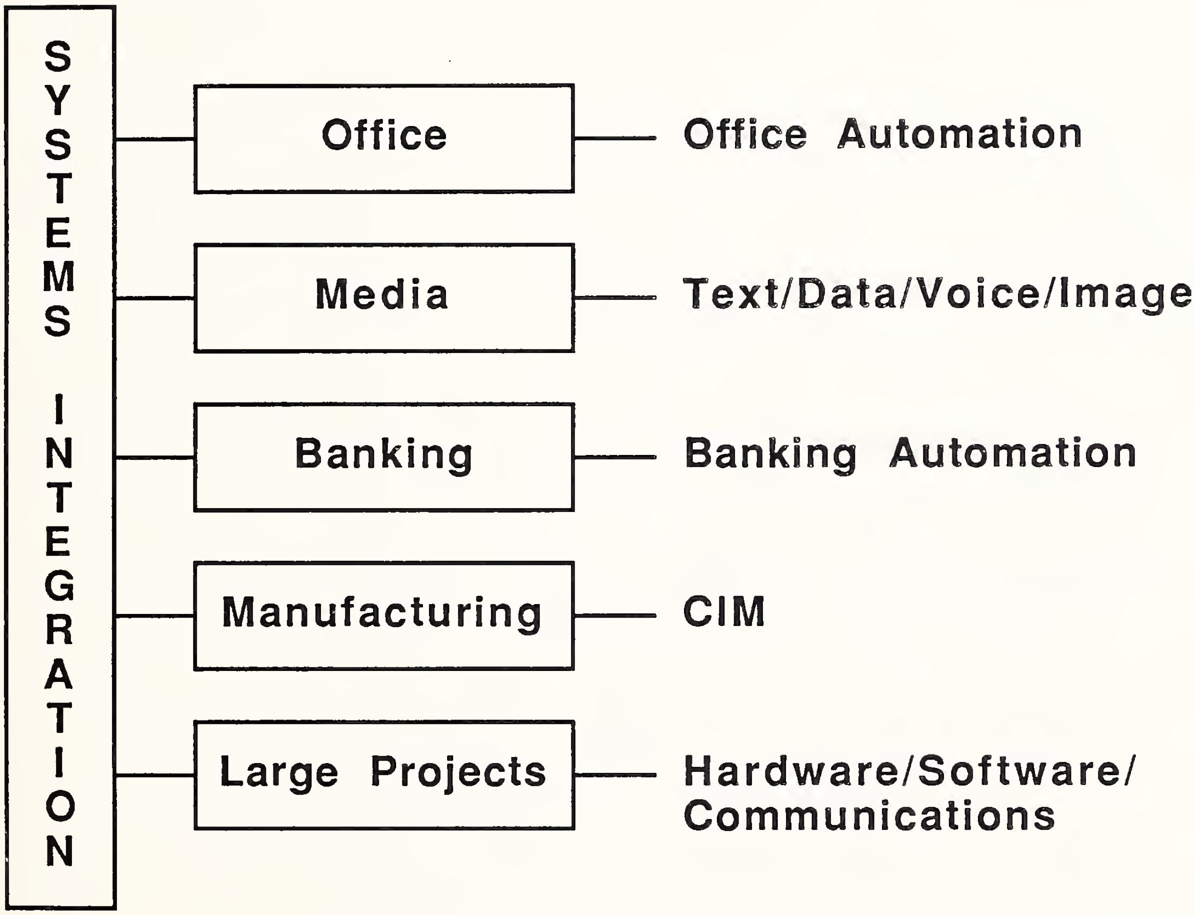
- For example, office automation has ultimately been most successful in selling "islands of automation" such as word processors, personal computers, PABXs, workstations, FAX devices, and copiers, with very little integration between these devices. Similarly, banking automation proved to be a mixed bag--at first it provided a significant market for software vendors (such as Hogan and Anacomp), but then became too complex to implement, causing the vendors to stumble and the banks to hesitate.

- Now we have the opportunity to apply these experiences to CIM. The lesson from the banking and office automation environments is to avoid the temptation of expecting too much too soon and, above all, to implement automation only when the processes involved have been thoroughly analyzed and simplified.

- Systems integration is here to stay--it is the necessary path to an efficient, productive, and cost-effective environment in industry, commerce, and government. In the manufacturing environment it is not an option. Many of today's plants will not survive if they do not achieve a part of the efficiences and cost reductions offered by CIM.

EXHIBIT II-2

CIM: SYSTEMS INTEGRATION IN MANUFACTURING



C. DRIVING FORCES BEHIND CIM

- Over the last five years U.S. and European manufacturers have had to suffer sharp market share declines and drastic price competition on a wide front. Most of this competition has come from foreign products produced by countries with lower labor costs, better productivity, and higher quality products.

- Naturally, the reaction has been been to seek to overcome these competitive advantages by targetting the factors that are perceived to be the cause. For the most part this has been reduced to an effort to diminish the direct labor content of the manufacturing process through automation.

- While it is undeniable that the application of automation has reduced labor content in defined areas, it has not, in general, had the drastic effect hoped for. Indeed, some manufacturers have come to the conclusion that even a total elimination of the so-called "touch" (or direct) labor from current operations would not achieve their goals for manufacturing costs.

- Two areas have emerged as the new goals of the cost reduction thrust: white-collar labor and purchasing. Specifically, there has been a recent push to reduce the layers of indirect labor content (which have been growing as a result of the desire to exercise control over all aspects of the manufacturing process) and to involve up-stream suppliers in the development, scheduling, quality, and just-in-time delivery of parts on a "partnership" basis rather than just competing on a "lowest-price-wins" basis.

- This is still not adequate. CIM means producing and following a company-wide strategy that integrates all aspects of the manufacturing cycle with company goals that target market share, efficiency, and product quality. In other words, it is a continuous, evolutionary process, not a punctual injection of technology or systems.

EXHIBIT II-3

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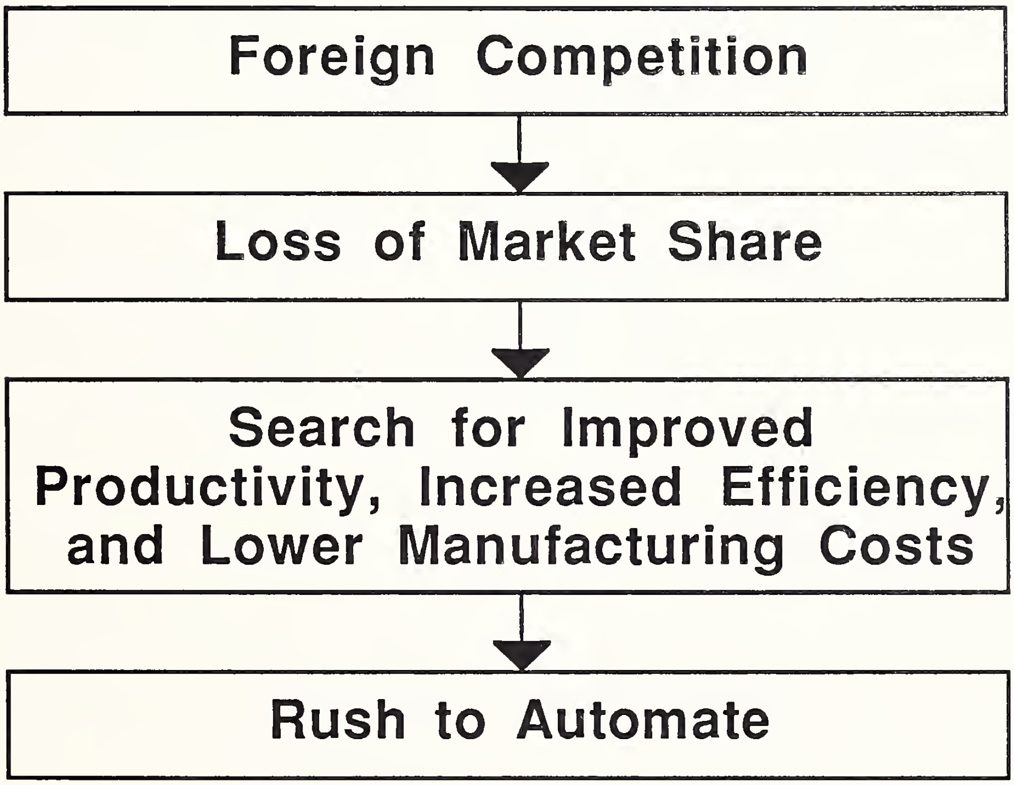
WHY CIM?



D. MANUFACTURING REALITIES IN 1986

- During the last five years a fundamental shift has occurred in the composition of the U.S. economy. For the first time, the manufacturing sector is no longer the most important component; it has been replaced by the services sector. The trend is irreversible.

- Other trends are discernible that affect all areas of manufacturing: product life cycles are shorter, limiting production runs; product diversity has increased, leading to a broader product mix; and higher quality is a requirement and lower cost a necessity.

- If all this was not enough, U.S. Department of Commerce statistics show that over the last 10 months the total U.S. new factory orders has declined steadily for a total decline of $10 billion. Every sector of manufacturing has been affected. Even in those areas where business has not declined, growth has been minimal.

- As market shares have shrunk, the competition for what business there is has increased. This has produced a wave of incentive programs (which generally reduce prices through discounts) and a drive for improved customer responsiveness. The result has been to increase product variety and create further pressure for cost reductions.

- The U.S. manufacturing sector has rarely been under so much stress, and the pressures are not going to go away. Short-term, cost-cutting measures and isolated attempts at automation are not going to provide the answer. What is needed is a complete overhaul of the manufacturing process. The systems integration thrust of CIM provides the framework for accomplishing this.

EXHIBIT II-4

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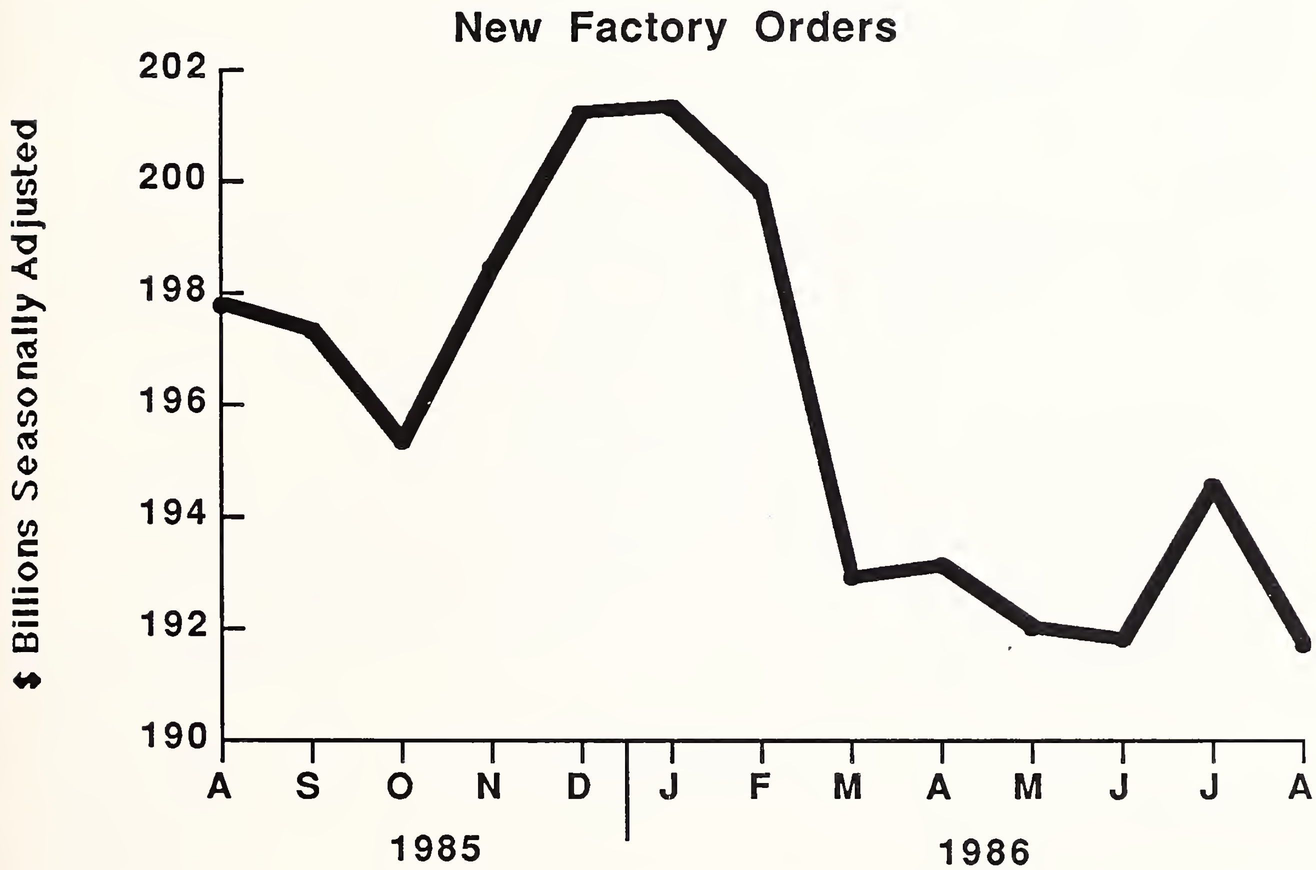
MANUFACTURING REALITIES IN 1986



Source: U.S. Commerce Department

E. CIM ISSUES

- CIM is so difficult to implement because it calls for a fundamental "rethink" of the relationships between three spheres of a company's operations: financial (i.e., the goals the company has set itself in terms of profitability, return on investment, costs, growth, market share, etc.); technological (i.e., the technologies of the manufacturing processes themselves as well as the technologies of automation and integration); and human (i.e., the aspirations of the workforce, including job satisfaction, career goals, compensation, etc.).

- The interfaces of these three spheres sometimes raise issues that go beyond the experience, authority, and concern of the organizational divisions that traditionally have responsibility for them. In addition, some of the issues raised have a companywide impact that affects multiple divisions.

- For example, at the juncture of human resources and technology issues of job content (a joint concern of personnel and the management responsible for the labor), questions concerning in-house knowledge of the operations (i.e., is operational knowledge lost at the human level as automation proceeds?) and phobias of the workforce (is this robot replacing me?) are raised.

- Similarly, at the juncture of technology and finance, tradeoffs between the need to maintain competitiveness and a reasonable return to shareholders conflict with the sometimes huge and difficult-to-justify investments in technology or automation that appear to be solutions.

- The crux of the matter (and the point where CIM raises the most difficult issues) lies at the center (see Exhibit II-5) where all of these conflicting issues overlap. Reconciling the differing, though valid, aims and concerns of every arm of the company is CIM's role.

EXHIBIT II-5

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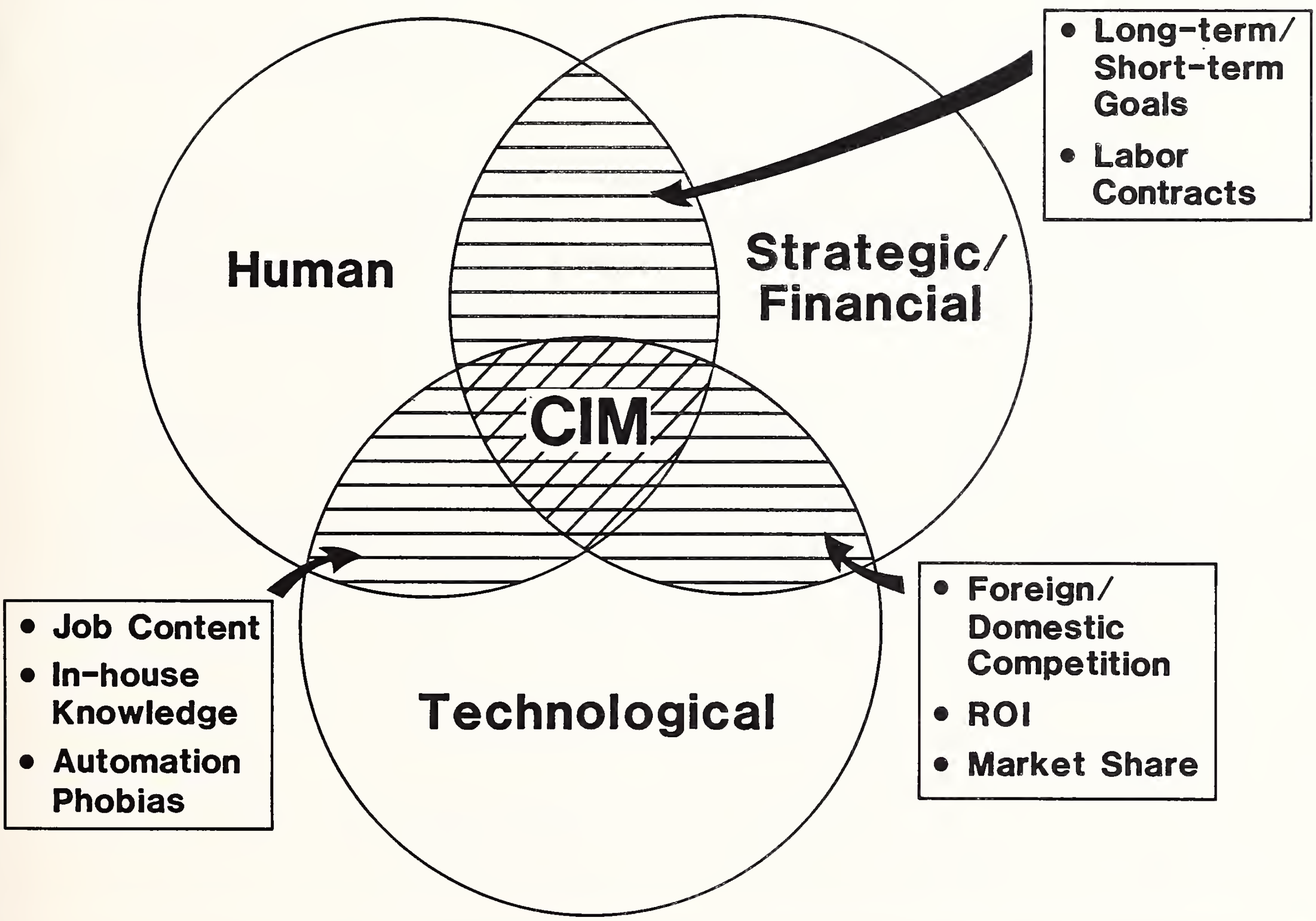
CIM ISSUES



F. CIM INFORMATION SERVICES MARKETS, 1986-1991

- The total CIM information services market will be $7.7 billion in 1986 (see Exhibit II-6). The component markets shown include the implementation of "islands of automation," not just integrated CIM projects, since it is virtually impossible to determine whether the long-range intention of the end user is to integrate these islands or to leave them isolated. The component markets must, therefore, be treated as if they were all CIM expenditures.

- From 1986 to 1991, the combined overall average growth rate for the entire market will be slightly more than 20%, bolstered by the surge in demand for CIM consulting and professional services. The fees generated by assisting end users in formulating plans for and implementing CIM projects now add over $3 billion in yearly revenues to an already very attractive market.

- The second largest share of this market is for CAD/CAE turnkey systems. Micro-based versions have been very successful, and the potential to link CAD/CAE with shop floor operations has been demonstrated. Meanwhile, Flexible Manufacturing Systems (FMS) have been making inroads at a rapid pace; over the next five years the FMS market will quadruple to top $2 billion per annum by 1991.

- Some of the new wave technologies are having a harder time convincing end users of the need for their use. In particular, robotics, which had started in 1985 with a tremendous surge, has seen a large part of the projected growth fade as 1986 wore on.

- Some of the more recent developments include GM's cancellation in July of $80 million of orders for robots which were already scheduled for installation. This led to GMF Robotics reducing its staff from 700 people to 500 in the space of a month. Machine Vision, a leading proponent of the new range of vision robots, also announced a 1986 first-half loss of $7 million due to a rapid slowdown in orders.

EXHIBIT II-6

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CIM INFORMATION SERVICES MARKETS, 1986-1991

	$ BILLIONS		AAGR (Percent)
	1986	1991	
Processing/Network Services	$1.4	$2.9	16%
Software Products	$1.0	$2.9	24%
Professional Services	$3.1	$8.3	21%
Turnkey Systems	$2.2	$5.3	19%
Total	$7.7	$19.4	20%

G. CIM STATUS, 1986

- For the most part, CIM projects being implemented in 1986 tend to be for large/very large corporations, with very little activity in the bulk of U.S. factories (where the impact could be very beneficial).

- In addition, an increasing proportion of the medium/large-sized companies who have attempted to implement even partial automation are having trouble implementing, and there is a growing concern by large corporations who are considering making significant CIM investments that it might be "too soon."

- To complicate matters, there are very few vendors in the market who are willing to assume total project responsibility. Most hardware vendors are not willing to do anything other than supply hardware. Software vendors have a slightly broader view, generally extending to the interaction of at least some of the component parts of CIM, but many will not customize their software products.

- Larger public companies generally screen their investment decisions for short-term, quantifiable returns (generally two- to three-year payback). This is often difficult to prove for a CIM implementation because the data is simply not available. Whole-hearted approval is therefore difficult to come by.

- But CIM is no longer a manufacturing option. Foreign and domestic competition demands that every manufacturing company now have a CIM strategy. The fundamental guidelines for such a strategy are given in Exhibit II-7.

EXHIBIT II-7

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CIM STATUS, 1986

TEAMWORK. . .

- Problem-solving Culture Beats Automation
- User/Vendors (CIM)
- User/Suppliers (Manufacturing)
- Management/Supervisors/Workers

. . . AND PATIENCE!

III MARKET SIZE, ANALYSIS, AND FORECAST

III MARKET SIZE, ANALYSIS, AND FORECAST

A. MARKET STRUCTURE

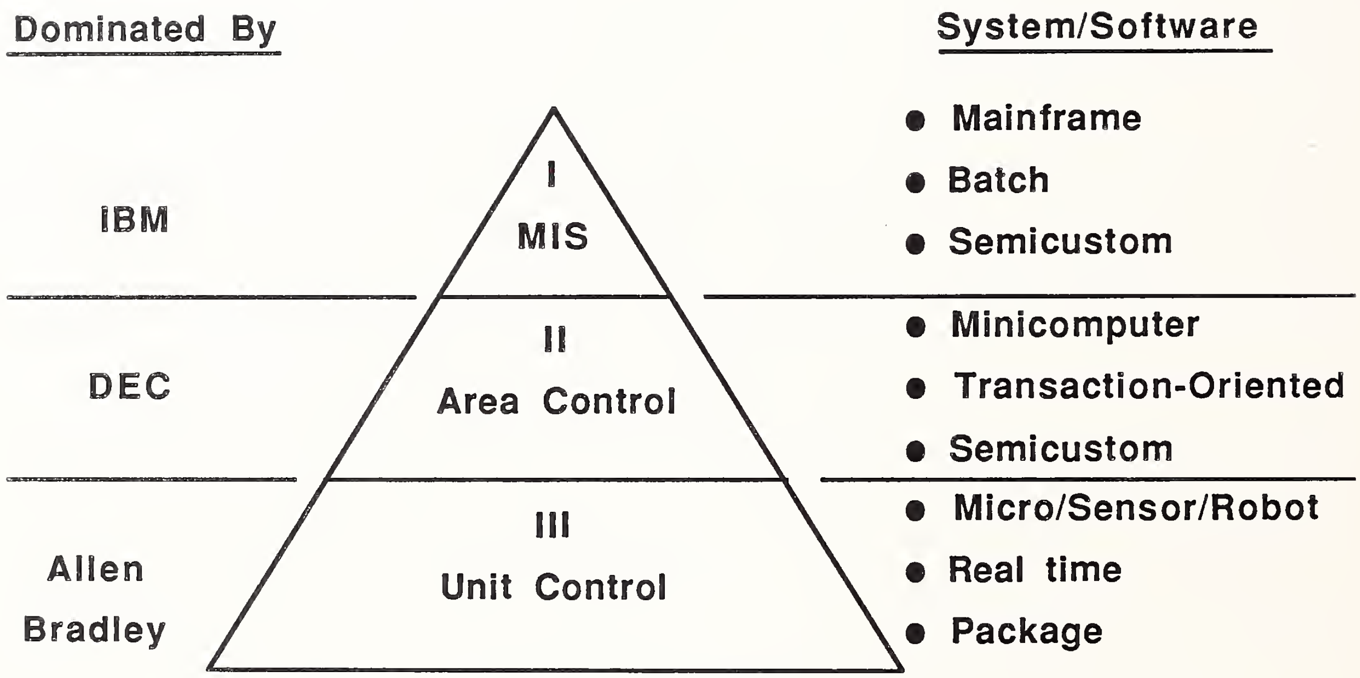
- The CIM market can be structured as in Exhibit III-1 with the MIS department nominally in control of the top of the pyramid (and having theoretical control over the lower levels). In reality, no such intercommunicating hierarchical structure exists; rather, each operates independently from the others and is at a different stage of development in terms of the use of technology.

- In area I, systems are typically large mainframes running batch applications using semicustomized software. Generally speaking, emphasis is on business planning and control, accounting, process/capacity planning, order entry, design, and procurement. The key word here is control, with the company management (which the MIS department serves) trying to direct the flow of operations. Data base management and group technology are key requirements. The buyer of such systems tends to be the corporate staff with the direct involvement of top management. The decision to buy is justified based on improved operational control.

- In area I, the drive has been for MRP and MRP II systems, computer-aided design and engineering (CAD/CAE), group technology, and, more generally, data base management systems and decision support systems (DSS). Much of the initial penetration of these markets has been achieved and the most obvious targets sold.

EXHIBIT III-1

CIM MARKETS



- In area II, systems are typically transaction oriented, running on minicomputers (or, more and more frequently, supermicrocomputers) and using semicustomized software. Here the emphasis is on production scheduling, resource allocation, process flow, and plant management. Typically, such a system is purchased by the plant manager based upon its ability to manage production runs and control/monitor process flow. Corporate staff approval is usually, though not always, necessary.

- Area II is in full expansion. Process control systems have been relatively successful, but the growth of distributed numerical control systems, shop floor data collection systems, and FMS (flexible manufacturing systems), the application of JiT/KANBAN processes, and the increasing use of local area networks all combine to make this area the most exciting of the three in terms of growth.

- In area III, workstation, cell, and machine tool equipment controlled in real time are the principal requirements. Productivity, product quality, and process flexibility/repeatability are the goals. Microcomputer-based equipment, robotics and sensor-driven tools are the essential ingredients.

- Sales in area III of the old numerical control (CNC) and programmable control equipment are slowing down while the value of massive robotics programs, whether firmware driven, sensor driven, or vision driven, are being disputed. While it is unlikely that the automation of manufacturing cells will stop, there has been a decided slowing of the anticipated growth.

- Area I is dominated by IBM, but this is changing gradually in favor of DEC based on DEC's ability to provide networked distributed processing systems. Area II is dominated by DEC, with Hewlett-Packard and IBM distant runners up. Area III is dominated by Allen-Bradley with a variety of smaller vendors active in narrow vertical markets. This will continue in the future due to the diversity of products required, both in nature and task.

- The diversity in product requirements and the autonomous implementation of products, automation, and services by different levels of the plant naturally bring about the need to interface a variety of vendors' systems. This points up the strategic value of a network capable of not only interfacing existing equipment, but of leaving the door open to the continued expansion and growth of the plant's capacity and technology. Very few vendors have taken the time to investigate the loading, bandwidth, and performance characteristics of a plantwide network.

- Another aspect of the long-term value of an adequate network lies in the fact that the implementation of certain aspects of CIM assumes that sooner or later retail sales locations (downstream) and outside suppliers(upstream) will need to be synchronized with the manufacturing process. Since they can be very broadly distributed (not atypically internationally), there is a need to be able to include global market communications in the specification of the network.

- The CIM industry has been so far characterized by the application of relatively simple technology to isolated requirements seen independently of one another. Because vendors found a ready market for these partial solutions, the development of the CIM market has been that of a loosely-knit, often totally independent set of niche markets.

- This has been encouraged by the fact that production managers and top management in general have short planning horizons; they are not interested in year 2000 goals but in what can be achieved, at most, in the next 18 months. Consequently, it has been far easier to sell a 30% reduction in direct labor for a single process than to generate interest in a companywide blueprint for total systems integration.

- This is slowly changing. Some of the lessons of partial automation are becoming apparent; e.g., that the benefits are all short term and that as integration is implemented (and manufacturing processes evolve) today's solutions may become tomorrow's liabilities. In particular, what may appear as the optimum solution to an isolated requirement can be unacceptable from the total plant integration perspective. System interfaces at the hardware and the software levels may be intractable, and file and record structures may need restructuring.

- Exhibit III-2 summarizes the overall size and growth to 1991 of the CIM market by major component. In 1986, the market was worth $9.07 billion. By 1991, this will have grown to $23.31 billion. The vast majority of expenditures are made within factory automation, while the greatest growth will occur in factory communications.

B. FORCES SHAPING THE MARKET

- The harsh reality of the business environment in the U.S. today is one of rising costs of personnel, materials, and capital coupled with the ever-increasing pressure of foreign competition. The cost of U.S. labor doubled for the period 1970-1980, and since 1981 the balance of foreign trade has swung from a surplus to a deficit of increasingly large proportions (see Exhibit III-3).

- Foreign trade has begun to play a more and more significant role. Since 1965, imports as a share of U.S. GNP have risen from 5% to 8% in 1975 and 12% in 1985. At the same time, U.S. exports as a percentage of the same GNP have declined steadily to only 9% (see Exhibit III-4).

- This shift in the dependence of the U.S. markets on foreign suppliers has created a parallel shift in the trade patterns, as shown in Exhibit III-5. The most dramatic shifts have occurred in manufacturing-related markets such as machine tools (where imports now account for 45% of domestic consumption), semiconductors (where imports account for 40%), and radio and TV sets

EXHIBIT III-2

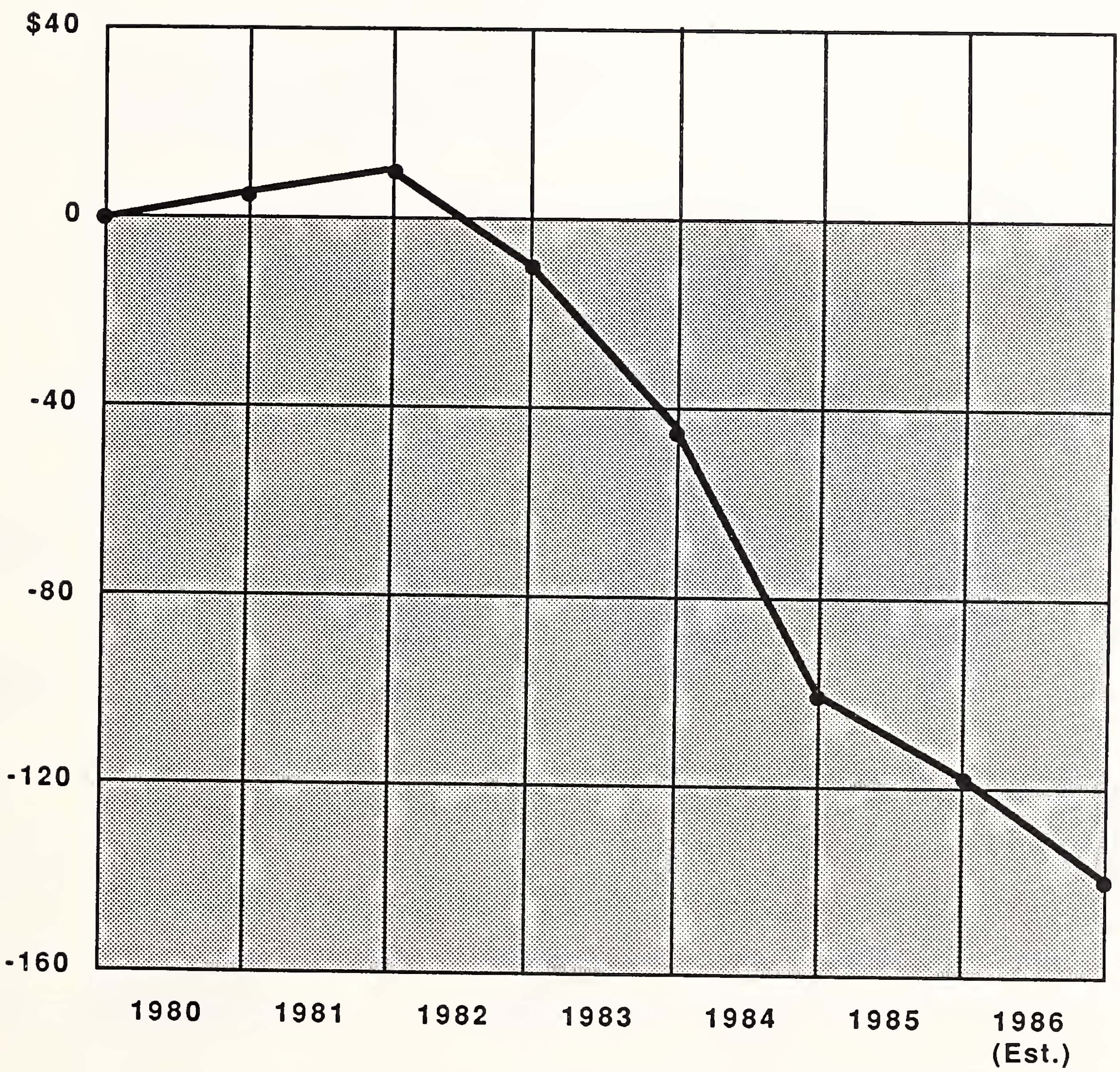
CIM MARKET GROWTH

MARKET	$ MILLIONS 1986	$ MILLIONS 1991	AAGR
MPCS	$ 900	$1,470	10%
CAD/CAE	1,700	5,340	26%
Factory Automation	6,425	16,050	20%
Factory Communications	45	450	58%
Total	$9,070	$23,310	22%

(Includes hardware and software)

EXHIBIT III-3

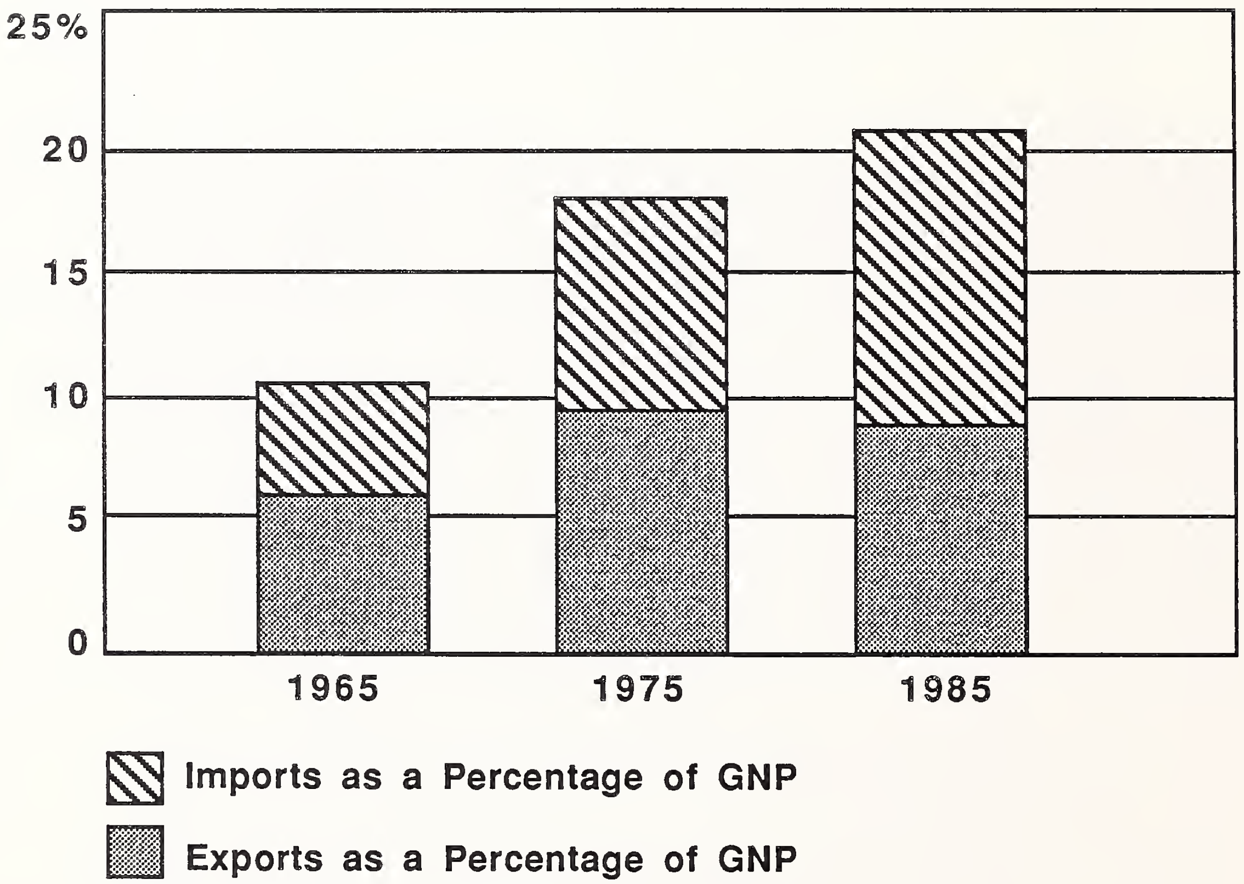
THE U.S. TRADE DEFICIT



Source: U.S. Commerce Department

EXHIBIT III-4

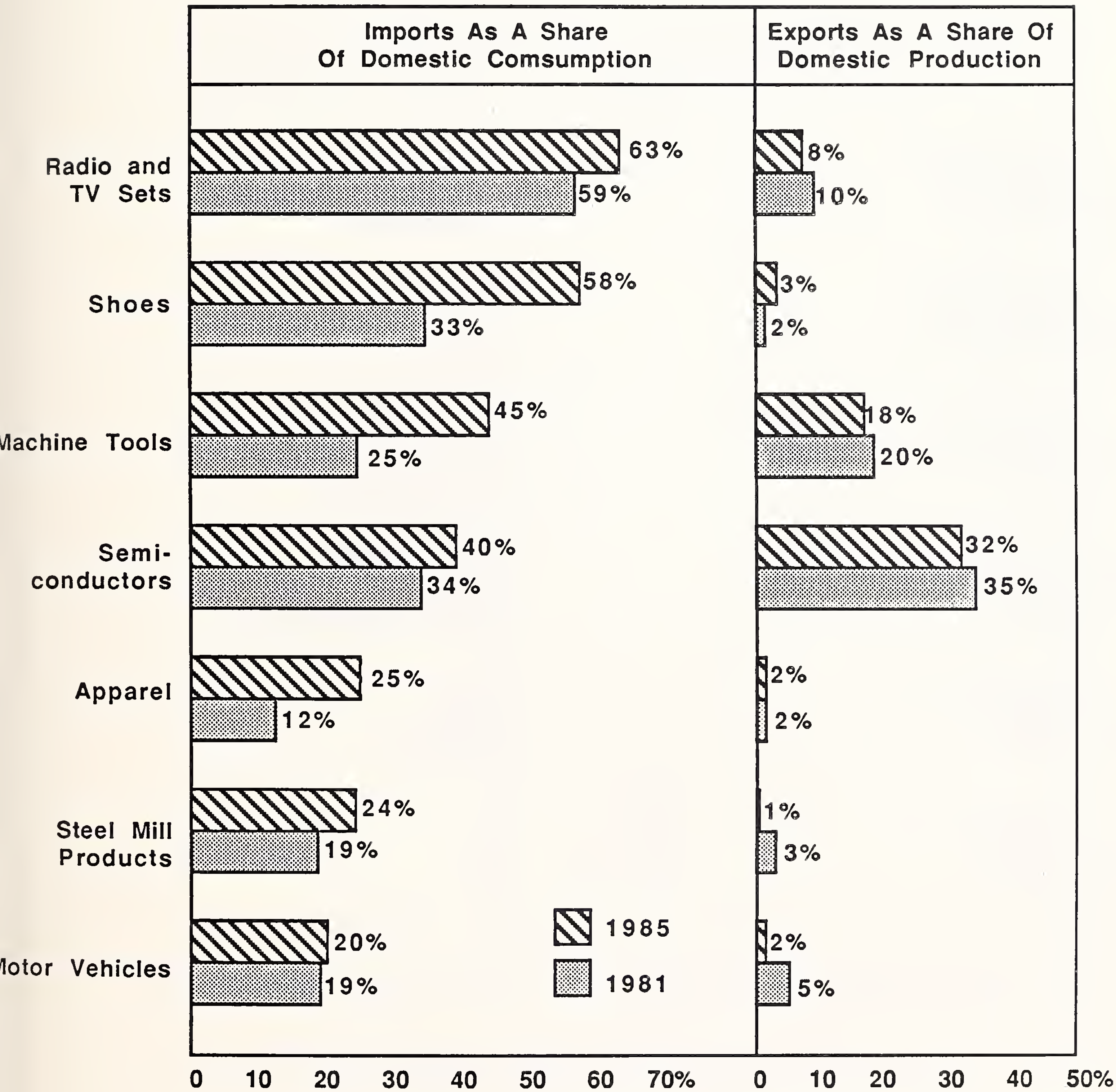
RISING ROLE OF FOREIGN TRADE IN THE U.S.
(Includes Goods and Services)



Source: U.S. Commerce Department

EXHIBIT III-5

SHIFT IN TRADE PATTERNS 1981-1985

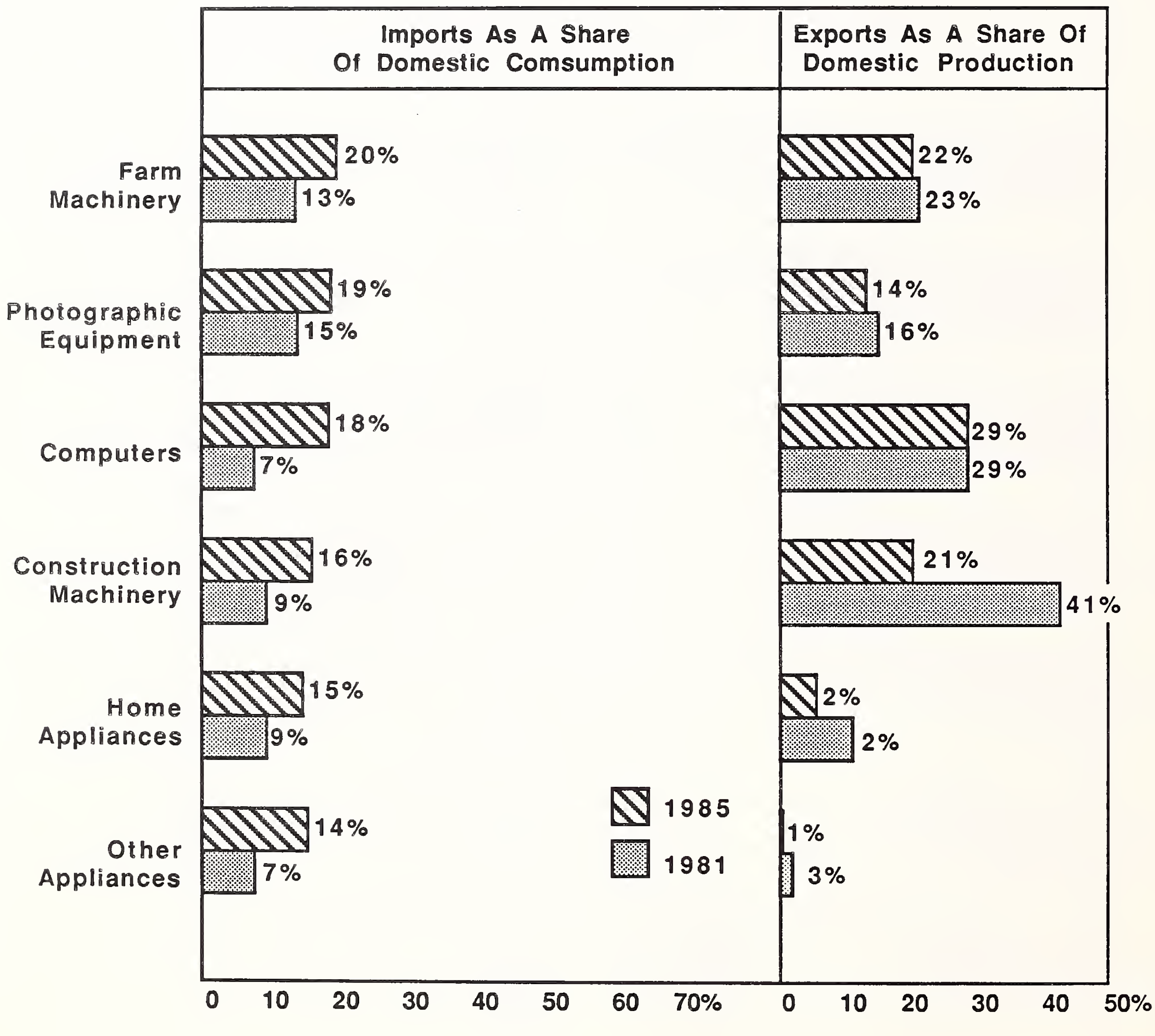


Source: U.S. Commerce Department, National Association of Manufacturers

(Continued)

EXHIBIT III-5 (Cont)

SHIFT IN TRADE PATTERNS 1981-1985



Source: U.S. Commerce Department, National Association of Manufacturers

S1 S

(63%). At the same time, the domestic suppliers have lost ground in all major fields except computers.

- Material and equipment utilization has been extremely low, and the rate of growth of productivity in the U.S. has been significantly lower when compared to other industrialized nations such as Japan, France, and Germany. This is reflected in the comparison of their economic performances (Exhibit III-6).

- For foreign manufacturers whose goods are sold in the U.S., product costs are down and quality is up, thereby placing tremendous pressure on domestic operations. At the same time, there is an increasing need to be more responsive to customer demands in both delivery times and product flexibility.

- To combat this deteriorating situation, U.S. manufacturers have sought to emulate their foreign counterparts by a determined drive to reduce costs and improve quality while at the same time revamping the order processing/manufacturing/delivery cycle to reduce delays. This is a tall order for any one system to accomplish overnight but, rightly or wrongly, this is the role that has been assigned to CIM.

- A major factor that has given a big push to CIM has been the rapid changes in microprocessor technology. The personal computer (PC) has opened up the manufacturing floor to a completely new set of concepts in controlling NC machines, automating assembly and test operations, and allowing these new concepts to be brought into the price range of a very large number of small companies.

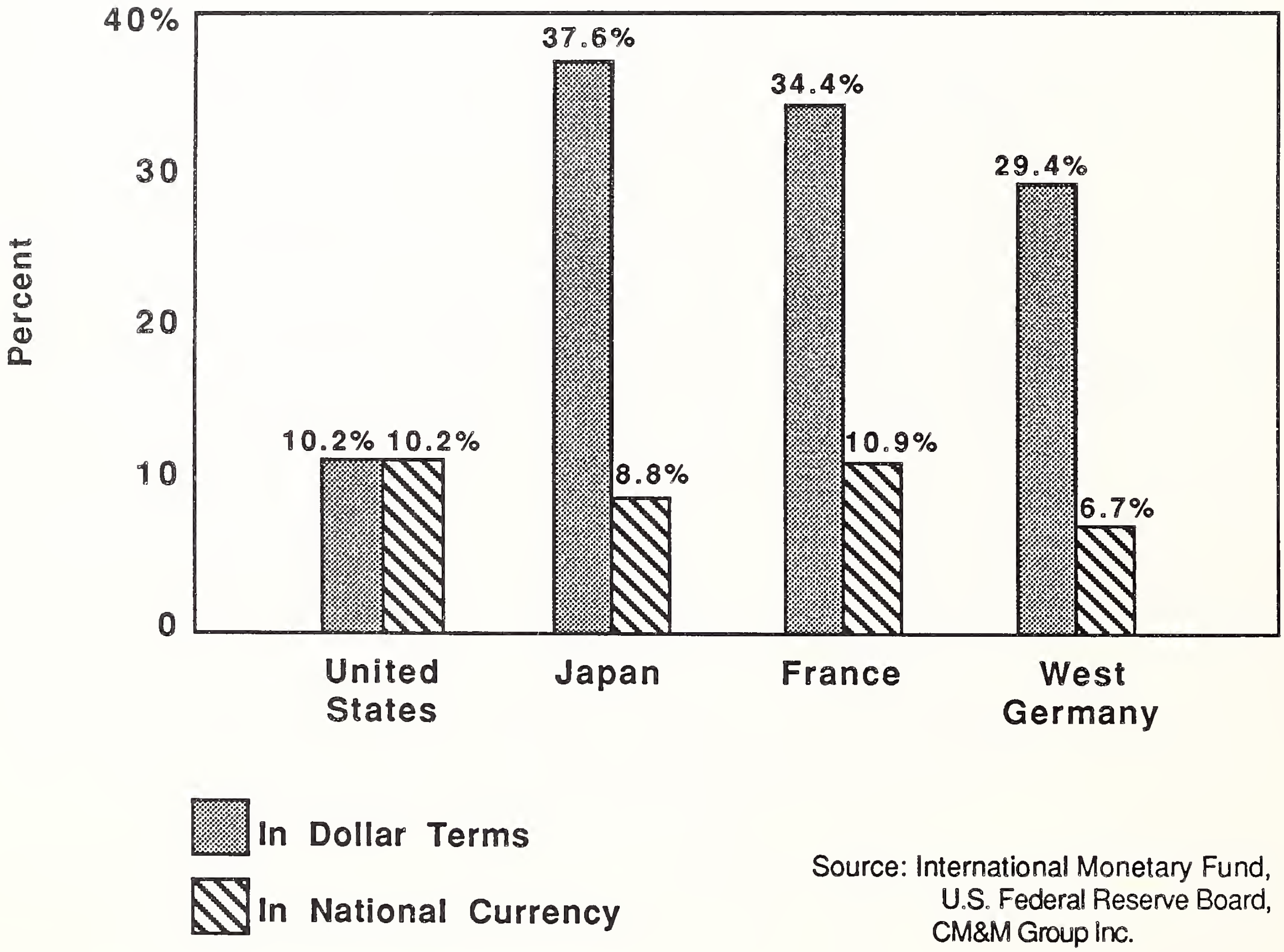
- There are essentially five major components in the CIM market, as shown in Exhibit III-7:

    - Manufacturing planning and control systems.

    - CAD/CAE systems.

EXHIBIT III-6

RELATIVE ECONOMIC PERFORMANCES
(GNP FROM 1984 TO Q1 1986)



Source: International Monetary Fund,
U.S. Federal Reserve Board,
CM&M Group Inc.

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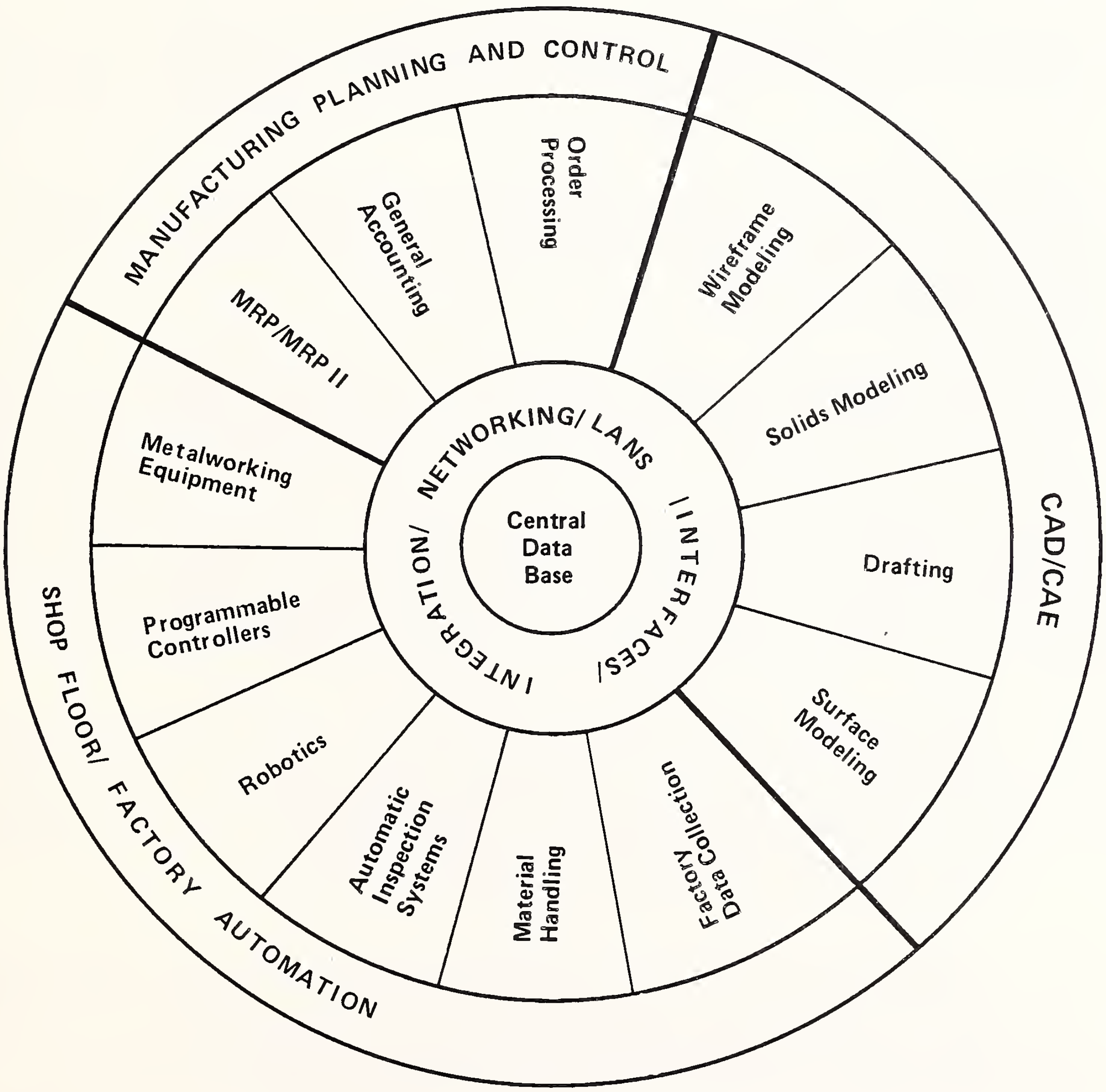
EXHIBIT III-7

THE MAJOR COMPONENTS OF CIM



- Factory automation (including CAM).

- Factory communications.

- Data bases.

• Manufacturing planning and control systems accept information on the mix of products to be manufactured and create a list of manufacturing resources to support production on a scheduled basis. The complete scope of MPCS includes: master production scheduling, material requirements planning, bills of material, routing and work orders, purchase orders, inventory control, and shop floor data collection.

• CAD/CAE systems physically reside in the engineering department where most of the product design takes place. A variety of applications are available such as 3D solids and wireframe modeling, surface modeling, drafting, analysis and NC tool instructions, and parts list. CAD/CAE systems are available in the form of bundled turnkey systems or unbundled hardware and software. A separate market segment for CAD/CAE services also exists.

  - In addition to the well known advantages of using CAD/CAE systems, the two most significant features are those having a digital product data base and the availability of that same file to others for a variety of uses such as modification, updating, viewing, etc.

  - NC tool instructions and detailed parts list can be generated at this point to initiate the material planning and costing functions. It is these features that allow CAD/CAE to become an integral part of CIM.

• Factory automation equipment can be divided into six broad categories:

- Metalworking equipment--by far the largest segment of the factory automation market. It has three major components: metal cutting; metal forming; and flexible manufacturing systems (FMS).

- Programmable controllers--this equipment has brought the advantages of the microprocessor to the factory floor and is a truly universal productivity tool. The market can be broken down into three segments: small (up to 128 channels, standalone); medium (129 to 896 channels, communications-ready); and large (more than 896 channels, networked).

- Robotics--industrial robots were introduced in the U.S. 10 years ago amid much fanfare and glowing predictions but have not turned out to be quite the panacea for this country's manufacturing problems. The market, dominated by the Japanese, can be divided according to process function: point-to-point, assembly, pick and place, production, and continuous path.

- Automatic inspection systems--it is only in the last five years that these systems have become independent of operators for dimensional measurements. Once the subjective nature of the measurement process was eliminated, the flood gates opened to product innovation:

  - Dimensional measuring equipment suitable for 100% real time inspection of modest production rate parts.

  - Surface measuring systems.

  - Machine vision systems which can be applied to many levels of production from raw materials inspection and parts inspection to assembly verification.

- Factory data collection systems--data collection technologies ranging from keyboard and magnetic strip to voice entry bar codes. Bar codes and voice are the most promising shop floor data collection technologies for updating work orders, sales orders, and purchase orders.

- Automated material handling and transfer systems--there are as many applications for automated handling and transfer systems as there seem to be systems designed for those particular applications. There is an overlap in the application of the several material handling technologies as a result of their basic suitability.

• Automated material handling and transfer systems consist of three broad product groups:

- Automatic storage and retrieval systems (ASRS)--these systems fetch parts from bins, convey them to the point of use, and offload them exactly where and when needed. The systems employ cranes or specialized conveyor installations in the warehouse to allow use of narrow aisles or special retrieval equipment, permitting in-depth storage while maintaining equal, ready access to all the inventory. ASRS are best for order picking and horizontal and vertical storage; they are also put to good use for sorting.

- Automated guided vehicle systems (AGVS)--applications range from raw materials transport to integral components in a FMS installation. Many interface directly with ASRS. The vehicles may be guided using a variety of techniques and will function either under computer control over guide paths or may roam free.

- Conveyors--modern enclosed track conveyors provide manufacturers with increased flexibility and control over plant operations because of their abilities to accumulate loads without stopping the entire system, and to handle in-process storage. Inverted and floor conveyors were designed to be used in industrial applications that require greater versatility and efficiency than afforded by conventional overhead or floor conveyors.

- Without communication, there is no way to integrate the various islands of automation on the manufacturing floor; this is the role of factory communications. The communications network can be a combination of both hardware and software and local and remote networks.

- Local area networks, or LANs, which have been proposed as a solution to the perplexing and complex task of interconnecting various pieces of hardware, are based on four different technologies: twisted pair, fiber optics, baseband, and broadband. Generally, for the factory floor broadband is the most suitable.

C. MARKET ANALYSIS

1. CAD/CAE MARKET

- Traditional turnkey CAD/CAE systems suppliers have suffered over the last two years as low-cost workstations have flooded the market. This has produced heavy losses for such major vendors as Auto-trol and Computervision and the closure of many startups.

- Heavy competition has caused products without a distinct technological application, or ergonomic advantage, to fail. Significant price erosion and squeezed margins have also occurred. Companies without deep pockets are finding it difficult to remain in the market.

- CAD/CAE workstation vendors who have done well, such as MicroCad and Sun Microsystems, have had a well-integrated strategy and recognized the trend toward a distributed CAD/CAE environment in which workstations must perform a variety of tasks and communicate with a range of equipment.

- Some vendors have chosen to develop a product tailored to a single application and to market a range of such products by entering into joint marketing agreements with other workstation vendors and third-party software vendors. Daisy markets the IBM PC as a low-performance, entry level workstation while concentrating on higher performance workstation markets on its own products. Auto-trol is another company which targets the mechanical CAD/CAE market with its general purpose 3D packages but uses third-party manufacturing software to supplement its own software and markets an integrated design and manufacturing system.

- CAD/CAE turnkey system vendors include Intergraph, IBM, Applicon, Computervision, Calma, Auto-trol, Aydin Controls, Cadlinc, and Hewlett-Packard. All vendors provide drafting capability, and about half of them provide at least one of the following: wireframe modeling, surface modeling, solids modeling, and interfaces to manufacturing.

- A majority of these vendors sell workstations purchased from OEM vendors such as Apollo, DEC, Data General, Hewlett-Packard, and Sun Microsystems. Apollo and Sun have the lion's share of the installed base.

- The common thread that ties together the diverse functions in the "factory of the future" is part geometry. Hence, automation of design with 3D modeling is often the first step toward CIM. The key players in this market are IBM with 23%, Intergraph with 17%, and Computervision with about 15% of the market. Market shares of these and other players are shown in Exhibit III-8.

- There is a bright future for the 3D modeling market, but a variety of technical issues have to be resolved before its full potential can be realized.

EXHIBIT III-8

MARKET SHARE OF 3D MODELING VENDORS, 1986

VENDOR	MARKET SHARE (Percent of Sales)
IBM	23%
Intergraph	17%
Computervision	15%
Calma	9%
Applicon	4%
McAuto	4%
Auto-trol	3%
Control Data	3%

2. FACTORY AUTOMATION MARKET

- The entire factory automation market is in a state of flux due to:

  - The sudden caution being expressed by those who have already invested heavily in the existing technology but are having difficulty reaping the expected rewards.

  - The speed of evolution of the technology, making yesterday's decisions look overhasty.

  - The constant influx of new players attempting to find a niche for themselves.

- Most damaging are the horror stories from major investors such as GM which recently announced that it was "postponing" its launch of the much-touted Saturn plant and then ousted Ross Perot, the head of EDS which was supposed to be carrying the major part of the implementation burden. This is symptomatic of the impatience being felt by U.S. manufacturers as their hopes for a "quick fix" to their quality, cost, and competition problems are not being satisfied despite the millions of dollars being thrown at the problem.

- The metalworking equipment market is not only the largest segment of the factory automation sector but also the most mature. Products in this category have long life cycles and relentless overseas competition. Of its three major components (metal cutting, metal forming, and flexible manufacturing systems (FMS)), FMS will have the fastest growth.

- Domestic suppliers are concentrating on FMS and other large semicustom installations rather than on freestanding, individual metalworking equipment which has traditionally dominated the market. Foreign competition is taking a strong hold on this traditional equipment market.

- The major players in metalworking equipment are:

  - Acme-Cleveland.
  - Cincinatti-Milacron.
  - Ex-cell-O Corporation.
  - Ingersoll Milling Machine.
  - Litton Industrial Products, Inc.
  - Textron.
  - White Consolidated Industries.

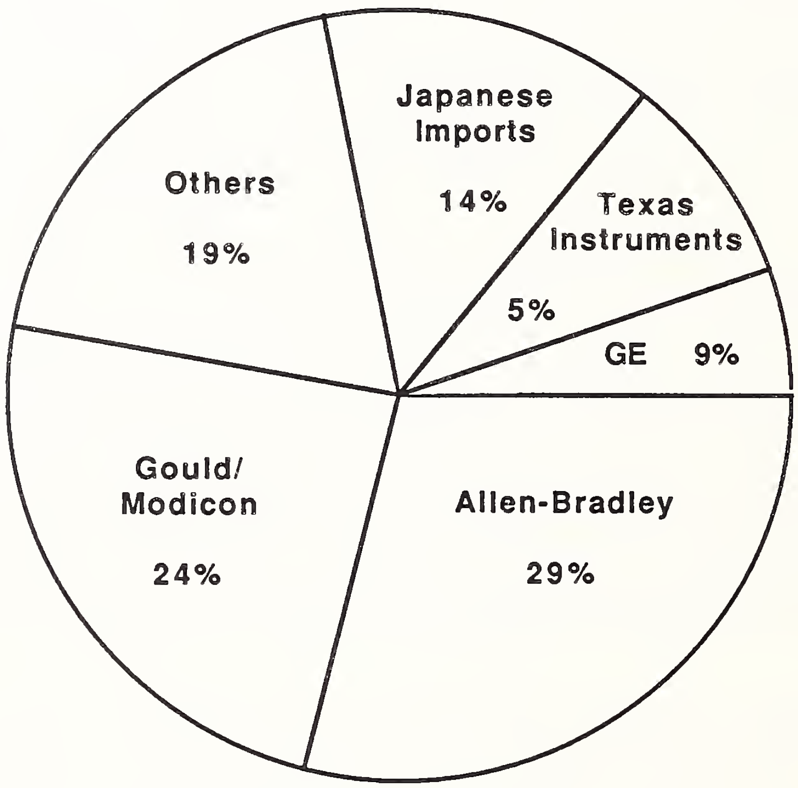
- The programmable controller market has grown remarkably over the last five years from practically nil to $650 million in 1986. There has been an erosion in the price per channel of the programmable controller which has dropped from $125 to $25 over the same period. This factor alone has undoubtedly helped in increasing market penetration dramatically.

- Programmable controller manufacturers are largely made of groups or divisions of large industrial concerns, typically those involved in other aspects of industrial electronics. The remainder come from either the electronics industry or old-line electric companies. Small startup companies account for only a very small fraction of the PC industry, while imports account for an increasing market share, virtually dominating the low end of the business.

- The market has historically been dominated by Allen-Bradley and Gould/Modicon, but over the last two years General Electric and Texas Instruments have increased their shares appreciably. Exhibit III-9 shows the relative market shares of the key players. Japan entered the U.S. market for

EXHIBIT III-9

MARKET SHARE OF PROGRAMMABLE CONTROLLER MANUFACTURERS, 1986



1986: $650 Million

low-cost (up to 128 channels), standalone units of programmable controllers in 1984. One can expect to see them dominating this low-end market in the next few years.

- The robotics market is another factory automation area that has not quite met the expectations of a few years ago. But despite the false starts, robots are finding a viable and growing niche in today's factory. Again, U.S. suppliers do not have a leadership position in the robotics market. There are few viable U.S. robot producers, and many of them have engaged in joint ventures with the Japanese. The U.S. manufacturers have already lost the low end of the market.

- The major players in the U.S. market are:

  - GMF Robotics (associated with FANUC of Japan) with 35% of the market.

  - Cincinatti-Milacron with 14%.

  - Unimation/Westinghouse with 12% has Kawasaki, Mitsubishi, and Komatsu as licensees.

  - ASEA, Inc. of Sweden with 9% of the market.

- Exhibit III-10 shows the market shares of the major players.

- Automatic inspection systems have a key role to play in the CIM framework if U.S. manufacturers are serious about improving quality of their products. With these systems, defective parts are not produced in any quantity before the defect is detected and corrected. Frequently, one bad part is enough to initiate corrective action.

EXHIBIT III-10

MARKET SHARE OF KEY U.S. ROBOT PRODUCERS, 1986

MANUFACTURERS	MARKET SHARE (Percent of Sales)
GMF Robotics	35%
Cincinnati Milicron	14%
Unimation/Westinghouse	12%
ASEA, Inc.	9%
De Vilbiss	8%
Automatix	4%
GCA	3%
IBM	3%
Other	12%

- An especially interesting subcategory of these systems are vision systems. Recent progress in these systems is very impressive. The technology for these systems leverages the high computing power of large-scale integrated circuits and new computational schemes for image comparisons and 3D vision.

- The market for these systems, especially the vision systems, is just emerging, but one can expect it to grow significantly over the next several years as the CIM concept becomes more of a reality. The largest demand for these systems is presently from the aerospace sector and will continue to be so over the next several years.

- The key players in the automatic inspection systems market are:

  - Brown & Sharpe with 24% of the market.

  - Starret with 22%.

  - Jones & Lamson with 12%.

  - Cross & Trecker with 12%.

- Exhibit III-11 shows the distribution of market share.

- Material handling and transfer systems have a strong market justification and penetration, and one can expect this market to perform strongly over the next several years. The automatic storage and retrieval systems (ASRS) segment of this market has three subcomponents: equipment for parts and raw material delivery, the largest component; equipment for subassembly transport; and equipment for finished goods handling.

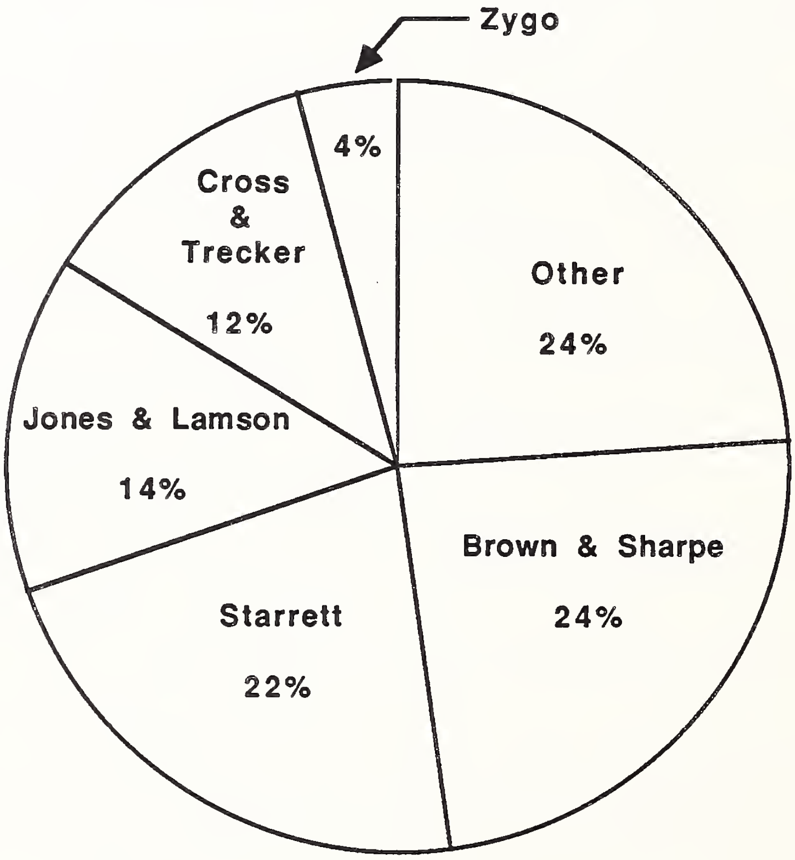
- The ASRS market is shared by four major players:

  - SPS Technologies.

  - Lear Siegler.

EXHIBIT III-11

MARKET SHARE OF AUTOMATIC INSPECTION SYSTEMS VENDORS, 1986



1986: $600 Million

- Litton Storage Systems.

- White Consolidated.

- As seen in Exhibit III-12, SPS has the lion's share of the market with 41%.

- Automated guided vehicle systems (AGVS), the other segment of the material handling market, have found a receptive niche, though a small one at the present time. AGVSs have solved many of the control problems and exhibit greater flexibility than previously possible. This market has three segments: light duty vehicles, the largest component; heavy duty vehicles; and special purpose vehicles.

- The AGVS market should take off in the next few years as JiT inventory controls become more widespread.

- There are a number of new companies entering the field with products based on innovative guidance systems. Many of the new products are aimed at specialized market segments such as heavy loads, hazardous areas, high lift, special fixtures, or other adaptations. In addition to flexible controls, many of these new products embody motors that do not require periodic maintenance and batteries which will last the life of the vehicle with minimal attention.

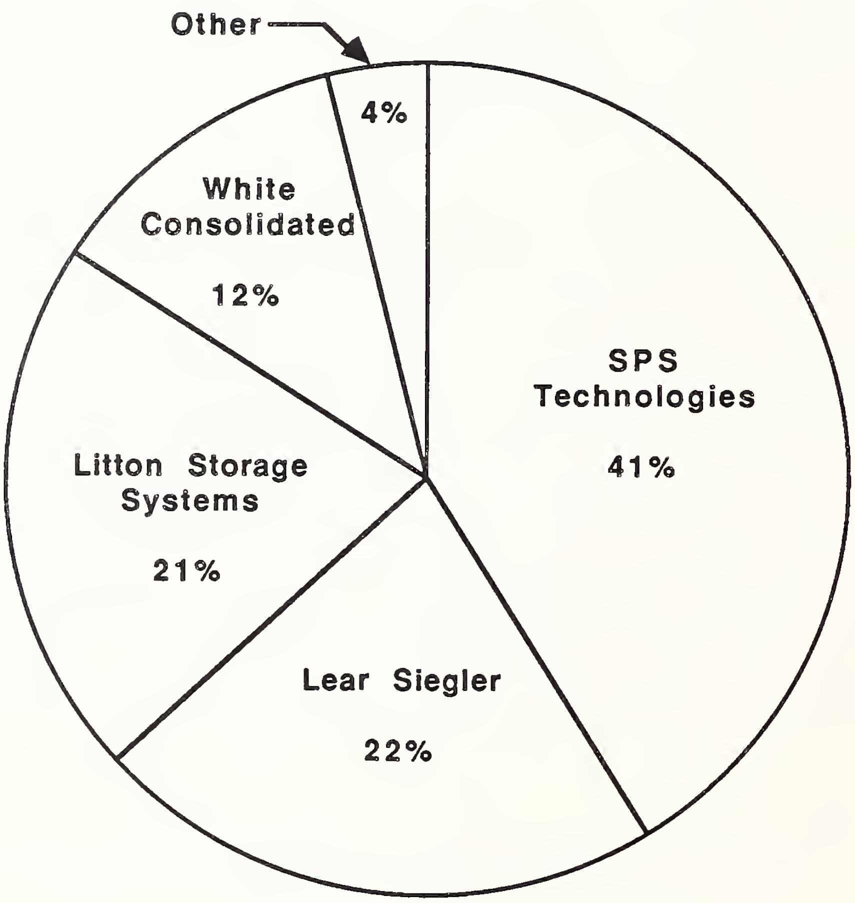
3. MANUFACTURING PLANNING AND CONTROL SYSTEMS MARKET

- The MPCS segment of the CIM market is an area of high growth but at the same time is very fragmented. There are over 165 vendors who supply software to run on mainframes, minicomputers, and microcomputers.

- Vendors vary in size and in financial health, with some companies being heavily hit by the 1985-1986 slowdown. Competition is fierce and margins are under pressure, particularly with low-end products.

EXHIBIT III-12

MARKET SHARE OF KEY ASRS VENDORS, 1986



1986: $230 Million

- The electronics industrial sector is the heaviest user of MPCS, followed by aerospace. More than 30 companies have moved into the MPCS arena over the past two years with low-priced offerings that run mostly on the IBM PC, XT, and AT. Though the capabilities of these systems do not come close to their minicomputer-based counterparts, there is a growing demand in the market for less expensive, easier to use products.

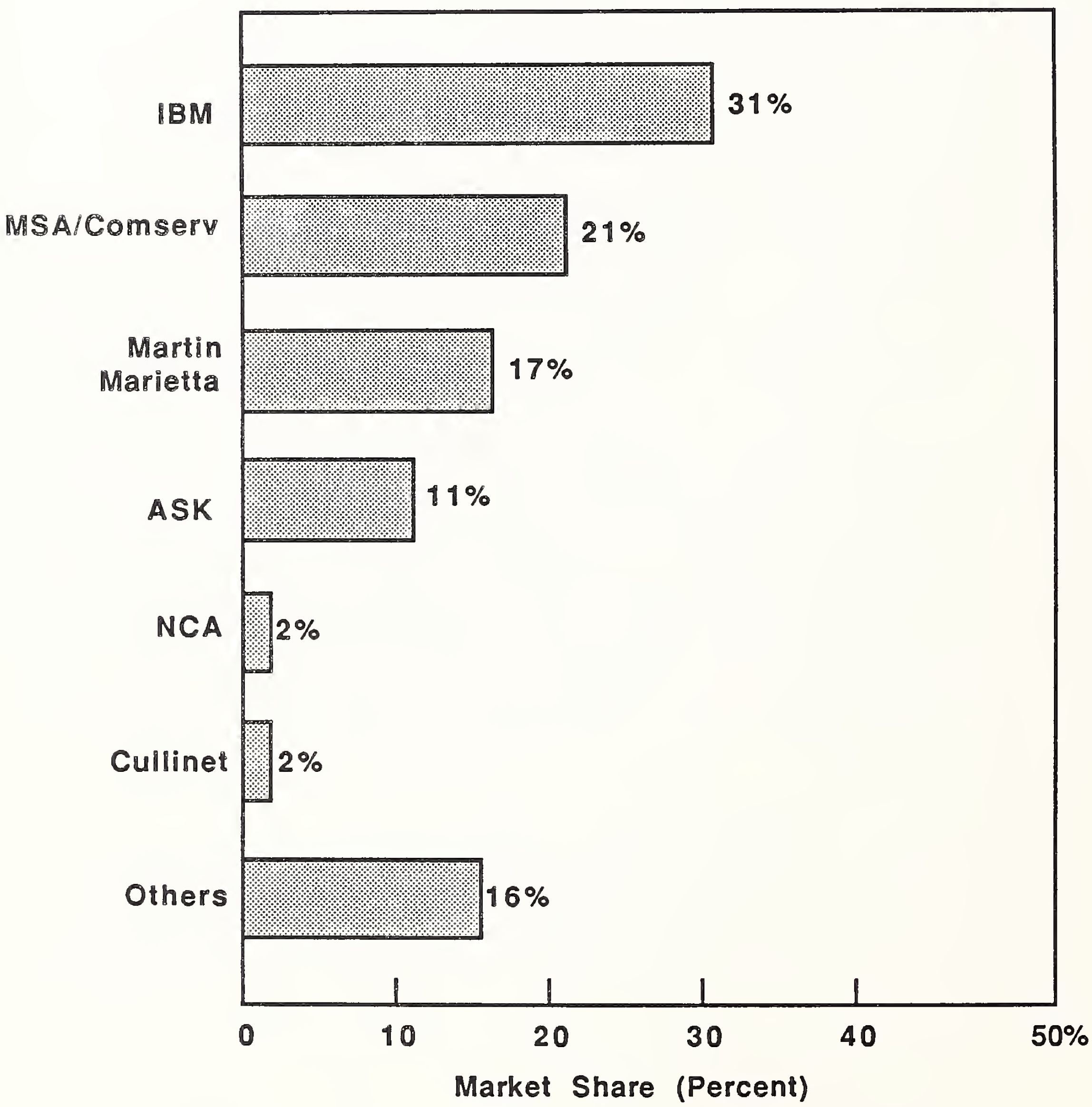
- Vendors are expanding the market to include user companies in the range of $10-100 million in sales. The market for mainframe-based MPCS systems is close to being saturated and will become a replacement market for the rest of the decade. IBM, because of its huge installed base and huge marketing capabilities, is the dominant player, with almost one-third of this market. The other key players are: MSA/Comserv; Martin Marietta; and ASK Computer Systems. Exhibit III-13 shows the relative market shares of the participants.

- The software market for quality control is fragmented, with 65 vendors competing for a share of the market. Most of the vendors provide software packages that run on microcomputers. The price range is wide; at one end of the spectrum is the QDM/1000 from Hewlett-Packard designed to run on minicomputers priced at $45,000. At the other end of the spectrum there are packages priced to sell at about $500 which provide statistical analysis based on keyboard input.

- Many vendors provide a turnkey solution, installation, and training. The higher-end products, such as HP's QDM/1000, offer process and product analysis tools in addition to statistical analysis such as histograms, bar charts, regression charts, etc.

EXHIBIT III-13

MARKET SHARE OF KEY MPCS PLAYERS, 1986



4. FACTORY COMMUNICATIONS MARKET

- Linking the many components of each manufacturing location (shop floor, design and engineering, and the planning and control office) offers a major challenge in itself. Ideally, however, the manufacturing facility should also be connected to each remote facility that is involved in the day-to-day operations. These include the supplier network, the company's own sales and service groups, and other manufacturing facilities that provide or receive subassemblies or parts from the factory.

- Baseband LANs penetrated the manufacturing market initially with equipment for process and production control using point-to-point systems. These systems have been well received and have proved remarkably stable and error free, contributing greatly to user confidence in LANs.

- The relatively higher initial cost of the broadband systems has slowed their acceptance, but as installations increase, one can expect costs to drop significantly. This will be the dominant technology over the next five years.

- Fiber optic LANs, which are particularly well suited to the manufacturing environment, have had their progress slowed due to the exceptionally high cost of these systems.

- Manufacturing automation protocol (MAP) has become the industry standard and has given rise to a variety of MAP products. Key players are:

    - Sytek, with its broadband network offering.

    - General Electric, with its GENet product.

    - Concord Data Systems, which assisted General Motors in MAP implementation.

    - Allen-Bradley, with its data highway.

5. CENTRAL DATA BASES

- It is becoming more and more apparent that a key component of the factory of the future will be a centralized, all-purpose data base capable of storing and cross-correlating the myriad data, text, and graphic information that is the lifeblood of the company and its operations. Ideally, this would be relational in structure.

- A truly relational DBMS system necessary to operate in a CIM environment is far from reality. It is generally accepted that relational structures offer the most powerful DBMS capabilties, but the demands on processor cycles and on storage requirements made by relational DBMSs impair their penetration of the market. This is unfortunate because users lacking programming knowledge can perform complex queries on relational data bases through standard tools such as the structured query language (SQL).

- Choosing a data base that combines portability of applications with compatibility across a wide spectrum of hardware and is accessible through a standard query language would be ideal. Better yet, the user should be able to concentrate on solving corporate manufacturing problems rather than on the design and nuances of the DBMS used. Greater versatility and ease of use are the constant, not a particular DBMS structure.

- Unfortunately, it would be irresponsible for any MIS director to make his choice based on functionality, compatibilty, and ease of use alone. IBM's directions are of direct concern to all, in particular the introduction of DB2, IBM's contender in the relational data base field. This immediately became the standard against which all other relational DBMSs are compared and with which other DBMS vendors have announced they will provide connectivity.

- Sidestepping the performance issue completely is Britton-Lee with its data base processor. This hardware unit offloads all DBMS functions from the processor, interfacing with the main processor via an RS-232 link (see Exhibit

III-14). The unusual advantage offered is that of sharing a data base between dissimilar hosts or even between banks of PCs, users of which could not individually justify the purchase of such a powerful piece of hardware.

D. CIM MARKET FORECAST

- The long-term outlook for CIM is a healthy one, but the short term is fraught with unknowns. There is no clear consensus as to whether the new tax legislation effective in 1987 will have a strong or mild negative impact on capital spending.

- The retreat by GM from massive automation projects such as the Saturn plant may have more farreaching significance than the curtailed spending attached to the plant itself, perhaps by convincing tentative purchasers to delay their CIM decisions to a later date.

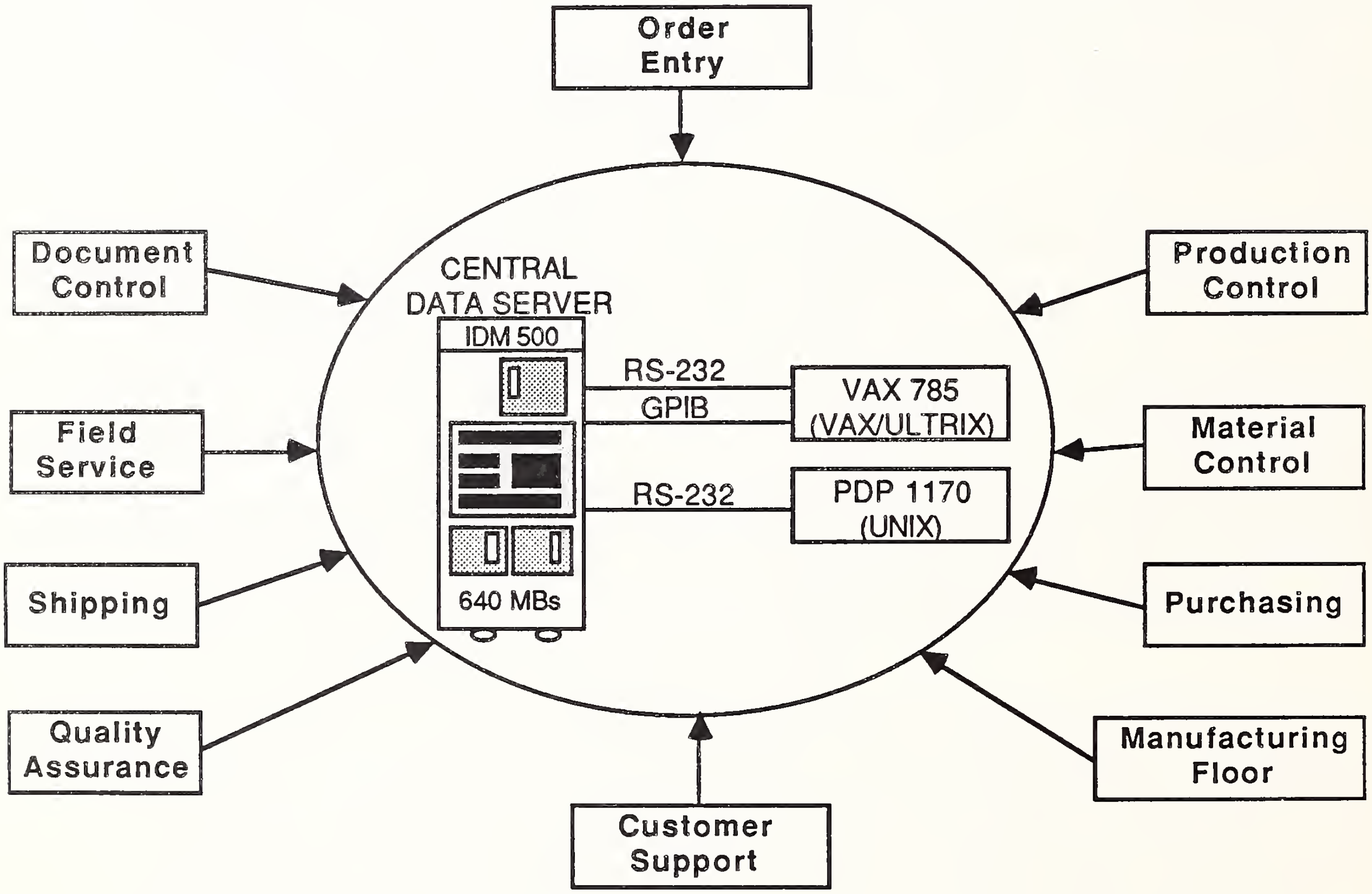
- In the longer term however, it appears inevitable that the U.S. industrial base has no option but to pursue conversion, upgrade, and automation without which further loss of market share is certain.

- In at least one area, advancing technology will continue to have a positive effect. Microcomputers are rapidly shrinking the performance gap between themselves and minicomputers while at the same time maintaining their price advantage. The upshot of this is to make advanced CIM solutions available to a broader share of the manufacturing sector, offsetting part of the expected decline in very large automation systems.

- Microcomputer technology will have far-reaching effects on the machine tool industry in particular. NC, CNC, and DNC should all benefit, particularly since the U.S. has a very large base of older installed equipment. On the whole, however, the trend in CAD/CAE and shop floor automation is likely to

EXHIBIT III-14

MANUFACTURING/MRP DATA MANAGEMENT



Source: Britton-Lee

be one of downsizing (to workstations rather than turnkey systems, or at least to micro-based systems rather than mini-based systems).

- Exhibit III-2 provides the overall forecast for CIM from 1986 (base year) to 1991. Factory automation forecasts for automotive, semiconductor, and process industries have been separated from discrete manufacturing, and CAD/CAE forecasts have been broken down into mechanical and other. The forecasts reflect the expected shrinkage of the automotive expenditures and the rapid growth of the penetration of the smaller manufacturing sites by micro-based systems and software.

- The most significant growth is in LAN/network implementations from a miniscule $45 million in 1985 to $450 million by 1991. This will be driven by the need to increase the interconnection of the shop floor with planning and control and the increased use and application of the MAP standard.

- Exhibit III-15 provides the forecast of CIM market expenditures in the four information services modes

E. COMPETITIVE ENVIRONMENT

1. MANUFACTURING PLANNING AND CONTROL SYSTEMS (MPCS)

- The primary components of the manufacturing information system are:

  - Inventory control.

  - Scheduling.

  - Material requirements planning (MRP).

  - Manufacturing resources planning (MRP II).

EXHIBIT III-15

CIM INFORMATION SERVICES MARKETS, 1986-1991

SERVICE	$ BILLIONS		AAGR (Percent)
	1986	1991	
Processing Network Services	$1.4	$2.9	16%
Software Products	$1.0	$2.9	24%
Professional Services	$3.1	$8.3	21%
Turnkey Systems	$2.2	$5.3	19%
Total	$7.7	$19.4	20%

- The underlying thrust for these "back office" systems is for planning and control, but manufacturers are having difficulty trying to figure out how the back office can truly support the other functional departments. This is a potential inhibitor to growth.

- Nevertheless, this segment continues to grow. In 1986, expenditures increased 19% to $650 million. This growth is expected to continue from 1986 to 1991, growing at 21% and reaching $1.7 billion by the end of the forecast period. This segment should benefit from new systems that are being developed which can be merged into the computer integrated manufacturing architecture and, in some cases, into networked systems.

- Vendor participation in these back office systems is highly fragmented and diverse. The dominant vendor is IBM. Others are:

    - MSA/Comserv, ASK Computer, NCA, and MMDS--the major software companies in the MRP II market.

    - Computer Task Group, GM/EDS, Arthur Andersen, Analysts International, Systems Control, Keane Associates--the major players in the professional services market.

- Hardware manufacturers which will be the major competitors are: IBM, DEC, DG, Honeywell, Unisys, and Prime. INPUT recommends information services vendors partner these firms, especially for very large opportunities.

- Another opportunity that is emerging with respect to these complex systems is systems integration. Long a practice by the federal government in procuring large complex systems, systems integration as a discipline has begun to emerge as a major procurement strategy of CIM users.

2. CAD/CAE

- The size of the CAD/CAE market has attracted many vendors. However, it is not as fragmented as the back office segment. The participants can be grouped in the following four categories:

    - Hardware from vendors like IBM, DEC, HP, Tektronix, CDC, Perkin-Elmer, Apollo, and Sun Microsystems.

    - Software (operating systems, image processing, animation, application-specific packages, etc.) from Applicon, Cadam, Grafcon, and others.

    - Intergraph, Computervision, Applicon, Auto-trol, and Calma in the turnkey systems arena.

    - McDonnell Douglas Information Systems, Boeing Computer Services, and GEISCO in the processing/network services arena.

- The highly structured nature of CAD/CAE applications mandates that they be strongly focused on end-user requirements, requiring vendors who truly understand the market at a detailed applications level.

- The supermicro and, to a lesser extent, micro-based products are creating confusion in this segment due to the very low price systems these products allow. The most dramatic evidence of this can be seen by the very poor performances of vendors like Auto-trol, Computervision, and Gerber.

- The CAD/CAE area is still a growth market, but the emphasis for the future will be integrating CAD/CAE with shop floor products and activities:

    - Programmable controllers.

    - Area controllers.

- Quality control.

- Planning.

• Computer-aided manufacturing maintenance (CAMM) involves computer-based analysis and scheduling of maintenance. This is a most valuable tool and is primarily used for scheduling preventive maintenance. The next step is predictive maintenance that allows the system to analyze machine performance and predict when failures are about to occur.

• CAMM systems consist of three major components:

  - Machine and production monitoring.

  - Maintenance dispatch.

  - Preventive maintenance.

• The leading users of CAD/CAE will continue to be in the electronics and transportation segments. The overall market for CAD/CAE systems will continue growing from a base of nearly $1.7 billion in 1986 to $5.34 billion in 1991, an average annual growth of 26%.

3. LEADING COMPETITORS

a. IBM

• IBM has developed a vast array of hardware and software components for the CIM area but has preferred to establish working relationships with systems integrators to assume the responsibility for integrating its (and other vendor's) products and services. IBM works with the customer to identify the systems integrator best qualified to respond to a particular user requirement.

- In the hardware arena, IBM offers processors ranging from the new 9370s, through the 4300 family, and to the upper end of the 3090 family. In the workstation and plant operations arena, IBM offers the System/88 and Series/1, plus 5080 graphics, 7575/6 robotics systems, IBM RT personal computer, and a wide selection of printers, plotters, and SNA/LAN communications devices.

- IBM's strength centers around the widespread use of its hardware combined with the strength of its name recognition and support capabilities. In addition, IBM has the additional advantage of being able to integrate hardware and software at the point of sale.

- IBM has not attempted any significant integration activity in the area of CIM or in the integration of its traditional manufacturing software with CAD/CAE data conversion. However, IBM is active, licensing AML, a manufacturing language, to machine tool vendors such as Cincinatti Milacron.

- IBM has begun to move quickly in the commercial integration market to increase penetration of the manufacturing sector and leverage that presence in development of the CIM market. IBM will use its control of the corporate data base to gain control of factory systems through a "data integrity" strategy.

b. DEC

- DEC's hardware presence in the area control portion of the manufacturing sector is enormous and is equivalent to IBM's presence in the MIS department.

- Like IBM, DEC's strength is based on widespread use of its hardware, especially in industrial environments. DEC has been very strong in manufacturing communications and government applications. DEC also has a worldwide support and training services operation and provides services in 47 countries.

- DEC has been emphasizing relationships with third-party application developers as well as developing new OEM relationships with machine tool and automated materials handling vendors.

- DEC will seek to develop allies in the noncomputer technology segments and to leverage its existing strengths on the factory floor and with OEMs. DEC will also seek alliances with potential large-scale systems integrators.

c. <u>MSA</u>

- MSA has been successful at selling its manufacturing system (MRP II) to very large (greater than $100 million) discrete and process manufacturers using IBM mainframes. MSA benefits from excellent name recognition and size, with a large user base and enough resources available to build a successful sales and support force. MSA entered the marketplace by acquiring ARISTA Manufacturing Systems from Xerox in 1982 and further strengthened its position in the marketplace by working with DBMS specialist ADR in developing MRP II's data base capabilities. Thus, MSA has been able to keep product development costs down while providing a truly integrated manufacturing/financial/design package based on an advanced DBMS product.

- MSA has placed much emphasis on its fourth-generation language, known as Information Expert, which provides links from purchasing to accounts payable, from order processing to accounts receivable, and from manufacturing accounting to general ledger. MSA hopes to demonstrate the effectiveness of this product extension toward the ultimate goal of CIM.

- The recent acquisition of Comserv makes MSA the second largest supplier of manufacturing software in the U.S. with revenues over $100 million per annum. (The largest, of course, is IBM.)

d. Cullinet

- Cullinet entered the manufacturing software market in 1980 by purchasing a manufacturing system from Rath and Strong. Prior to 1981, Cullinet (then known as Cullinane Data Base Systems) made a name for itself in data base development. Cullinet stresses the advantages of its MRP II software offering, utilizing the highly regarded IDMS/R relational data base. While competitors tend to point out Cullinet's relative inexperience in manufacturing, Cullinet counters that a truly integrated manufacturing solution revolves around the data base and that its competitors' MRP II products utilize revamped 1970s technology in data base design.

- Cullinet's success has been with medium to large discrete and process manufacturing firms using IBM and plug-compatible mainframes. The company obtained from Comserv the right to sell Comserv software in conjunction with Cullinet's data base software, but has had little success.

- A recent shakeup at Cullinet reflects a desire to strengthen its image in manufacturing. Cullinet brought in former Data General executive David Chapman as Vice Chairman and Chief Executive Officer, prompting President Robert N. Goldman (one of Cullinet's original 10 employees) to resign. Chapman's last position with Data General was Senior Vice President for manufacturing, and this move should signal increased attention to technological development in the manufacturing industry.

- After 21 consecutive quarters of growth in the 50% range, Cullinet slumped in the second quarter of its fiscal year 1986, down $2 million from the previous year. While initial reactions were still optimistic, in recognition of a slowdown in the overall software market, Cullinet apparently recognizes the stagnancy of the cross-industry market and instead will concentrate on enhancing its manufacturing software. Specifically, Cullinet will increase activity in the areas of repetitive manufacturing processes and in integration of CAD/CAE and CIM applications.

e. ASK Computer Systems, Inc.

- ASK Computer is the manufacturing software success story of the early 1980s with its MANMAN Information System, available as a turnkey system, as a software package, or as an RCS processing service. ASK has been mainly successful with discrete and process manufacturing firms. Smaller companies (less than $10 million) are targeted with the RCS offering. Larger companies ($10-100 million) that currently have DEC VAX or HP 3000 systems are targeted with the software offering. ASK has announced plans to offer a package for the IBM 4300 small mainframes and the DEC Micro VAX II.

- After targeting the HP 3000 market exclusively, ASK's MANMAN sales for VAX systems are quickly catching up to MANMAN/3000, and ASK expects that MANMAN/3000 sales should be equaled by the VAX sales in 1987. ASK's attempt to access the microcomputer market (via the Micro VAX II) is not its first. In 1983, ASK hoped to expand the financial software offering into a micro version of MANMAN; however, distribution problems and persistent losses moved ASK to discontinue the project in 1984. With the Micro VAX II offering, ASK will compete for smaller ($1-10 million) manufacturers with such vendors as MDS Qantel.

- ASK has announced its intention to link MRP with automated test equipment and to develop a transaction-oriented data base management system. 1985 proved to be a difficult year. While ASK has established plans to broaden its offering to additional hardware, reality may force it to focus its effort. Being a major player in this sector may be beyond ASK's resources.

f. Xerox Computer Services

- Xerox continues to be successful with its Xerox Manufacturing System. The group has targeted discrete manufacturing companies with IBM 4300, 370, 303X, and 308X mainframes systems. Xerox also targets smaller, decentralized manufacturing companies with its RCS manufacturing product, the Xerox Business Management System (XBMS), intended for customers as small as $10 million in annual sales. Xerox also markets a turnkey system called the Entry Turnkey System for companies with revenues of $40 million and up.

- In 1982, approximately 90% of XCS total computer service revenues were derived from processing services, with just under 10% from software products and only a fraction of a percentage coming from turnkey systems. Since then, the costs of acquiring computing power have come down to a level that has enabled many companies to bring processing in-house. Software and turnkey sales, particularly in the manufacturing market, now account for over 30% of XCS' annual revenues and could grow to 50% by 1987.

- While Xerox is certainly emphasizing manufacturing software sales, it is by no means abandoning its RCS business. For those large manufacturers with widely dispersed operations, XCS stresses the advantages of RCS processing due to XCS' networking expertise and the increased difficulty in dealing with multiple phone companies since the breakup of AT&T. Other prime candidates for RCS manufacturing processing are startup companies who have not yet decided on their own data processing strategies. Thus, XCS steps in on an interim basis, providing both the industry-specific expertise and the data processing experience.

- XCS' recent developments in software include the introduction and improvement of specific modules for its integrated manufacturing software products. Within the last year, XCS has introduced a number of new modules, including a repetitive manufacturing module for its Xerox Business Management System. Xerox also expanded its CAD/CAE systems line by introducing its Xerox Professional Mechanical Systems, an Ethernet-linked LAN of workstations that share common data bases.

- XCS has made public two specific goals for the future:

- First, to concentrate on accessing an enormous potential market of small- to medium-sized manufacturing companies and automating their factories' work floors.

- Second, to place greater emphasis on moving toward computer integrated manufacturing with much greater integration between CAD/CAE and MRP applications.

- Further, XCS has targeted Cullinet as its chief competitor in the market and should continue to make improvements and enhancements in its own package to compete with Cullinet's manufacturing system, particularly in the data base management area. XCS feels that its offering is already functionally superior.

g. <u>EDS</u>

- EDS is coordinating General Motors' efforts to actively pursue improvements in the manufacturing process. EDS has been spearheading the efforts of American manufacturers to force hardware vendors to implement MAP on their systems. Now it has gone one step further by designing and testing MAP at GM's plants.

- While EDS is working to put MAP on the factory floor, it is also building the large, complex data bases needed to tie in suppliers and dealers. Building and maintaining complex, accurate data bases is one of EDS' major strengths and will provide the means to integrate all segments of the manufacturing process. The dealers are being given direct electronic data communications with GM's computers, which will greatly speed up order taking and production scheduling. EDS will have great potential for commercializing this manufacturing systems integration expertise once the company can showcase a few automated GM factories.

- Besides manufacturing systems, EDS is building a private communications network for GM to expand communications capacity and reduce the cost of voice, video, graphics, and data exchange. This will provide new capabilities to enhance segments of the manufacturing information system. EDS will seek to expand the GM experience into the systems integration market and become a leader in CIM markets.

h. Comserv

- Despite its recent acquisition by MSA, Comserv is treated separately here because of its large and unique base of software users (AMAPS/Q, AMAPS/G, AMAPS/3000).

- Comserv has mainly penetrated discrete manufacturing companies with sales of at least $60 million using IBM and plug-compatible mainframes (AMAPS/Q); manufacturing companies who pursue government contracts (AMAPS/G); smaller manufacturing companies, and companies with decentralized data processing facilities running HP 3000 minicomputers.

- Comserv has relied on its reputation as the most experienced (its first product, MAPS, was introduced in 1976), most flexible (in terms of hardware on which AMAPS can run), and most specialized vendor in the manufacturing industry. Comserv has developed a loyal customer base, due in part to continual product development since the early 1970s, but more importantly, due to heavy emphasis on customer support services, including consulting, customization, and training. However, a slowdown in new orders (a slowdown that impacted most manufacturing software companies) along with questionable spending by the company (i.e., a $15 million headquarters in 1982) started a decline in revenue and profit that has forced the company to make a number of cost-cutting moves, including the divestiture of its service bureau and international subsidiary businesses, significant staffing cuts, and a restructuring of both executive and administrative organizations.

- Since 1983, the Securities and Exchange Commission has been investigating the company's financial reporting of 1981 and 1982 as a result of undisclosed agreements and irregularities in contract signing dates. Comserv took a number of steps to reverse its slide (selling Control Data Corporation the distribution rights for Comserv's products outside of the U.S., letting CDC acquire an additional 815,281 shares of stock in the company in exchange for the cancellation of a $1.5 million promissory note, etc.). Ultimately, in mid-1986, CDC preferred to sell its holding to MSA.

- MSA will need to continue the structural changes started in 1985. While customer satisfaction and loyalty to its products remained high, MSA will need to demonstrate to potential and new customers that the Comserv products are back on track strategically by emphasizing the strong points--an extremely well-developed yet flexible software package, experience in manufacturing, and customer support.

i. NCA

- NCA offers the MAXCIM Manufacturing and Financial Software System and the NCA/Design Verification System (NCA/DVS) to startup discrete manufacturing companies utilizing DEC VAX superminicomputers and DEC PDP traditional minicomputers. NCA also offers both systems on an interactive timesharing basis.

- NCA benefits from a close working relationship with DEC, continuing a cooperative marketing arrangement with DEC that facilitates NCA's ability to offer its software as a turnkey package. While NCA was able to survive the recent downturn in the semiconductor industry (which impacted NCA/DVS sales), it has gradually emphasized its MRP II package (MAXCIM) which now accounts for 80% of all company revenues, up from just under 60%. Like many other MRP II vendors, NCA recognizes the importance of increasing CIM capabilities in its manufacturing software.

- In early 1985, NCA completed the acquisition of two software development and consulting firms--The Systems Practice (Los Gatos, CA) and Avera Corporation (Scotts Valley, CA)--whose manufacturing products and expertise are complimentary to NCA's existing product family.

- In the past, NCA's only real competition has been ASK Computer. While the VAX penetration into manufacturing markets should provide steady growth potential, NCA will now have to be concerned with Martin Marietta Data Systems' entrance in the VAX market.

j. Boeing Computer Services (BCS)

- Boeing's main products are the Production Management System (PMS) and Maintenance and Materials Management (MMS) with which it has targeted the discrete and process manufacturing software market for HP 3000 systems.

- Boeing Computer Services provides remote computing services, facilities management, and software products. Major industry markets are the federal government, engineering, and energy sectors. Future markets for BCS services will emphasize telecommunications, manufacturing, and distribution.

- Boeing Network Architecture (BNA) is Boeing's architecture for systems within which its Technical and Office Protocol (TOP) has been linked with products from the Manufacturing Automation Protocol (MAP). Boeing will continue to develop capabilities in the manufacturing sector and will have the resources and technical know-how to be a major competitor.

F. SUCCESS FACTORS

- Achieving success in the CIM market is dependent upon a number of factors, not least of which is the ability to adapt to the rapid changes in the marketplace without getting ahead of users' ability to digest and implement the solutions and products offered.

- Products should meet industry standards and provide easy transition from one phase of implementation or use to another. Vendors must be solution oriented and must work closely with their users each step of the way, providing effective post-sales support. CIM should not be viewed as a product sell but more like a marriage--an ongoing commitment to making things work to the satisfaction of both parties.

- As CIM is a big stakes game, small vendors are in a better position to compete when they form strategic alliances with their peers. Vendors willing to take the trouble to understand the total needs of the user will be in a better position to provide custom solutions.

- Close relationships with industry leaders such as IBM or DEC (or at least an understanding as to how the directions taken by these industry giants affect the products and investments made) are vital. Lastly, a comprehensive strategy that is sensitive to rapid changes in market, technology, and user requirements will ensure success.

G. BARRIERS TO ENTRY

- There are many barriers to entry in the CIM market, in particular, detailed knowledge of the manufacturing environment in its present state and a keen understanding of where it is headed. In addition, three other key aspects must be considered: capital required, access to qualified resources for market growth and penetration, and access to the distribution channels necessary for product sales and support.

- Capital: the capital requirement to launch any venture in the CIM arena is now high, with the possible exception of a major breakthrough in systems software; certainly the launch of a new applications package is high. To make things more difficult, venture capital for high technology is very tight and nearly impossible to obtain for software products at the present time.

- Access to qualified personnel: this is a problem even for established companies. Expansion and continued development of CIM markets require highly qualified technical personnel. These personnel are in short supply and competition for them is high. For a startup, this represents a significant barrier; for the established company it represents a controlling factor on growth.

- Access to distribution channels: establishing a distribution network for a newcomer takes considerable time. The same applies to a CIM vendor branching out into new market areas. For both, this can be a significant barrier to entering a new market.

- Lack of market presence and/or installed base: this is a major barrier to new players entering the market, as many areas of CIM are currently dominated by established vendors who can reposition themselves to compete in the new environments.

• The timing for entry into the CIM market could be better than at present. Also, the market is in a state of flux due to the overheated pace of technological innovation, the difficulty users are experiencing implementing what they have already bought, and the lack of market direction due to the absence of a true, overall CIM market leader.

IV CAD/CAE MECHANICAL MARKET FORECAST, 1986-1991

IV CAD/CAE MECHANICAL MARKET FORECAST, 1986-1991

- Several major long-term developments will affect the CAD/CAE market over the next five years. These include the tax reform act, the impact of the trend toward distributed micro-based workstations, and the systems integration issue.

- The tax reform act affects capital expenditures of some of the main purchasers of CAD/CAE equipment (namely aerospace, manufacturing, and telecommunications companies) by reversing deferred tax accruals and raising effective tax rates. With less incentive to spend capital, some negative impact on the purchasing patterns of these major customer groups must be expected.

- Distributed micro-based engineering workstations offer a lower-cost alternative to traditional CAD/CAE turnkey systems while providing powerful processing capabilities once reserved for larger systems. This impacts turnkey vendors in three ways:

  - It reduces the dollar value of the average sale and obsoletes product lines at an increasingly rapid rate.

  - A continuous flow of new products is required to remain competitive in this rapidly changing technological environment which demands steady R&D, tooling, and marketing investment.

- As a result, operating margins will fall as the per-unit gross margins shrink and the mix of the systems sold moves toward the low end.

- Lastly, customers' CAD/CAE design functions must be integrated with shop-floor manufacturing functions to shorten the lead times between design and the production of a shipable product. (This is becoming a crucial element for survival in increasingly competitive manufacturing markets.)

- Turnkey vendors must therefore be prepared to address the issue of the integration of their products with a network of other vendor equipment or face the loss of market share. This was the key factor in the loss, by Computervision, of its dominance of the CAD/CAE market; its products could not be made to interface with the IBM mainframes usually found in the MIS department.

A. MAJOR ISSUES FACING USERS

- It is important for potential buyers of CAD systems to know, precisely, the differences in the capabilities of two-dimensional (2D) and three-dimensional (3D) mechanical CAD packages. There is still some confusion that dates back to the days when vendors first began marketing 3D wireframe "design and drafting" application packages.

- Many CAD salespeople continue to sell 3D software for pure drafting applications and drafting packages for design needs. This results from the salesperson's desire to sell a more expensive product, failure to explore the customer's real needs, and lack of technical knowledge.

- By understanding the advantages, disadvantages, and capabilities of one type of software over another, disappointments and costly miscaculations from false expectations on the performance of the system can be avoided.

- To differentiate which CAD packages are for design and which are for drafting, the user must look at the definitions of the two tasks:

  - Design is the process by which a product of a specific mechanical function is mentally conceived and symbolically represented.

  - Technical drafting is the process by which the geometry of an object is symbolically represented in accordance with a given set of standards on a two-dimentional medium (paper in manual drafting and the CRT in computer-aided drafting).

- From the two definitions it follows that drafting can be a design tool only if the drafter creates the drawing of a new object. However, if a drawing is merely copied from one piece of paper to another, or if the draftsperson simply makes the drawing of an existing part, then drafting is just a reproduction method.

- Another term that needs definition is "modeling." A CAD geometric model is the graphic representation of the shape of an object. Within the computer, this model is represented as computer data and is stored in the computer's memory.

- The mathematical procedures used for defining the geometric model determine whether the CAD model is a wireframe, surface, or solid.

- The geometric model is a subset of the design of a mechanical part which also includes other definitions such as material, surface finish, functional description, energy use, and environmental limits. Another capability of CAD/CAE systems is functional modeling, whereby the functionality of a system may be evaluated. For example, a product assembly may be functionally modeled by defining the space-time relationships between its moving elements and representing "snapshots" of the various states of the product during its cycle.

- At the current state of CAD/CAE technology, the creation of drawings is still a requirement for design documentation, even though it is not absolutely needed to manufacture the part. Statistics show that at CAD installations with 3D systems, the preponderant activity is still the creation of drawings.

B. ADVANTAGES AND DISADVANTAGES OF 2D AND 3D SYSTEMS

- The advantages of two-dimensional systems over three-dimensional systems are:

  - Easier to learn for first-time users; the similarity between the construction of geometry and creation of drawings with traditional manual paper-and-pencil methods makes it easier for beginners to change from drafting on the board to using CAD/CAE.

  - Depending on the package, the learning time may vary from one to three weeks before a user becomes productive. The prerequisite to using 3D packages is more demanding (a fairly good command of geometry and mathematics is required).

  - Drawings can be created immediately using the 2D model geometry (in fact, the principal use of 2D CAD/CAE systems is for drafting). In addition to drafting, some of the 2D systems are also capable of simulating planar mechanism and finite element analysis of two dimensionally approximated parts such as thin plates or membranes.

  - Two-dimensional parts libraries are much faster and easier to create than 3D libraries; also, the amount of storage space required by 2D data files may be considerably less than that of models representing the same part in 3D.

- The system response time for 2D packages is faster than that for 3D packages, which are computationally more intensive. This may be especially noticeable for host systems that support several work-stations.

- It is not necessary to update 2D models once the part's drawing has been changed. In 3D systems, if either the model or the drawing is updated, the other one must also be changed by the operator.

- Data transfer from one CAD/CAE system to another yields more complete results for 2D geometry than for 3D geometry.

- The hardware required for 2D packages is less expensive than that for 3D models, and the cost of 2D software packages is, in most cases, considerably less than that of 3D packages.

- 2D systems are suitable for drafting departments where the completion of a project is directly dependent on the timely production (and release of drawings and meeting deadlines is important).

- Many 2D systems also have NC output capability. Obviously, this capability is limited inherently by the 2D aspect of the geometry to machines in which third dimension is an operator-controlled function such as in two-axis mills, lathes, punch presses, planer welding machines, and flame/plasma cutters.

• The advantages of 3D over 2D are:

  - It is possible to create 3D models which can be viewed from any angle or point of the coordinate space. This is a much more natural way in which to design mechanical parts than to use projections because the human mind is inherently used to thinking in 3D.

- It is possible to check the relationship between parts and evaluate whether they fit together, whether they can be assembled properly, etc. With 2D systems, positional relationships between parts are made via projections, which are cumbersome, lengthy, and subject to errors.

- It is possible to create octogonal projections to be used for drafting views. In addition, isometric or perspective views can be created without extra effort.

- Section views can be obtained easily (depending on the type of modeler) by intersecting the part geometry with a sectioning plane.

- Surface and solid modelers can render good quality visual illustrations by a shading process.

- Solid modelers can compute the volumes and mass properties of objects.

- The ability to perform automatic hidden line removal is very helpful in visualizing objects and saves significant amounts of time for creating isometric views, facilitating detection of design errors.

- Surface and solid modelers can compute and graphically render the intersection contours for various intersecting surfaces. They can also create fillet and trimmed surfaces.

- Output for multi-axis NC machines can be generated from 3D models. This capability will progressively eliminate the need for dimensioned drawings for manufacturing.

• Some disadvantages of 3D CAD systems are:

- The need to exactly define all elements of a 3D model to be useful for NC manufacturing. For example, all fillets, chamfers, or tapered holes must be created rather than merely called out (standard drafting practice).

- There is no 3D CAD/CAE system for assigning tolerances to the model.

- To improve productivity on 3D CAD/CAE systems, extensive application standards must be adopted by the company.

C. THE DICHOTOMY BETWEEN THE DRAWING AND THE MODEL IN 3D SYSTEMS

- Almost all 3D systems have the capability of creating drawings from the 3D model representation. This is usually done by projecting the model geometry onto specially selected planes to obtain the views of the drawing, which then are dimensioned and annotated.

- One of the hidden disadvantages of using many 3D systems to create drawings is the dichotomy which arises between drawings and the model itself. This contradctory division between the two facets of a 3D model has its causes in the inevitable loss of association which occurs as a result of mapping 3D data onto a plane.

- In the process of creating a drawing from a 3D model, some of the geometry resulting from projecting the model must be changed to obtain a picture that conforms to drafting standards. For example, some lines are only partially visible in one view but fully visible in another. The drawing also needs additional graphical elements which are not present in the model such as hatching and various symbols.

- To alter the geometry in the drawing views but not in the model itself, the user must break some of the links from the drawing to the model. This will be transparent to the user by the commands used.

- Once the direct one-for-one association between what is in the drawing and what is in the 3D model has disappeared, it becomes possible to alter either one or the other without the change being reflected reciprocally.

- This may be dangerous if the changes are small enough not to be noticeable visually and time consuming if one considers that for each new revision of the past documentation, the operator must verify that both drawing and model have been changed equivalently. If the drawing is changed but the 3D model is not, future users of the 3D model may assume that the model is up-to-date and errors will occur.

- Newer CAD/CAE system developers have attempted to solve this problem by introducing associative links between elements of the drawing and the model, but the solution is only partially effective.

D. WIREFRAME VERSUS SURFACES VERSUS SOLID MODELING

- The disadvantages of wireframe modelers are:

  - The possibility of making errors by constructing impossible objects--clearly, using only lines makes it possible to draw wireframes which cannot represent a solid body.

  - All edges of the object are visible on the display, resulting in a confusing and difficult to interpret image. For complicated objects, it becomes difficult for the user to recognize and understand the actual shape.

- It is not possible to perform automatic hidden line removal. Since the information pertaining to the surface and volume of the part is not in the data base, there is no way in which to determine which edges are seen and which are hidden.

- It is not possible to obtain directly the volume and mass properties of the objects. The ambiguity resulting from defining an object by only its edges precludes the system from knowing which part of the model is solid.

- The NC capabilities of such systems are limited to 2 to 2.5 axes output.

- The main advantage of wireframe modelers over surface or solid modelers is that it is computationally less demanding and thus such packages can run faster and on cheaper hardware.

- A surface modeler is a CAD/CAE package which models objects by defining their "skins" as a collection of special elementary surfaces. The number and type of elementary surfaces available for constructing an object depend on the individual package.

- Surface modelers contain more information on the object than wireframe modelers. All points of the object's surfaces are precisely known. The limitation of this modeling technique is that there is no information on the volume occupied by the object.

- The advantages of surface modeling over wireframe are:

  - Objects can be modeled and constructed very precisely.

  - It is easier to implement automatic hidden line removal.

- Shaded pictures can be produced by defining one or several sources in the model. This can increase the comprehensibility of the model and may also serve to create illustrations for technical publications or advertising.

- It becomes possible to automatically create and display the intersection paths of objects.

- NC output to 3 and 5 axis machines can be generated.

• The limitations of surface modeling technique are:

  - The possibility of creating physically impossible objects.

  - The display can become even more cluttered than with wireframe representations because of the presence of surface display lines.

  - Surface modelers can be quite slow due to the greater number of calculations the system must perform to display the view of the model.

  - Hidden line algorithms can have only limited success because the model does not contain information on where the material of the part is located relative to the boundary surfaces. For the same reasons, volumes and mass properties cannot be calculated automatically.

• The most advanced method of modeling is to represent the object in the data base as "solid" geometry. In such a representation, the system has precise information on the volume space.

• Two basic solid modeling techniques are being used today:

  - Constructive solid geometry (CSG or C-rep), where the geometry is created in building block fashion by adding and subtracting elementary solids (cubes, prisms, spheres, cylinders).

- Boundary representation (B-Rep), which is based on the interactive definition of the solid object from boundaries defined by views or surfaces.

- The advantages of CSG solid modeling over B-Rep modeling are:

  - Ease of use and faster construction of relatively simple objects, with shapes which can be easily approximated by the available elementary solids.

  - More compact data storage for the model.

- The advantages of B-Rep over CSG are:

  - Ease of model constructions with many details of unusual form.

  - Faster display response time.

  - Ability to use existing wireframe and surface models as the basis for creating the solid model. This is an advantage where the system must be integrated with an existing wireframe package.

- As a result of the relative advantages of one solid modeling technique over another, some CAD/CAE vendors have adopted a mixed approach, offering both CSG and B-Rep construction capabilities in their packages.

- Solid modelers have unique advantages which make them an optimum tool for many mechanical design applications. Advantages include all capabilities mentioned for surface modelers, plus:

  - Ability to determine volume and mass properties of the designed part.

- Unambiguous object definitions.

- Fully automatic and 100% efficient hidden line removal.

- Ability to perform interference detection on two objects. This capability is important in the analysis of designs in which the possibility of interference of one part with another during the functioning of the product exists. It also leads to the ability to determine tolerance limits for fittings of complicated parts.

• Solid model data bases contain all information necessary for implementing group technology-based CIM. Solid modeling has the following disadvantages over wireframe and surface modeling:

  - More difficult to use.

  - It requires more powerful and expensive hardware. Solid modeling packages require a great deal of computing power and, thus, are not very effective on low-cost workstations.

E. INTEGRATION: LINKING DESIGN AND MANUFACTURING FUNCTIONS

• The central idea behind the integration of CAD/CAE applications that is universal to most companies is the idea of a common data base. Of all the 3D modeling techniques, solid modeling might be the key to the common CAD/CAE data base. But if solid modeling is to be the key, it must provide the missing ingredients to support the many CAD/CAE functions.

• There are two basic requirements for the common CAD/CAE data base if it is to provide for complete CAD/CAE integration. The first requirement is that the format and contents of the data base be agreed upon beween the different engineering and manufacturing functions. This requirement is often more of a management challenge than a technical problem.

- The second requirement is that the product definition contained in the common CAD/CAE data base must be complete and unambiguous enough to support all the applicable CAD/CAE applications. This product definition is made up of geometric data along with an associated set of non-geometric specifications.

- The CAD/CAE integration potential of solid modeling lies in using the solid geometric model as the basis for the geometric portion of the product definition. Solid modeling could conceivably provide a complete and unambiguous representation of the geometric portion of the product definitions data base. This solid geometric model definition could provide both direct and indirect benefits.

- The direct use of the model would be made by applications that are only dependent or mostly dependent on geometry, such as numeric control (NC), finite element modeling (FEM), and quality assurance. Use of the solid geometric model for these applications has the potential of demanding less user interpretation while allowing more applications to be automated.

- Indirect use of the model would be made by having non-geometric portions of the product definition reference or point to entities contained in the solid geometric model representation. For example, surface finish requirements could reference faces of the solid geometric model.

- If the solid model is to be the key in integrating CAD/CAE applications, some of the applications that it must aid are:

    - Mass properties analyses of individual parts and assemblies of parts; automatic or semi-automatic finite-element mesh generation using solid elements as well as plate and shell elements.

- Space coordination studies such as routing of tubes and wires, automatic checking for past interferences and/or clearances, and allowing the use of the "electronic" workup to check part and assembly compatibility.

- Realistic display of parts and assemblies of parts including exploded views, section cuts hidden line removal, and color shaded display.

- Association of dimensions and tolerances with the geometry of the model.

- Automated quality assurance checking using the geometric model and its associated dimensions and tolerances.

- Generative process planning through automatic recognition of important features of the solid geometric model.

- Automated or generative NC--also, verification of NC data by comparing the original engineering-created model to a model generated by NC data.

- Automatic tooling and fixture design.

- Robotics work cell design allowing for automatic checking of potential interferences and optimization of object placement and orientation.

• However, solid modeling has not reached its CAD/CAE integration potential as yet. There are a number of technical and implementation problems that need to be resolved before the potential applications of solid modeling can be realized. Some of the most pressing technical problems include:

- Difficult access to the solid model data base--more complete and standardized data base access routines are needed to allow application problems to intelligently use the solid model data. Contributing to the problem is the fact that there is little internal intelligence in the data base itself.

- Sparse recognition of defining model features--a modeler may not know that a void in the model was intended to be a cylindrical hole; it may only have a collection of faces that visually represents a hole. If the modeler does know that an exact cylindrical hole is contained in the model, it may not know that a particular surface is pierced by the cylinder without considerable processing.

- Limitations in model size--the limitations may be practical or may be imposed by the system. If a part is complex enough to provide needed manufacturing data, it may be too large to combine with other models for interference checks or workups.

- Difficult extractions of geometry for NC work--there is currently no method to automatically extract drive, check, and part surfaces.

- Absence of dimensioning and tolerancing data--there is no way to associate dimensions and tolerances with the nodel geometry.

- Limited capabilities to query model--it is very difficult to measure distances between entities, find absolute coordinated, or determine canonical definition parameters.

• In addition to these technical problems, there are these implementation problems:

  - Complicated and awkward user interfaces--the interfaces need to better reflect engineering needs and methods.

- Shortage of modeling tools--it is often difficult to fit models together into assemblies. For example, it is often difficult to place the model of a bolt in an arbitrary hole.

- Slow interaction speed--this is especially true of interferance checks and many Boolean operations.

- Need for large computing resources--many solid modeling processes are extremely computer intensive and require a large amount of computer horsepower if operating speed is to be acceptable.

- Large model-storage requirements--when compared to other CAD/CAE systems, solid modeling systems generate very large files for model storage.

- Difficult editing of geometry--once a model is initially constructed, it is often difficult to make changes.

- Solid modeling provides the potential for increased CAD/CAE integration but more applications of solid geometric data are needed to make the increased integration a reality. If industry hopes to top the potential of solid modeling, it must actively pursue the development and refinement of applications programs.

- Efforts towards some form of solid modeling data format standardization by groups such as CAM-I and IGES may help make industry development of solid modeling applications more viable.

F. MAJOR ISSUES FACING VENDORS

- Increasing competition has become a standard part of the markets makeup. New companies continue to enter the market while established vendors still maintain supremacy in the medium- and high-end markets where they compete among themselves.

- The high-growth, low-cost systems market belongs currently to startup companies. These startups are aiming at acquiring large market shares in their category, recognizing the potential of low-end systems while penetrating higher-end markets with further product offerings.

- Profits are decreasing across the board because of high development and support costs and increased competition. Most vendors are having difficulty in supporting growing user bases. Support of customers is key to the success of a CAD/CAE company but presents logistical, staffing, and capital requirements problems. These problems become more difficult to solve with the growth of the company.

- Even though the U.S. is the largest geographical market for 3D modeling systems, ample opportunities exist in Europe, Asia, Australia, and South America. Vendors planning to enter these new markets must deal with the differences in the culture and economics of each country before they can be successful.

- Advances in software and harware technology are the determining factors behind the 3D modeling industry's ability to introduce better and cheaper systems. On the negative side, the same factors result in rapid product obsolescence, driving vendor companies to invest large amounts of their revenues into R&D. Thus, vendors are faced with difficult choices between developing hardware or using OEM components, what software to develop in-house, and how to support third-party applications.

- Introducing new products and integrating them with existing ones is a difficult task. User requirements for new capabilities and applications are growing at a faster rate than vendors can develop and integrate new products. Vendors are discovering that third-party applications software is a good alternative to in-house development.

- Many vendors lack sufficient qualified personnel for product development, sales, and support. CAD/CAE professionals have the highest average turnover rate of all high-tech industries (20% to 30%). This, combined with the explosive growth of the industry, has created a staffing problem for many vendors.

G. KEY ASSUMPTIONS FOR FORECAST

- Many of the technical issues facing 3D modeling users today will be resolved in the next three to five years. A few of the issues are: limitations in model size, difficult extraction of geometry for NC work, and the absence of dimensioning and tolerancing data.

- The push toward industrial automation spurs the growth of CAD/CAE systems. Availability of low-cost, high-performance graphic workstations will be the key driver of the 3D modeling market. Penetration of mechanical CAD/CAE systems, currently at 7%, will increase significantly to 15%. Competition from Japan will push prices of 3D modeling software down further. Computer hardware prices will continue to decrease at a rate of 10% per year.

H. MARKET FORECAST

- The worldwide CAD/CAE market for all applications is expected to grow from \$3.0 billion to \$10 billion at an annual compound growth rate of 27% (Exhibit IV-1).

- The U.S. market will continue to be the single largest market, growing from \$1.7 billion to \$5.34 billion at an annual growth rate of 27%.

- Of these revenues, 77% were from host-based systems in 1986. However, this percentage will drop to 57% by 1991. This decline will be due to the drop in "per-seat" cost for the engineer and the increased functionality available at the terminal in workstation- and personal computer-based systems. Host-based systems will still be in demand for large-scale analysis and data management (Exhibit IV-2).

- Since most of the host-based vendors sell their products bundled, it is our estimate that the software component of CAD/CAE systems was 30% in 1986 and will account for one-half of the total systems cost in 1990. The reason for this change is the continuing decline of hardware prices and the increasing value-added importance of applications software.

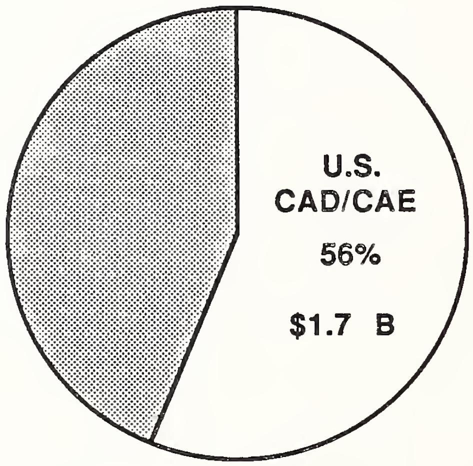
- As shown in Exhibit IV-3, in 1986 the largest share of revenue in the CAD/CAE area came from 2D drafting software (45%), followed by 3D design packages which included wireframe, surface, solid modeling, and analysis.

- In 1991, we expect this ratio to change quite significantly--revenue for 2D drafting decreasing to 25% of the total. The biggest gains will go to 3D solid modeling and manufacturing software. As the price of the hardware decreases, the host-based systems will be used for the more sophisticated tasks such as 3D modeling. Drafting will be done on lower "per-seat" systems.

EXHIBIT IV-1

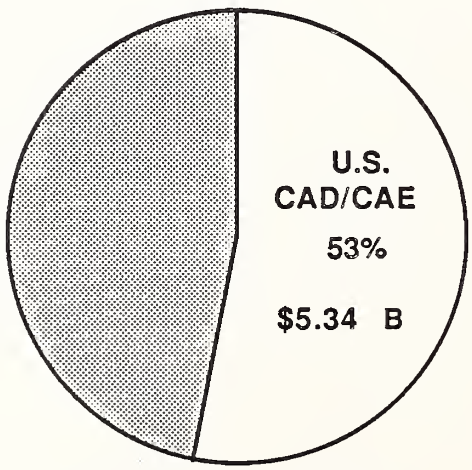
WORLDWIDE CAD/CAE REVENUES

1986



Total = $3.0 Billion

1991



Total = $10 Billion

EXHIBIT IV-2

CAD/CAE REVENUE DISTRIBUTION BY SYSTEM TYPE

SYSTEM TYPE	1986 REVENUE ($ Millions)	1986 MARKET SHARE (Percent)	1991 REVENUE ($ Millions)	AAGR (Percent)
Host-Based Systems	$1,320	77%	$3,025	18%
Personal Computer-Based Systems	$150	9%	$995	46%
Workstation-Based Systems	$230	14%	$1,320	42%
Total	$1,700	100%	$5,340	26%

EXHIBIT IV-3

CAE SOFTWARE FORECAST BY APPLICATION FOR HOST-BASED SYSTEMS

APPLICATION TYPE	1986 REVENUE ($ Millions)	1986 MARKET SHARE (Percent)	1991 REVENUE ($ Millions)	1991 MARKET SHARE (Percent)
Drafting	$153	45%	$375	25%
3D Wireframe	$85	25%	$75	5%
Surface	$51	15%	$225	15%
Analysis	$27	8%	$150	10%
Manufacturing	$17	5%	$300	20%
Solids	$7	2%	$375	25%
Total	$340	100%	$1,500	100%

- Use of CAD/CAE workstations networked together will grow rapidly, reflecting the need for data sharing, integration of design and manufacturing, and a growing market for CAD/CAE in small engineering companies.

- CAD/CAE software revenues will grow at an annual compounded growth rate of 65% to reach $790 million in 1991 (Exhibit IV-4).

- The increase in functionality and rapid decline in prices of PC-based systems will help increase their share of the CAD/CAE market from 9% in 1986 to 19% in 1991. Software for this segment will grow at an annual compounded growth rate of 94% from $21 million in 1986 to $580 million in 1991 (Exhibit IV-5).

- The predominant use (90%) of PC-based CAD/CAE mechanical systems is for drafting at the present time. With improved price/performance ratios, however, PCs will be increasingly used for analysis and 3D modeling packages.

I. LEADING VENDORS

- IBM has constantly lead the host-based system vendors, while Computervision, who for so long lead the market, has steadily lost market share. The other major players in this market are Intergraph (which has been very good at recognizing the needs of users), Applicon, Auto-trol, Calma, and McDonnell Douglas.

- IBM's dominance is due to its attractively priced products (such as CADAM and CATIA) being well regarded by users. The model 5080 graphics terminal used with these products is a superior product from the standpoints of price, versatility, and performance. Exhibit IV-6 compares the processors of host-based system vendors and the maximum terminals they can support.

EXHIBIT IV-4

CAD/CAE SOFTWARE FORECAST BY APPLICATION FOR WORKSTATION-BASED SYSTEMS

APPLICATION TYPE	1986 REVENUE ($ Millions)	1986 MARKET SHARE (Percent)	1991 REVENUE ($ Millions)	1991 MARKET SHARE (Percent)
Drafting	$29	45%	$198	25%
3D Wireframe	$16	25%	$40	5%
Surface	$10	15%	$119	15%
Analysis	$5	8%	$79	10%
Manufacturing	$3	5%	$158	20%
Solids	$1	2%	$196	25%
Total	$64	100%	$790	100%

EXHIBIT IV-5

CAD/CAE SOFTWARE FORECAST BY APPLICATION FOR PERSONAL COMPUTER-BASED SYSTEMS

APPLICATION TYPE	1986 REVENUE ($ Millions)	1986 MARKET SHARE (Percent)	1991 REVENUE ($ Millions)	1991 MARKET SHARE (Percent)
Drafting	$19	90%	$290	50%
Analysis	$1	4%	$116	20%
3D Wireframe	$1	3%	$17	3%
Manufacturing	*	1%	$29	5%
Solids	*	1%	$87	15%
Surface	*	1%	$41	7%
Total	$21	100%	$580	100%

* = < $1 Million

EXHIBIT IV-6

HOST-BASED SYSTEM VENDORS

VENDOR	PROCESSOR	MEMORY	MIPS	MAXIMUM NUMBER OF TERMINALS SUPPORTED
Calma	VAX 11/780 32-Bit	4 M Bytes	1.06	12
Computervision	CDS 4201 32-Bit	4 M Bytes	N/A	16
Intergraph	VAX 11/730 32-Bit	2 M Bytes	0.36	2
IBM	4381	4 M Bytes	2.7	50
	3081	16 M Bytes	18.8	300
McDonnell Douglas	VAX 11-750 32-Bit	4 M Bytes	0.72	6
	Prime 2850	4 M Bytes	N/A	20

- The workstation-based CAD/CAE mechanical market is fragmented with a number of small vendors. Some of more interesting products in the market place are:

    - Prime's 3D packages with good solid modeling capabilities but limited capabilities for interfacing to manufacturing.

    - Cadlink's excellent interface betwwen design and manufacturing.

    - Auto-trol's very user-oriented design package.

- The leading player of PC-based CAD/CAE systems is Autodesk, followed by Robocom and P-CAD. As a general-purpose drafting package, AutoCAD is targeted in the mechanical industry to small companies and individual users with low volume and complex drafting needs. Its interface with CADAM has opened up a large market. CADAM users can use AutoCAD to lower the cost of drafting terminals and ease the load on the host computer.

V FACTORY AUTOMATION EQUIPMENT MARKET

V FACTORY AUTOMATION EQUIPMENT MARKET

A. MAJOR ISSUES

- For most would-be factory automation equipment users, there is no single source for advice, planning assistance, equipment selection, installation, or training. A project as complex as CIM is difficult to start from scratch. A viable starting point of specific experience is required.

- A group of professional services vendors are emerging to meet that need, developing experience as they go. They are to be distinguished from the vendors of software, hardware, or network systems who have a vested interest in convincing the user to adopt a single point of view--theirs.

- Even then, it is unrealistic to expect a quick payout. There is a natural tendency to perform a detailed analysis of hardware requirements while neglecting software needs and the necessity, short term or long term, of interconnection of the various systems and automation equipment planned.

- The availability of appropriate software is all important. Selection of hardware should not even be considered until software has been selected and thoroughly evaluated--preferably under real-world conditions. It may be necessary or advisable to obtain the services from an experienced professional services or management consulting firm. Their opinions will be unaffected by internal politics and the natural tendency of company employees to maintain the status quo.

B. LACK OF INDUSTRY STANDARDS

- It is important to recognize the significance of industry standards if products from several vendors are to communicate easily within the hierarchy of CIM equipment. For example, General Motors has thousands of pieces of automated equipment and only 15% can communicate.

- Martin Marietta in Orlando (FL) spent six man-years tying 22 pieces of equipment into an integrated system. It required 21 different software protocols.

- General Motors, frustrated by its problem, set out to develop a standard industrial LAN. Its effort produced the manufacturing automation protocol (MAP), which is a token-passing broadband network married to open system interconnect, a seven-year LAN model developed by ISO.

- While far from perfect, MAP represents a major step forward to assure interconnect compatibility among equipment from different vendors. Wide acceptance of MAP is assured through the huge purchasing power of GM and its acceptance by leaders in the computer industry (DEC, IBM, HP, and AT&T) and the major semiconductor manufacturers (Intel, Motorola, and Siemens).

- This latter group is important as the availability of custom chip sets has a significant bearing on the cost of network interconnect hardware and the speed limitations of practical network standards.

C. ORGANIZED APPROACH

- Systematic approaches are essential if CIM is to be effective. The temptation is to go for partial solutions which produce short-term results and therefore are more easily justified than risking long-term coordinated projects which are almost impossible to evaluate going in and require years to implement.

- Frequently, economic limitations restrict the paralleled implementation of a large project. This is especially true for updating existing production facilities compared to building new ones. However, staged implementation is preferred to piecemeal approaches to automation.

- Staged projects imply that the entire project is planned and evaluated before any part is actually contracted for. Therefore, the planners are not restricted in their decisions by having to accomodate equipment that does not fit into a comprehensive plan for the facility.

- This point is most important since the overall problem must be considered, not just its individual parts. Otherwise the solution will not be optimized and expensive equipment replacements will no doubt be needed at a later date as the initial discussions prove unworkable in the overall scheme.

D. ALLOCATION OF RESOURCES

- Effective resource allocation is a tricky process but an essential one because of the high cost and long-term commitment. Existing accounting systems usually prove insufficient since they were not designed for correctly monitoring the task at hand. The benefits of CIM are difficult to quantify and to track on a pro forma basis.

- Conventional wisdom fails us in this situation because the benefits are no longer derived principally from direct labor savings. Experience has shown that although some direct labor savings can be attributed to flexible systems, the significant savings are in work-in-process, material inventory and handling, inspection and quality control, scrap reduction, and virtual elimination of rework.

- Despite these facts, production management typically spends 75% of management resources searching for further reductions in direct labor although the average direct labor in U.S.-produced goods is already down to 10-15%.

- It is essential to tie the CIM commitment directly to company objectives, goals, or strategies. The company may need CIM to become, or remain, the industry leader, to increase market share, to introduce new products or product improvements, to improve return, or to coordinate the physical plant.

- Unfortunately, cost accounting systems are devised to monitor direct labor-based costs. The other important costs are buried, frequently along with material costs, inspection time, and other essential cost data. Therefore it is rare that hard cost data is available to the decisionmakers which makes monitoring a CIM implementation all the more difficult.

- Investments in CIM are for the long haul and frequently have very adverse short-term effects, such as disruptions in production, long payout periods, and extended and protracted installation schedules. Without a comprepensive plan it is easy to reduce efficiency rather than improve it, especially in the short term. This fact has caused the abortion of many otherwise viable projects.

- Labor problems arise as soon as the production environment is changed, or sooner if the rumor mill is operating normally. Management must develop techniques of mitigating this time bomb effect. Good communication is essential, along with a humane approach.

- Automation can be almost painless in this respect or be a major cause of disruptions with lingering ill effects. Various management approaches to this problem are discussed elsewhere in this report.

- The availability of qualified professional personnel will remain a challenge for management as the supply is always tight.

- Reliable information on equipment, software, and the field experience of comparable organizations must be obtained and maintained because CIM technology is progressing at a rapid pace. Management must employ the resources of vendors, systems houses, associations, government sources, trade journals, exhibitions, and competitors.

- The most risky challenge facing management is to go with untried technology. They are frequently tempted to be pioneers because of the rapid change of technology, believing that only the latest wrinkle will keep them ahead of their competition.

- In any given market, technological developments tend to come in waves rather than in a continuous steam. It is between waves of change that optimum profitability should be sought, mindful of the fact that the organization needs to prepare for the next wave of change.

E. POLITICAL CONSIDERATIONS

- Both the political process and climate inside an organization and its external environment, such as the federal goverment, have a tremendous impact on decisions relating to manufacturing automation. The process ultimately determines what will be done.

- Resources can be shifted among industries through tax incentives for investment down to tax exemptions and outright financial aid for new plant construction and the acquisition of capital equipment. Most government entities justify their business involvement on the basis of job creation. Automated factories, on the other hand, create a minimum of permanent jobs, and those are professional and technical. These hardly make good political issues where the voters are primarily blue collar workers.

- Past experience at the federal level has produced mixed results and cost a lot of money either in the form of outlays or tax incentives. The present trend is for less federal intervention and regulation. The federal government can no longer afford to prop up certain industries that have fallen victim to shifting markets, world competition, and inadequate management.

- At the state and local level, the political motivations are clearer. Most areas want commercial development for their people and are willing to take the steps necessary to attract it. Every area is in competition with other areas in this respect. Management must learn to interface with these local requirements and capitalize on their benefits.

- Most U.S. organizations practice a top-down system, passing down commands and filtered information and allowing only trickles in the upward direction, despite the fact that the person closest to the action usually has the best understanding of the job.

- This knowledge must move upward if management is to gain an understanding of the work and formulate plans for making it more productive for all concerned. When workers feel that information does indeed flow upward, quality improves. Workers who feel that management listens to their needs do a far better job. Results can be very tangible.

- Walls have been erected between production and the other functional areas of a business. Too often, design engineers will not go into the shop floor to address production problems caused by the design or accept corrective suggestions from the floor which are known to work in practice.

- Another major problem is how management performance is reviewed. Rewards are small for major contributions while failure is severely punished. Vital decisions are always fraught with uncertainties and peril.

- The greatest unknown for most managers is new technology. There is no experience to draw on, and most of the sources of information are advocates rather than unbiased (at best) or are misinformed (at worst).

- Conversely, there is a large risk in not deciding to venture forth and in not timing that step correctly. Much of the fear of new technology is in making the wrong financial decision. A successful manager in the US system is one who has made a series of sound financial decisions. This leads to an attitude of caution rather than aggressive innovation.

F. LABOR AND THE WORK ENVIRONMENT

- The U.S. labor force has been as slow, if not slower, than U.S. management to accept CIM. This is an issue of great importance to any company planning to install a CIM system. The prior experience of a company and its employees with computer-based systems makes a great deal of difference in the manner in which a CIM system can be installed.

- Generally, most companies have computerized some portion of financial accounting but have done very little to automate the factory floor. A problem in dealing with the introduction of any computer system into the manufacturing floor in some companies is that the labor force could perceive computers as a threat to job security.

- In the case of union-organized shops, this can be even more serious since the job structure may be quite rigid. A method of approaching this problem is to first introduce a simple data collection system into the manufacturing environment so as to allow the workers to become familiar with computer procedures. More automation and computer control can then be introduced gradually.

- In those companies where factory automation is already in progress, the issues are somewhat different. Even though there is recognition in these organizations that workers are more productive and do a better job when motivated and able to use their skills, experience, and creativity, managers seem bent on increasing output at the expense of making jobs more routine, boring, and stressful.

- When people degrade the work they do, they ultimately demean their lives, whereas CIM holds the extraordinary promise for improving life on the job and elsewhere. What is needed is a shift in emphasis on the part of management. An enlightened approach to overall planning invariably results in a more efficient system than short-sighted goals of increases in throughput only.

- CIM and other technical innovations have shifted management's focus from humans to machines, despite the fact that humans will continue to play a major role in the factory of the future. Our ability to develop successful interpersonal relationships dramatically affects our ability to apply new technologies.

- The concept of the automated factory must be "communicated" correctly throughout all levels of the organization and society in general if it is to become an everyday part of our lives. If it is not communicated, it will be communicated unofficially by the "grapevine" which exists within all organizations and by the press or other official media.

- These "back door" avenues will then take precedence over any attempts to communicate "officially." Communication is difficult at best, and is virtually impossible in an atmosphere of suspicion, distrust, and alienation.

G. COST JUSTIFICATION

- Despite the fact that viable technology exists and proven benefits are available, justification and implementation of CIM is difficult. The benefits of CIM are difficult to quantify and to prove pro forma.

- In the past, direct labor accounted for as much as 50% of the total production cost, with the remaining split about equally between material and burden categories. Today, because of management effort and numerous capital projects implemented over the past few decades to reduce direct labor content, direct labor now accounts for an average of only 10-15% of product cost.

- However, other cost categories, particularly overheads, have grown to account for a combined total in excess of 80% of product cost. Despite this fact, a major share of management resources continue to go toward obtaining further reductions in labor content.

- Experience has shown that although some direct labor reductions can be attributed to flexible systems, the most significant savings are in other categories such as work-in-process, material handling, inspection, scrap, and rework.

- Another problem is availability of cost data. In most organizations, the manufacturing engineering department is charged with the justification of capital spending projects; yet in a number of cases, the product costs are witheld from the engineers because of company policy.

- As a result, the engineer has no cost data to use as the base from which to justify any improvement and must rely on the accounting organization to translate the CIM features and technical advantages into proposed cost savings.

- In other cases, the cost data is made available, but the cost accounting system that generates the data is a direct labor-based system. The data provided offers a precise view of direct labor content, but all other costs are buried in the burden or material categories. Consequently, any burden or material savings are difficult to identify, let alone justify.

- Some CIM benefits are difficult to justify; once assumptions are made, they are almost impossible to defend. Examples are the number of producing design changes over the product life cycle or the number of new product introductions over a five-year period.

- Such assumptions are always subject to criticism even though there may be a basis in operating history to support them. Nonprovable assumptions become the focus of lengthy debates that stall the justification or force concessions that make the apparent ROI less attractive and thus less likely to be approved.

- If one could predict the exact future for all factors of systems design and related matters, a flexible approach would not be the best solution. One of the big advantages of a CIM is its capability to economically adapt to non-predictable changes in production requirements or product designs.

- It is clearly ironic that the lack of predictability in benefits of CIM plagues justification of the system. Hence, it is small wonder that it is perceived as a high-risk alternative from a financial standpoint.

H. MARKET FORECAST

- Though not growing at the lofty rates initially forecast, the factory automation equipment market has already exceeded $6 billion in annual sales and will continue to grow at 20% per annum over the next five years.

- The impact of the Federal Government's new tax legislation has already begun to cool the market from earlier forecasted growth rates, but nothing can postpone the renovation of U.S. manufacturing plant. By the year 1991, expenditures in this area will top $16 billion (see Exhibit V-1).

- The metalworking equipment market is easily the largest segment of the factory automation market and is expected to grow from $3.0 billion in 1986 to $7.0 billion in 1991 at an annual compound growth rate of 19%. Metal cutting equipment is the largest subsegment of this market, but FMS is the fastest growth area with annual growth rate of about 20%, from $850 million in 1985 to $2.5 billion in 1991 (Exhibit V-2).

- The 1986 market for programmable controllers was $650 million, representing a remarkable penetration for a product virtually unheard of in 1980. Sales will continue strong for the rest of the decade, growing to $1.5 billion in 1991, growing at an annual rate of 15%. Because of the continued drop in price per channel, the unit growth rate will be significantly higher than in dollar volume.

- Batch manufacturing, where the greatest need for automation exists, will increase its share of the market from 48% in 1986 to 60% in 1991 (Exhibit V-3). Because of increased penetration of automation in smaller companies, the small standalone programmable controller will increase its share of the market from 35% in 1986 to 38% in 1991 (Exhibit V-4).

- The robot market is divided among several types of units (Exibit V-5). The point-to-point machines will lose market share mainly because of their replacement by the dedicated assembly robot types. The market will grow from $275 million in 1986 to $850 million in 1991, at an annual rate of about 21%.

EXHIBIT V-1

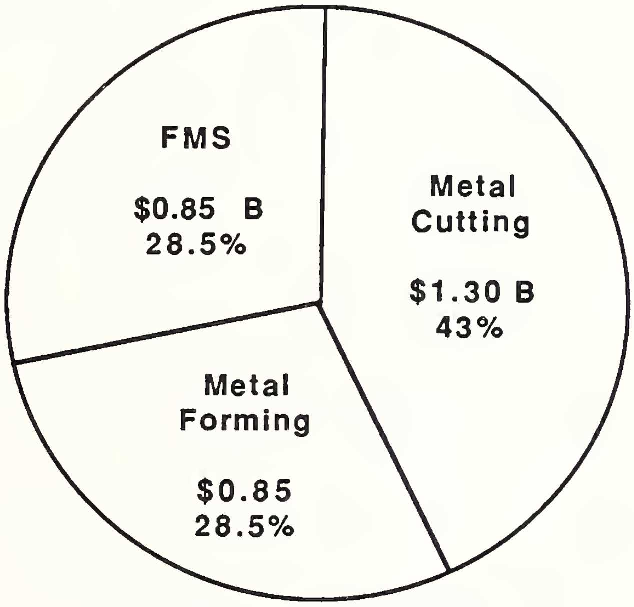
FACTORY AUTOMATION EQUIPMENT MARKET AND FORECASTS

ACTIVITY	$ MILLIONS		AAGR
	1986	1991	
Metalworking	$3,000	$7,000	19%
Programmable Controllers	650	1,500	18%
Robotics	275	850	25%
Automatic Inspection Systems	600	1,900	26%
Automated Materials Handling and Transfer Systems	1,950	4,800	20%
Total	$6,475	$16,050	20%

EXHIBIT V-2

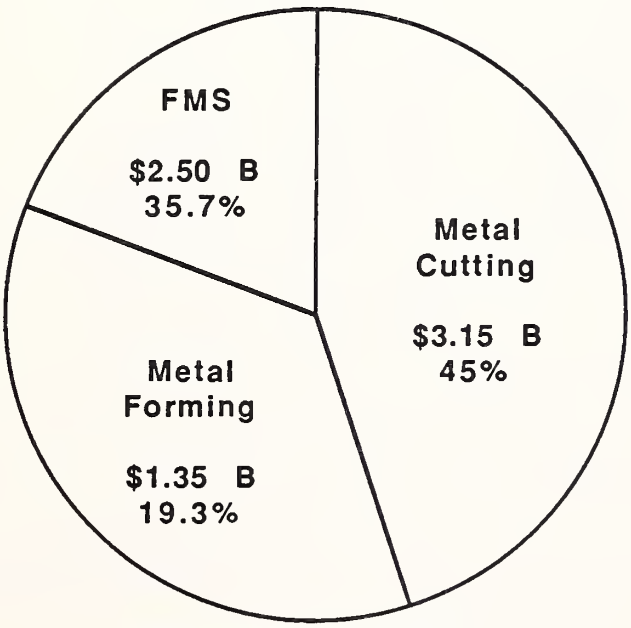
METALWORKING EQUIPMENT FORECAST, 1986-1991

1986



Total = $3.0 Billion

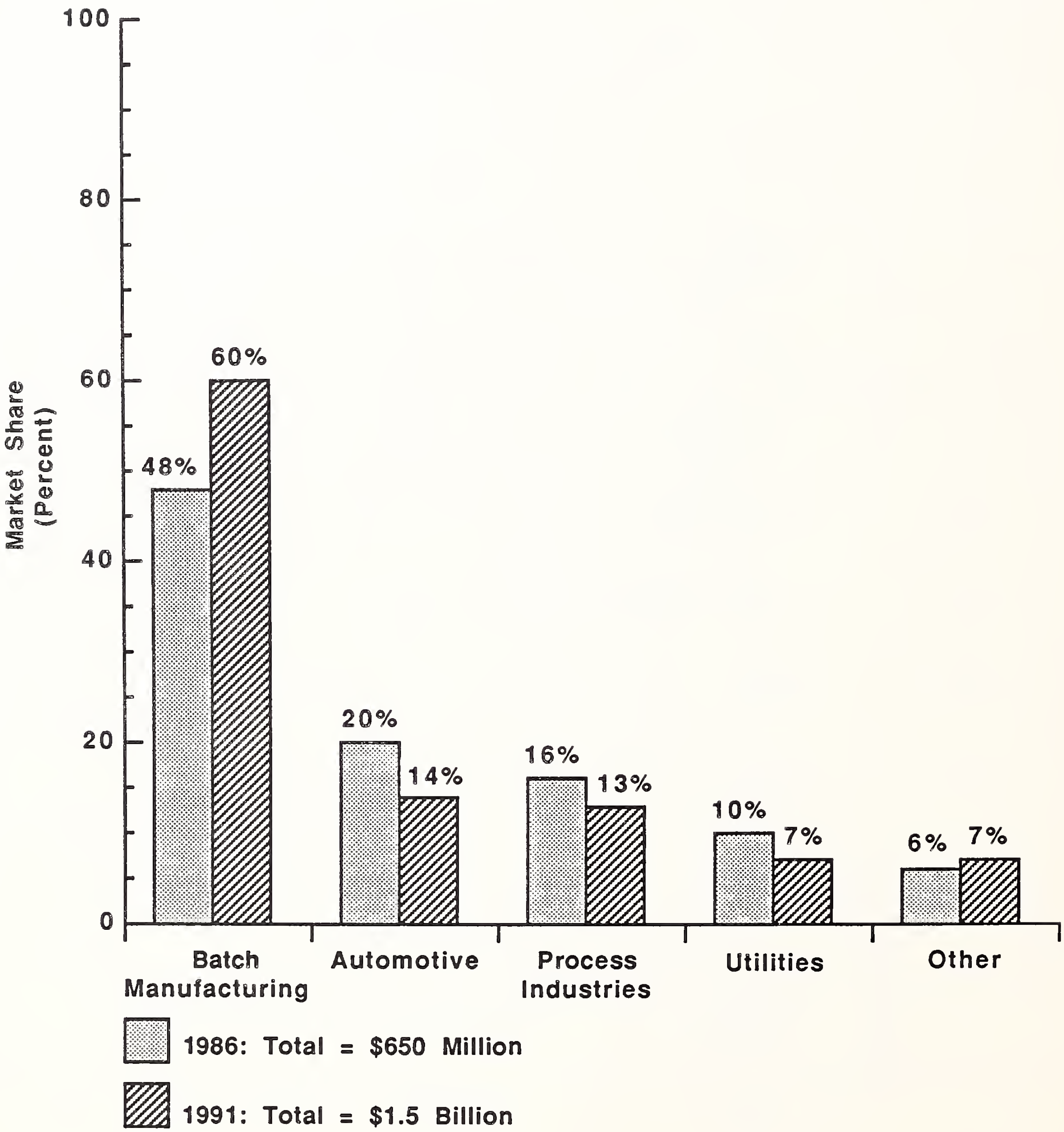
1991



Total = $7.0 Billion

EXHIBIT V-3

PROGRAMMABLE CONTROLLER MARKETS, 1986-1991

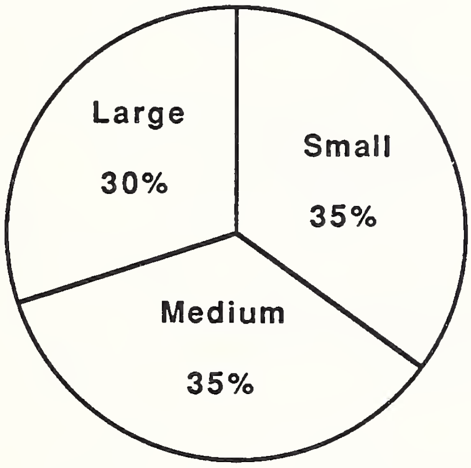


Source: U.S. Industrial Outlook.

EXHIBIT V-4

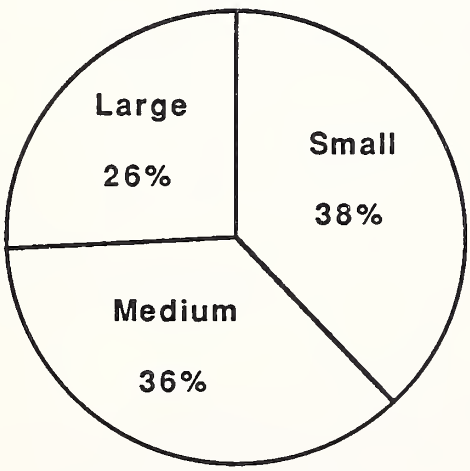
PROGRAMMABLE CONTROLLER MARKET FORECAST BY PRODUCT CLASS, 1986-1991

1986



Total = $650 Million

1991

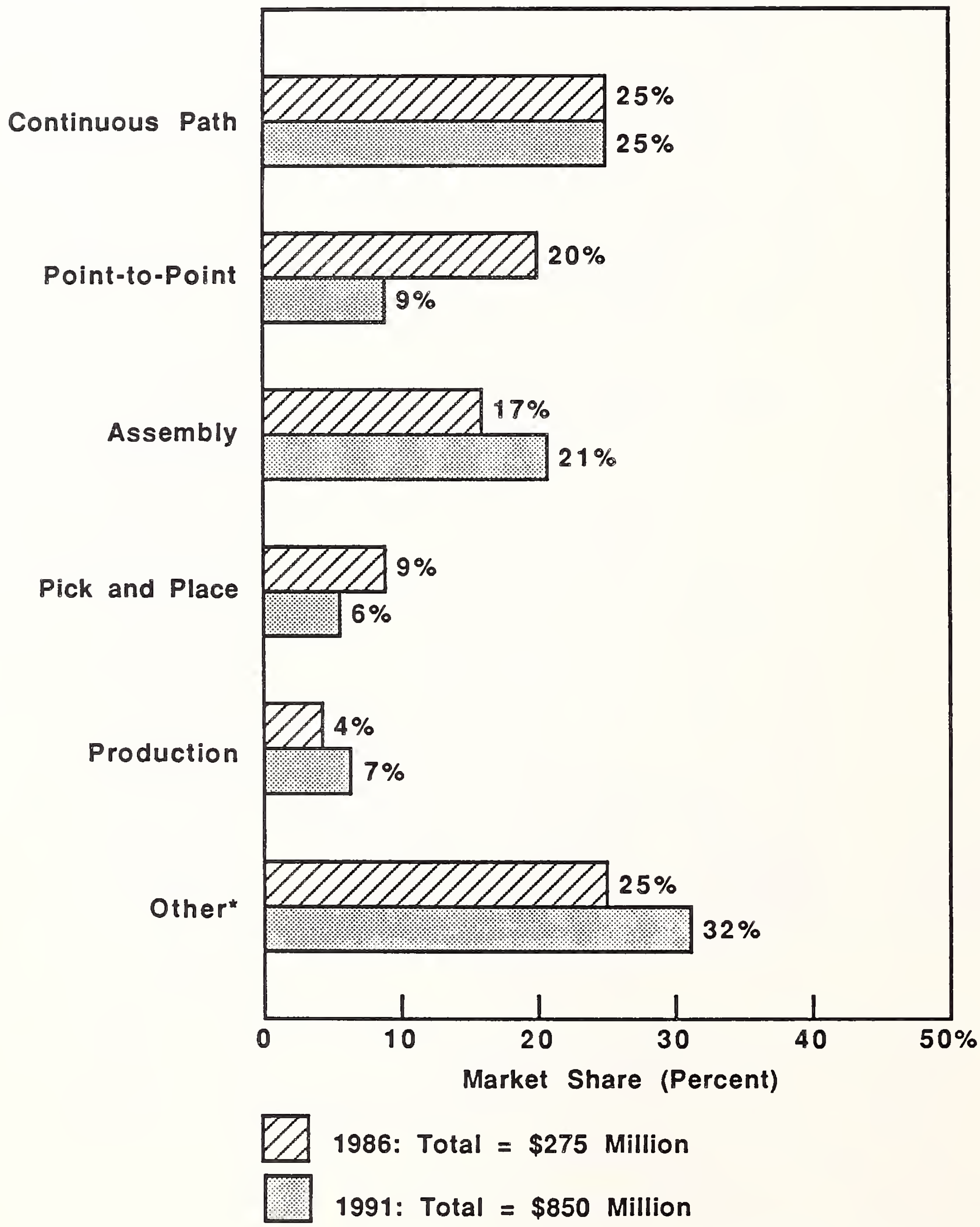


Total = $1.5 Billion

Small:	Up to 128 Channels, Standalone
Medium:	129-896 Channels, Communication-ready
Large:	More than 896 Channels

EXHIBIT V-5

U.S. ROBOT MARKET BY ROBOT TYPE, 1986-1991



*Other category includes tactile and vision systems plus miscellaneous robot types.

MSS1 Jd

- The segment to watch here is the "other" category which includes the tactile and vision systems where the real market opportunities lie. This category will increase its share from 25% in 1986 to 32% in 1991.

- The automatic inspection systems market, which until 1986 was dominated by dimensional measuring equipment suitable for 100% real time inspection of modest production rate parts, will lose some of its share to vision inspection systems by 1991 (see Exhibit V-6). This market will grow from $600 million in 1986 to $1.9 billion in 1991 at an annual rate of 21%.

- The material handling and transfer systems markets has three major components with overlapping technologies and functions: guided vehicle systems, automatic storage and retrieval systems (ASRS), and automatic handling and transfer systems. The latter is more than three times as large as the other two combined (see Exhibit V-7).

- ASRS already has a strong market justification and penetration, as shown in Exhibit V-8. With a forecast growth rate of 26%, it will turn in stellar performance during the next five years. The largest component of this market is for equipment handling parts and raw materials delivery.

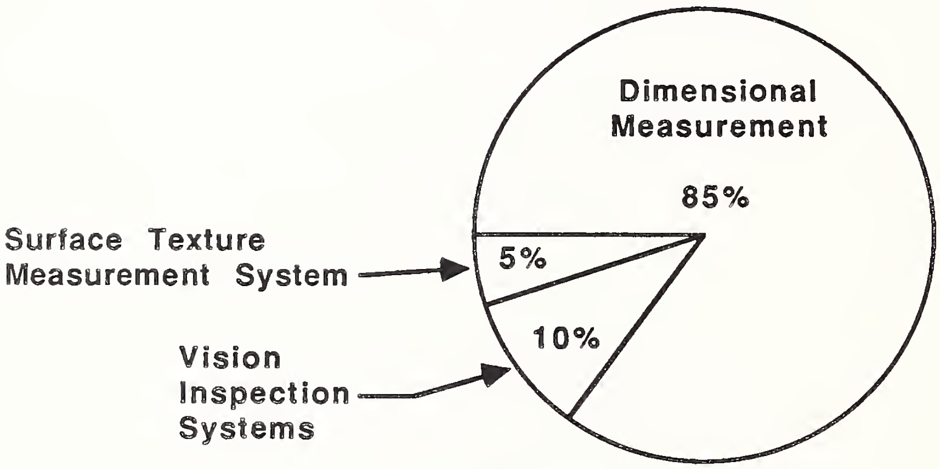
- Automated guided vehicle systems (AGVS) have found a receptive, though relatively small ($75 million in 1986), market. It will grow to $300 million in 1991 at an annual growth rate of 24%. The light duty AGVS will be the major component of this market compared to heavy duty or special purpose GVS.

- The automatic handling and transfer systems market is by far the largest of the three, having a 84% share of the total materials handling and transfer market. Expenditures for these systems will rise from $1.6 billion in 1986 to $3.5 billion in 1991.

EXHIBIT V-6

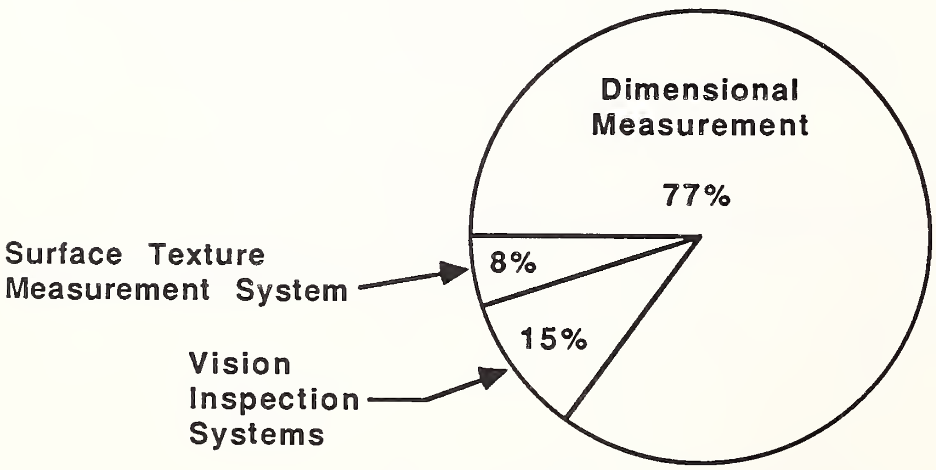
AUTOMATIC INSPECTION SYSTEMS MARKET FORECAST BY PRODUCT CLASS, 1986-1991

1986



Total = $600 Million

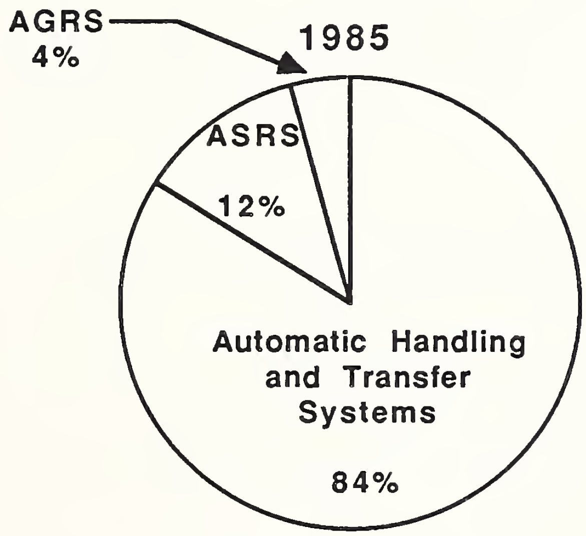
1991



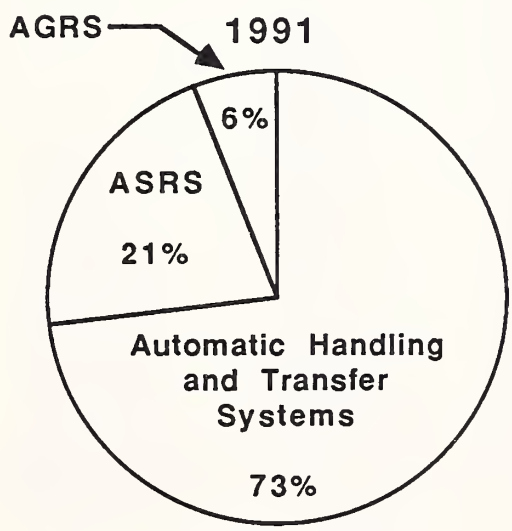
Total = $1.9 Billion

EXHIBIT V-7

AUTOMATED MATERIAL HANDLING AND TRANSFER SYSTEMS MARKET FORECAST, 1986-1991



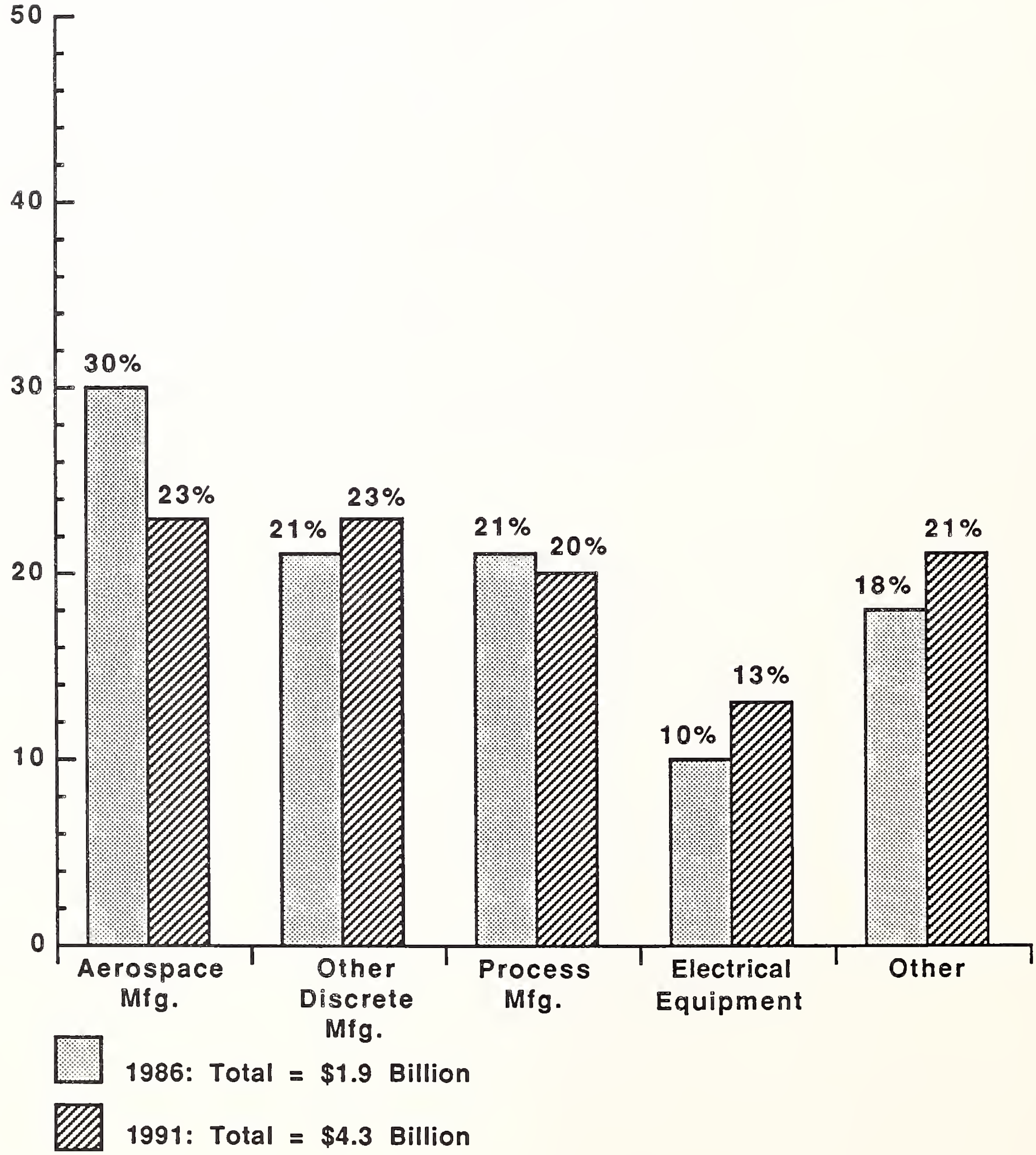
Total = $1.9 Billion



Total = $4.8 Billion

EXHIBIT V-8

AUTOMATED MATERIAL HANDLING AND TRANSFER SYSTEM MARKET FORECAST BY INDUSTRY SECTOR, 1986-1991



I. LEADING VENDORS

- The key vendors in the materials handling market are:

  - FMC's materials handling and equipment division with sales of $800 million in 1985.

  - Eaton-Kenway, based in Salt Lake City, a subsidiary of Eaton Corporation, which produces fully automated small parts storage and retieval systems.

  - Lear Siegler and SPS Technologies, both manufacturers of ASRS systems.

  - Litton, which produces ASRS systems and has been very successful in the AGVS market, featuring on-board, computer-driven, flexible load handling capabilties.

- The key participants in the metalworking equipment market are:

  - Acme-Cleveland whose product line includes metal forming machinery, machine tools, materials handling equipment, and special products. The company, which was a strictly mechanical product supplier, now offers the latest electronic control technologies.

  - Textron, a multinational whose product lines include milling and grinding machines.

  - White Consolidated, which supplies FMS, CNC with robot loading, and tool management systems.

- In the programmable controller market, the important players are:

- Allen-Bradley with its wide range of models and the broadest indusrial customer base in discrete manufacturing.

- GE's Industrial Control Division, a supplier of a variety of 16-bit controllers (in addition to PCs, NC, robots, and GE-Net, a communications network for industrial applications) to predominantly batch production shops.

- Gould Inc., whose goal is to be a major supplier of factory automation equipment based on intelligent micro-electronics.

- The key robotics suppliers are:

  - Cincinnati-Milacron, the principal supplier of heavy duty robots with a variety of intelligence and dexterity.

  - GMF Robotics, a joint venture between GM and Fanuc of Japan, initially formed to meet the unique requirements of GM and now active in the marketplace.

  - ASEA Robotics, a manufacturer of robots for materials handling.

  - Unimation, an affiliate of Westinghouse, competing in most robotic markets.

- In the automated inspection market the major players are:

  - Cross and Trecker, which manufactures gauges for the charting of surface geometry, profile, and texture.

  - Jones and Lawson, which sells optical comparators.

  - Edmunds Manufacturing Systems, a supplier of 3D measurement equipment for contour analysis and inspection.

VI MANUFACTURING PLANNING AND CONTROL SYSTEMS

VI MANUFACTURING PLANNING AND CONTROL SYSTEMS

A. MAJOR ISSUES

- During the last decade, a constant flow of innovative manufacturing methods have been entering the U.S. workplace and have been received with varying degrees of acceptance. More recently, the rapid shrinking of domestic vendors' share of the U.S. market has accelerated the rush to automate--and copy Far Eastern competitions' methods. One such method, just-in-time materials control (JiT), has invaded operations planning and control challenging old assumptions and ways of doing things.

- There also appears to be a feeling that the Japanese manufacturers are the only ones who really know how to improve productivity. This is erroneous. While it is true that the Japanese have had great success in implementing JiT and other simple concepts, they do not have a monopoly on good manufacturing methodology nor on good automation technologies. They do appear, however, to be more patient than their U.S. counterparts in managing the implementation of new techniques.

B. MATERIAL REQUIREMENTS PLANNING (MRP)

- MRP makes available purchased and company components and subassemblies just before they are needed by the next stage of production or for dispatch. This system enables managers to track orders through the entire manufacturing process and help purchasing and production control departments to move the right amount of materials at the right time to production-distribution stages.

- MRP assumes even demand, attempts to achieve zero stockouts, and concentrates on setting priorities. It requires that a precise demand forecast for each product is available and that each and every product or subassembly's bill of materials is accurate.

- Managers using MRP can calculate the requirements of each and every part or subassembly week by week and identify in advance possible delays or shortages. People in inventory control can then reschedule the affected release dates for orders to try to meet the promised deliveries.

- MRP requires that every employee, whether operator, analyst, quality inspector, salesperson, purchasing agent, or planner, be thoroughly and strictly disciplined about feeding updates into the system. Without such adherence, the MRP system memory starts accumulating errors with regard to stock on hand, quantities needed, and when items are needed for specific parts or assemblies. Everyone interacting with MRP systems must make all their decisions using system data at each and every step.

- MRP requires a tremendous amount of data input and is complex. It assumes unlimited capacity in all work centers, whereas in reality some work centers always behave as bottlenecks. This contradiction destroys the accuracy of MRP scheduling logic and makes it ineffective for capacity planning and control.

- Successfully implementing MRP entails developing new communication lines and detailed auditing procedures, which mean extra efforts and possibly resentment from employees. Also, MRP is based on the premise that top management will always use it for planning and control decisions; in reality, managers often feel hampered by it.

- MRP cannot tolerate "informal systems" for getting the job done, and foremen and workers who like less formality can resent it. Consequently, inaccuracies tend to find their way into important MRP files. The bill of materials may not accurately represent the product components or assembly stages, or ongoing inventory transactions may not be correctly entered in the inventory records, or the master production schedule may not be updated to reflect the latest actual demands and delivery dates.

C. JUST-IN-TIME (JiT)

- This is an approach for providing smoother production flows and making continual improvements in production processes. JiT attempts to reduce work-in-progress to an absolute minimum. In addition, the system constantly attempts to reduce lead times, work-in-progress inventories, and setup times.

- JiT's core objective is to obtain low-cost, high-quality, on-time production. To achieve this, the system attempts to eliminate stock between the successive processes and to minimize any idle equipment, facilities, or workers.

- JiT assumes that the production rate at the final assembly line is even. Revisions in the monthly master production schedule needed to meet market conditions changes must be small. It cannot tolerate load fluctuations of more than 10%, and it starts breaking down under larger deviations from average conditions. It also requires that the daily schedule for each part or assembly remain nearly the same every day.

- JiT has its roots in employee motivation and assumes that workers will perform at their best when they are entrusted with increasing responsibility and authority. Each worker has the right to stop the assembly line when he or she is falling behind or discovers a defective part or subassembly.

- The JiT approach keeps the setup times and costs at negligible levels. In addition, the company's suppliers are supposed to act like extended storage facilities of the company itself.

- The system requires strict discipline and cooperation on the part of management, supervisors, and workers along with new methods and procedures for manufacturing planning and control.

- Workers experience the satisfaction of being in charge of the system and of making useful improvements in the company's operations. Most companies that use KANBAN also have quality circles that work to cut down on lot sizes, reduce lead and setup times, help solve vendor problems, and minimize scrap losses. Workers are highly motivated to implement their own suggestions.

- Not every application of JiT is a success story. Many U.S. users are encountering problems in implementing the approach; for example, distant suppliers, poor quality of parts, unreliable freight systems, and upstream strikes of parts suppliers.

- A JiT system's implementation takes approximately two years, but normally does not achieve optimum results for five to ten years.

D. INTEGRATING CAD WITH MPCS

- Almost every CIM model includes a linkage between CAD and MPCS (usually shown as a line connecting two bubbles) with a few words regarding the two systems sharing common data elements. The implication is that we are soon to have available some computing technology that magically integrates the two. Unfortunately, this is not the case.

- The basic challenge to U.S. manufacturers, especially those larger companies who intend to compete in world markets, is to become the low-cost quality manufacturer of products which are introduced in a timely manner.

- Both CAD and MRP systems individually have proven to contribute to a manufacturer's reduction in cost, improvement in quality, and timely product introduction. Yet despite the widespread use of these systems in the U.S., U.S. manufacturers are still not able to compete as effectively as they desire. If the answer were purely technical, it would have been in place years ago. Let us examine the three basic goals of manufacturing.

E. LOWER COSTS

- MRP systems are transactionally based and attempt to model the entire manufacturing operation. Studies have shown that the single costliest transaction for a company is an ECO (engineering change order) which must be incorporated into manufacturing. Studies also show that for similar industries, U.S. manufacturers release three to five times as many ECOs to manufacturing as do the Japanese.

- To solve this problem requires determining who or what is causing the generation of ECOs. This implies that the linkage of CAD and MPCS must provide the following:

- Identification and analysis of the justification and severity of ECOs.

- A plan to support the ongoing reduction of ECOs.

- An analysis of the underlying cause of the high number of ECOs will clearly show that it is the result of the physical, organizational, and logical separation of engineering and manufacturing. This separation is also fundamental in the problem of improving quality and reducing product introduction lead time.

- Quality is a value that must permeate the entire organization starting at the top. Given that the organization has established quality as a corporate value, the employees are motivated, and CAD/CAE systems are in place for product designs of the highest tolerances which have been properly analyzed for stress, strain, and other material properties, the question is why is quality still such a big issue.

- The issue arises because parts must be built, not just designed. This implies that a proper linkage between CAD and MPCS must provide for:

  - The consideration of manufacturing aspects, e.g., process flow, tooling, structure, achievable tolerances, etc., during the design process.

  - The timely and accurate display of the correct drawings and specifications during the manufacturing and inspection process.

  - Reduction in lead time from initial design to production.

- In many industries, this is the number one challenge for survival. With rapidly advancing technologies and changing market needs, being late to market can result in the failure of the enterprise. Fundamentally, there are two ways to achieve this objective:

- Reduce the number of different parts required to make products.

- Insure that when a needed new part is "released to production" it can indeed be built.

• To satisfy the first objective, a capability needed in the system is the ability to compare and analyze assemblies for common components to eliminate redundant parts.

F. LACK OF TOP MANAGEMENT INVOLVEMENT AND PLANNING

• Effectively implementing a MPCS system in the shortest possible time takes top management commitment and involvement. There is a definite difference between top management commitment and top management involvement.

• When manufacturing executives take time from their busy schedules to attend a seminar on MPCS for a few days, that is commitment. When they give the green light to purchase MPCS-related hardware and software, that is commitment. Appointing a full-time project manager and an MPCS project team is another sign of commitment.

• But involvement goes one step further. It means active participation throughout the life of the project, and this is something many manufacturing executives find difficult to do. Top management should be involved in helping to set MPCS objectives, assigning responsibilities, allocating resources, reviewing performance, solving problems--whatever is needed to make the system run smoothly and improve their company's bottom-line results.

• In past years, data base information has received the lion's share of attention in many MPCS implementations. The areas of bills of materials, inventory accuracy, and routings required substantial cost and time commitments in the overall game plan. Structuring bills of material, for example, can use man years of engineering resources. This burden is particularly heavy when a company lacks formal bills of material at the start.

- Another major MPCS hurdle for companies with limited access to stores facilities or a transaction-driven inventory processing system is the challenge of inventory control. For many companies, achieving a 95% inventory accuracy level is one of the most difficult and time consuming MPCS operations.

- Since many companies begin their journeys to MPCS within the MIS department, top management typically is not involved. Structuring bills of material, cycle counting, or routings development is left to lower echelons. When unforeseen serious problems develop, however, top management is cited for its lack of direct participation.

- It is more than ever important for the highest levels of management to be intimately involved in the planning and implementation of manufacturing automation and integration because it is unavoidable and strikes at the heart of the company's reason for being in business.

- Until now it was possible for the highest levels of management to consider the implementation of, say, an MRP II package to be the responsibility of the MIS director and no one else (and most MIS directors would agree with that!). In the same way, if a particular aspect of shop-floor operations was automated by installing robots, the MIS director was not involved.

- Now, however, U.S. manufacturers are faced with the need to integrate the daily operations of these separate islands of automation (or nonautomation in some cases), and this cannot happen without the direct participation and direction of the president and his corporate staff.

- The nature of the MRP/MRP II software in use must also change to account for a far broader scope of control of operations. This is why we have used the term MPCS as a way of referring to this broader scope of responsibility. The market for straight MRP/MRP II software is heading toward the smaller (and lower-priced) demand from smaller manufacturers. At the same time, the demand will emerge for higher-function, integrated MPCS software from the large manufacturers.

G. MPCS MARKET FORECAST

- New plant and equipment expenditures in all industrial sectors will continue to increase from about $57 billion in 1985 to about $80 billion in 1991. Long-term trend is upward in real spending, but at a steadily decreasing rate.

- Penetration of MPCS will rise at a rapid rate due to the falling hardware prices of the personal computer. The government's new revised tax code will put a damper on capital spending for the next two years before new tax amendments begin to help increase capital spending again.

- The MPCS market is a highly fragmented market with over 165 vendors supplying software for mainframes, minicomputers, and microcomputers. The 1986 MPCS software market was $320 million, and this is expected to grow to $700 million by 1991, at an annual compounded growth rate of 17.3% (Exhibit VI-1). Computer hardware sales will grow at a slower 6% from $580 million in 1986 to $770 million in 1991.

- Exhibit VI-2 shows the market breakdown and forecast by industrial sector. The electronics segment is by far the leader in the utilization of MPCS where about 31% of the sales were made. This is expected to increase to 37% in 1991.

EXHIBIT VI-1

MPCS MARKET FORECAST, 1986-1991

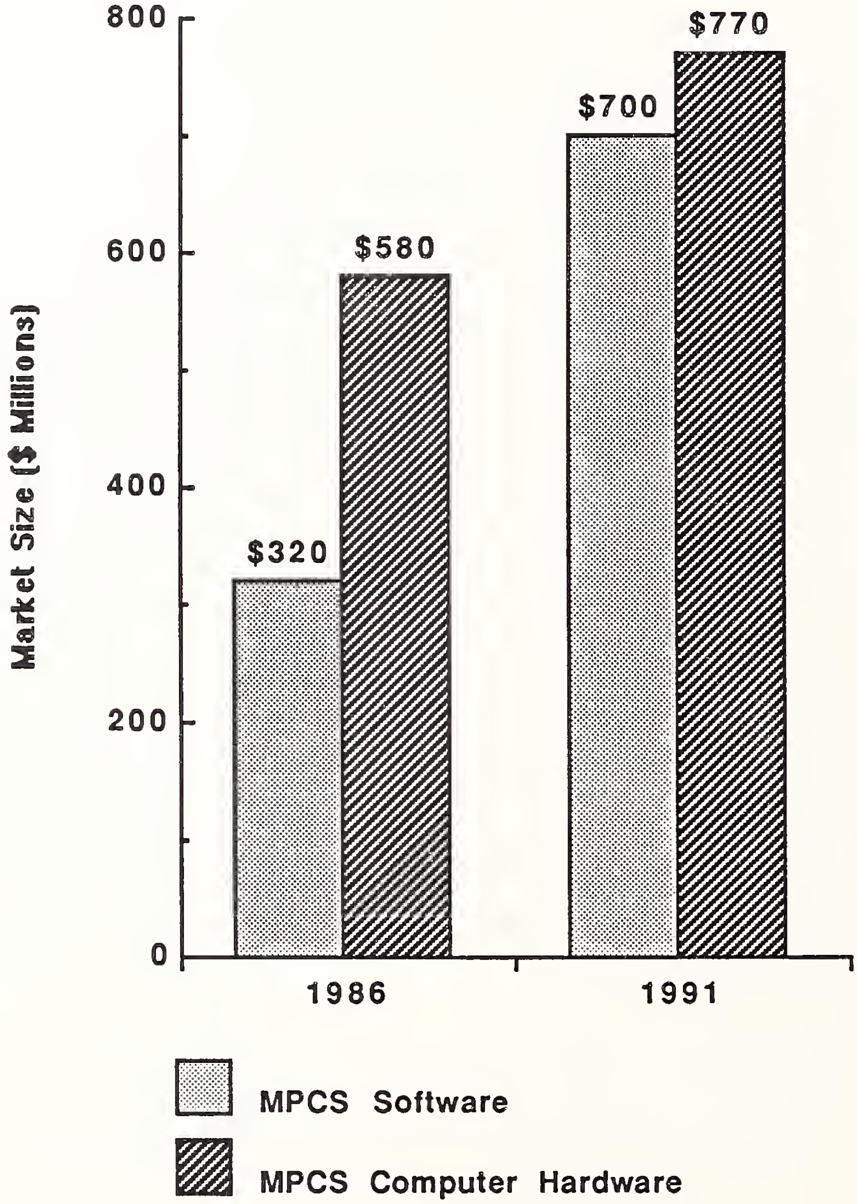
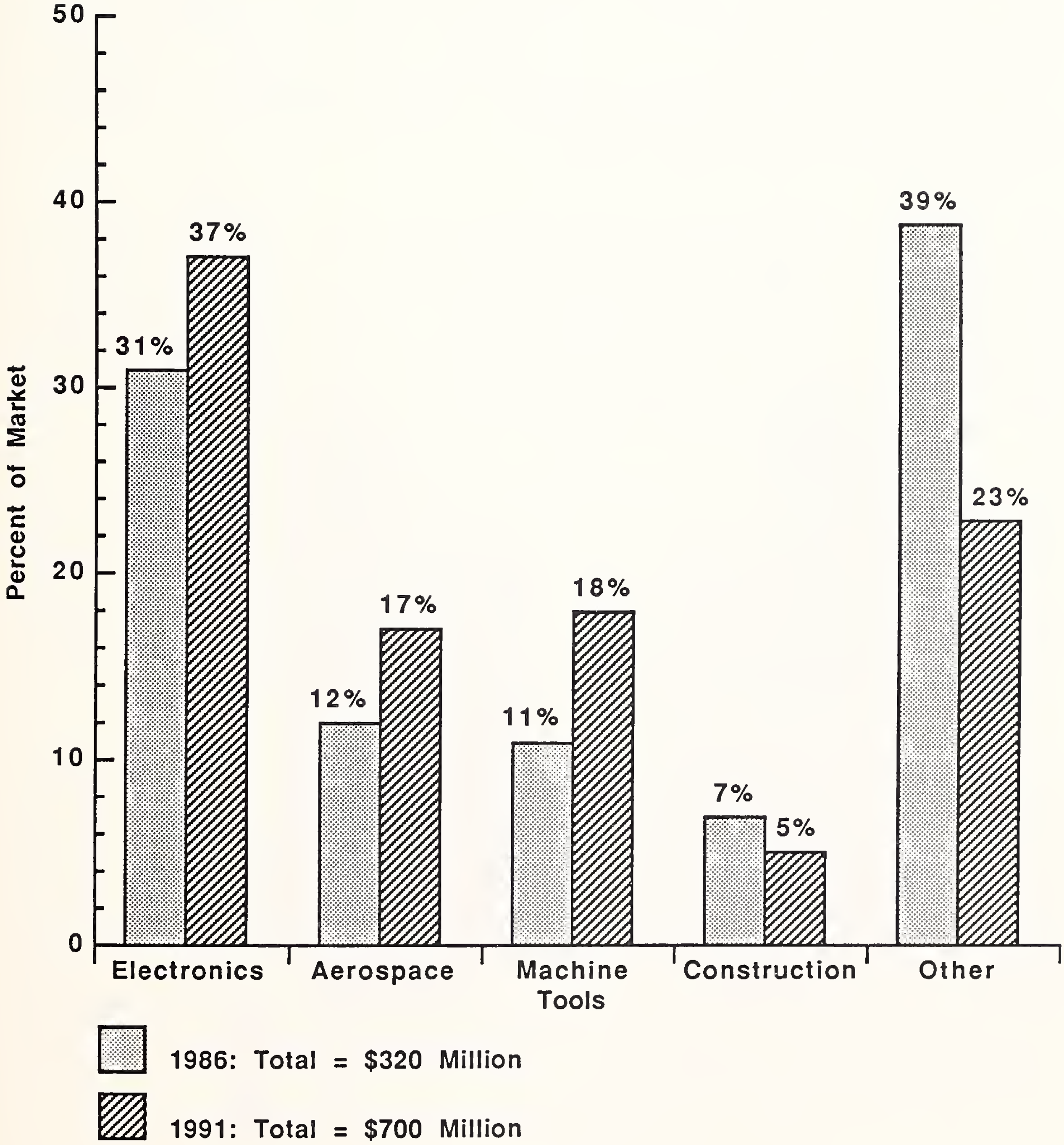


EXHIBIT VI-2

MPCS SOFTWARE MARKET FORECAST BY INDUSTRY SECTOR, 1986-1991



- Investment in new plant and equipment which drives the machine tools industry increased dramatically over the last two years, with operating rates for factories in many industries exceeding 80%. This is the level at which retooling may be considered and capacity restraints evaluated. Customer interest in flexible manufacturing systems (FMS) will benefit the machine tool industry.

- Overall, this segment will continue to be one of the strong users of MPCS software packages. The industry has been tradition bound, dependent on standard vendor-supplied software. Because of this, packages such as IBM's COPICS and MAPICS will be strong contenders in this market. The machine tools segment will grow from $35 million in 1986 to $126 million in 1991, at 29% annual compounded growth rate.

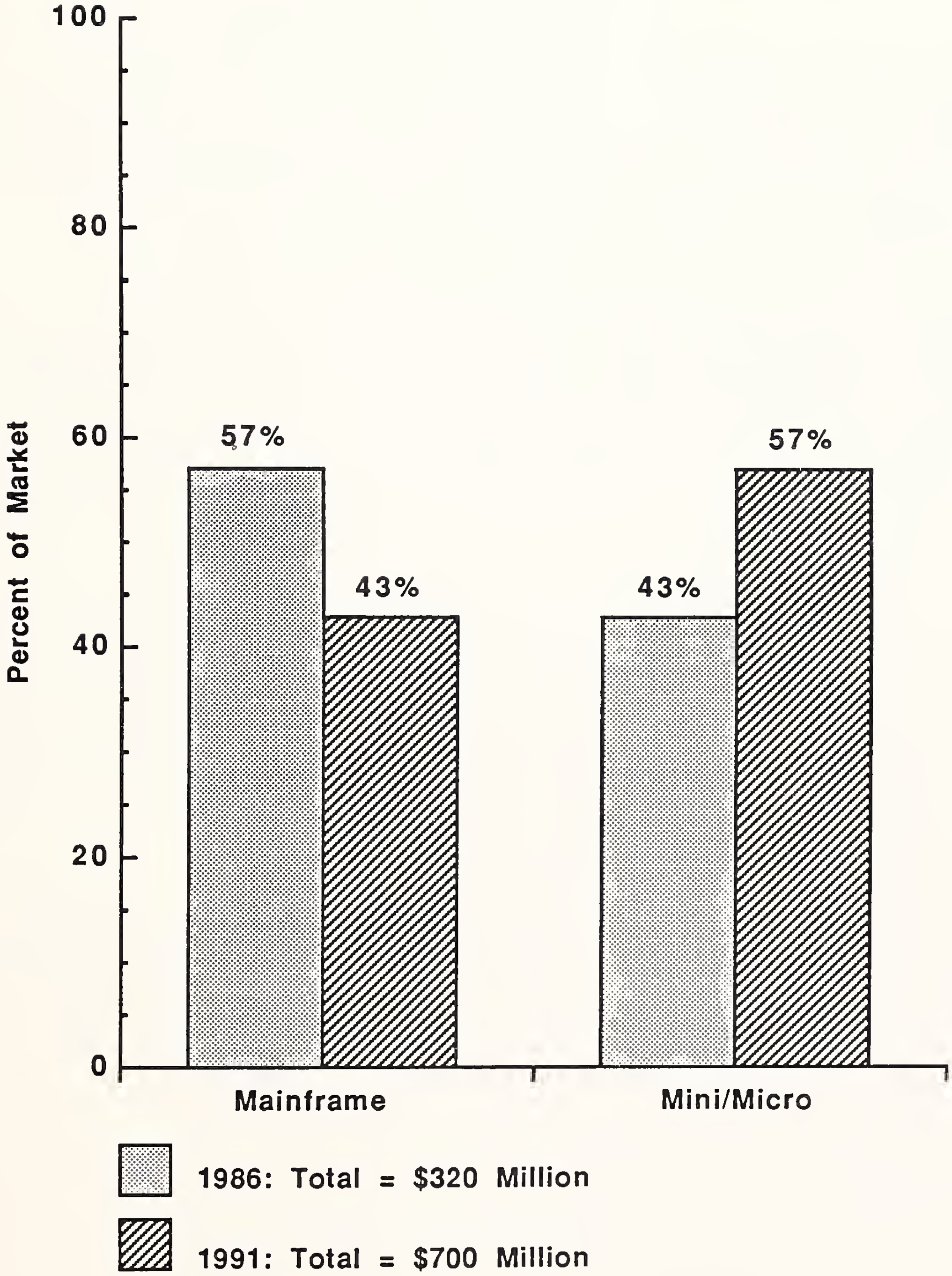
- The electronic components industry experienced strong growth through the 1970s and early 1980s due to strong demand from microcomputers and telecommunications equipment manufacturers. While sales rose approximately 20% during 1984, 1986 saw a softening of the market due to lower demands from computer manufacturers.

- The electronics segment of MPCS was the single largest user of MPCS with $100 million in sales in 1986. The industry has a strong need to utilize manufacturing control systems to produce products at competitive prices. Based on these considerations, we can expect continued steady growth of this segment of MPCS to $260 million in 1991 at an annual growth rate of 21%.

- Mainframe MPCS software constitutes 57% of the market in 1986 (Exhibit VI-3). This is because, historically, MPCSs have been implemented on mainframes and in larger companies. Developing and implementing a total MPCS solution used to be a major undertaking for most major companies requiring several hundred thousand dollars, and many times millions of dollars. However, with the advent of the mini and microcomputers and the corresponding drop in hardware and software prices, many of the mid-sized companies have joined the foray.

EXHIBIT VI-3

MPCS SOFTWARE MARKET FORECAST BY COMPUTER TYPE, 1986-1991



- There are an estimated 75 vendors in the microcomputer software market for MPCS packages. While further new entrants are expected during the next two years, we can expect that 57% of all revenue will come from MPCS packages running on minis or microcomputers by 1991.

H. LEADING PLAYERS

- IBM, with about 31% of the MPCS market in 1986, is the largest player. Its MAPICS and COPICS programs form the basis of many of the factory automation programs currently being marketed. IBM's MPCS programs run on mainframes.

- Following its acquisition of Comserv, MSA will have a manufacturing software group approaching $100 million of sales per year, representing a 28% share of the 1986 market and making it the second largest supplier to the U.S. market after IBM. This also represents MSA's first step toward "verticalizing" its software activities.

- Martin Marietta Data Systems (MMDS), with about 17% of the market, is the third largest vendor in the market. MMDS offers a full range of computing services, applications software, systems software, and professional services to the industry. It has computers and data centers located throughout the U.S. and in the U.K. which are linked by networks.

- The company's MAS software packages for manufacturing and control are widely accepted; they run on HP minicomputers. About two years ago, Marietta acquired Mathematica Corporation which markets RAMIS, a data base management system that uses conversational English.

- ASK Computer Systems, the fourth largest MPCS vendor with 11% of the market in 1986, provides minicomputer-based management information systems for DEC and HP computers. Its product, MANMAN, consists of a family of software products that manage information for all functional areas of a manufacturing concern, including accounting, production, engineering, and marketing. The company provides turnkey systems that include a license to its software and hardware. The company also offers timesharing (ASKNET) services.

- The other key players are NCA and Cullinet.

VII FACTORY COMMUNICATIONS MARKET

VII FACTORY COMMUNICATIONS MARKET

A. MANUFACTURING AUTOMATION PROTOCOL (MAP)

1. INTRODUCTION

- Impatient to get on with the task of automating its factory operations, General Motors Corporation decided to speed up the process by defining a protocol that vendor companies would be required to use if they wished to do business with the giant auto maker. That protocol, or set of specifications by which controllers and computers in the factory can communicate, is known as the manufacturing automation protocol (MAP).

- The purpose of MAP is to facilitate the interconnection of "islands of automation" and computers to form integrated manufacturing systems without having to be concerned with incompatibilities that exist among today's machines, workstations, controllers, and computers.

- Such incompatibilities have made it very difficult and costly to implement integrated manufacturing systems because a great deal of customization of computer hardware and software has to be done for each application. In response to considerable market pressure applied by manufacturers, individually and through the MAP users group, many vendors are now producing products that are intended to conform with the MAP specifications.

- MAP is a subset of the International Standards Organization (ISO) Open System Interconnection (ISO) reference model, an attempt to normalize the functional layers used in network design (which frequently differ from network to network).

2. THE SEVEN LAYERS OF MAP

- In technical terms, MAP is a seven-layer, 10-megabit per second, broadband, token, bus-based communications standard for factory applications. Because it is concerned with communications rather than applications, it specifies how a robot might communicate with a computer over the network, but not how the robot will respond to the computer's programs.

- In broadband transmissions, many signals can be transmitted over a network at the same time. To prevent data "collisions," a special bit pattern called a token is passed along the network. When one station receives the token, it may pass data to another station.

- The advantage of a token bus network is that the maximum time any station must wait before passing a message is precisely specified. This is vital for real time systems, where actions must take place within a particular time.

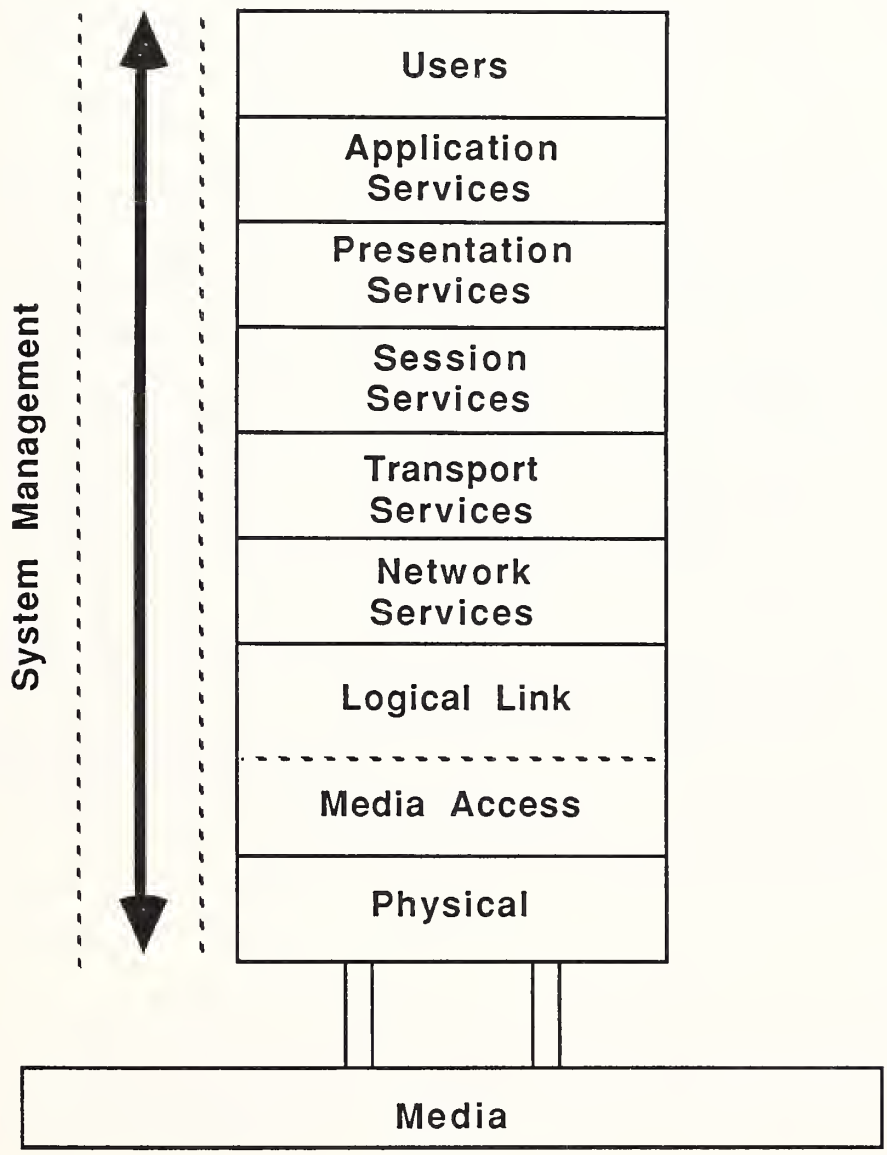
- With the MAP standard, a single broadband coaxial cable can link together many devices on a common network. It is sort of the interstate highway for factory communications. The cable not only can carry control signals and plant data, but channels can be devoted to audio or video transmissions for internal communications--say, for retraining.

- Exhibit VII-1 shows the OSI reference model, and Exhibit VII-2 shows the seven layers of MAP.

- The top three layers (5 to 7) govern the interconnection of different networks. The other layers are concerned with the interoperability of devices connected to a network.

EXHIBIT VII-1

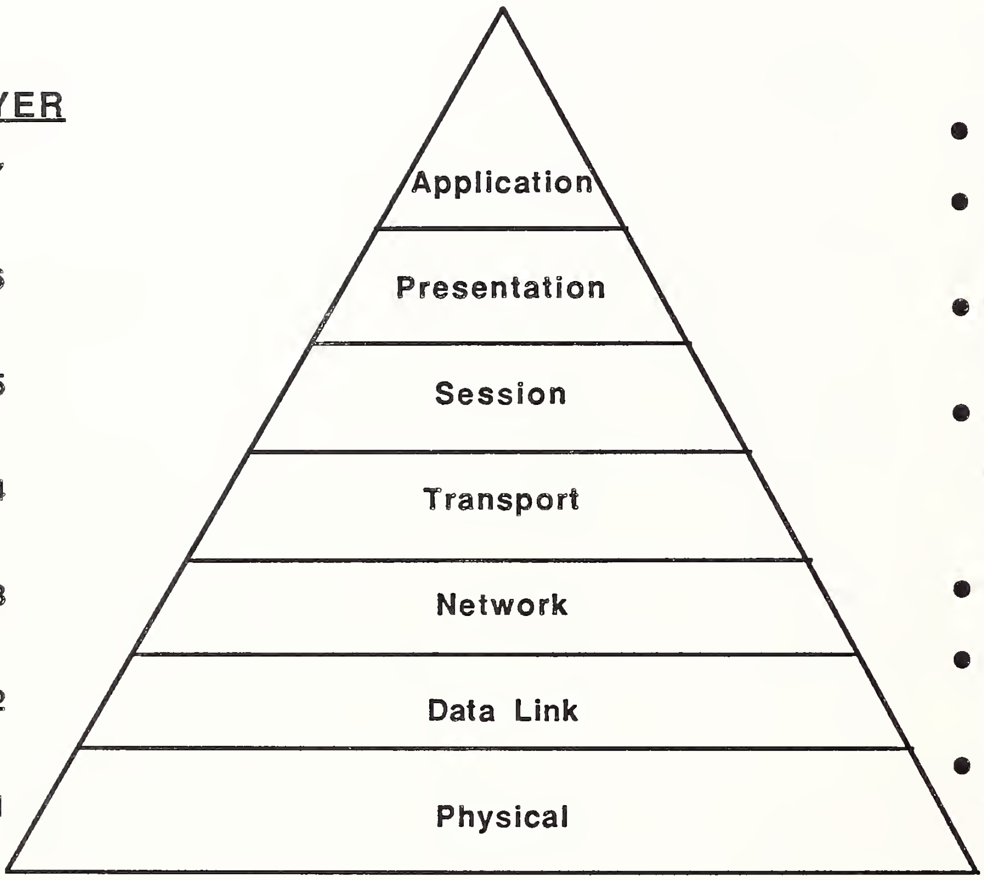
OSI REFERENCE MODEL



Source: IBM

EXHIBIT VII-2

THE SEVEN LAYERS OF MAP



LAYER	COMMENT
7	• E.g., E-Mail
6	• Converts message for Receiving Device
5	• Maps Logical Names onto Physical Addresses
4	• Divides Message into "Frames" for Transmission, Reassembles on Receipt and Sends ACK
3	• Communication Procedures
2	• "Frame" Composition and Transmission Protocals
1	• Medium Used, Rate at which Data is Sent, etc.

- To allow two different applications to communicate with a MAP-based network, as when files are transferred from a sales order system to the production scheduling system, requires all seven layers of MAP. But to permit two devices, such as a robot and a NC milling machine, to communicate might require only the first four layers.

- Level I, the physical layer, deals with most of the hardware questions involved in networking, such as the type of cable (75-ohm coaxial), the data transmission rate (10 megabits per second), and the network access method (token bus).

- At this level, two networks might be connected using a repeater, a device that amplifies signals. The second MAP level, the data link layer, manages the communications linkage between the two end systems. It is also responsible for error checking and the composition of the actual frames of data that are sent out on the network. Two associated devices, say a lathe and a measuring system, might communicate at this level, provided they use the same frame size for data and have a common addressing scheme.

- However, independent devices connected to the same network will most often require all of the lowest four layers of MAP for communications. Level three, the network layer, establishes a route for communications between devices with different addressing schemes, and level four, the transport layer, actually manages communications between devices, ensuring that messages are transferred correctly.

- Using all four layers ensures that the connected devices need not have a common addressing scheme. Each device is capable of sending and receiving messages intended for it.

- The upper three layers largely govern the interconnection of networks. The fifth, or session layer, an extension of the transport layer, manages connections between pairs of programs running on different devices. The sixth level, the presentation layer, translates and formulates data when required, so that, for example, application programs will work correctly with any display terminal connected to the network.

- Finally, the application layer provides access to the network for application programs and data file transfers. For one application to communicate with another on a MAP-based network will require all seven layers of the protocol.

3. KEY ISSUES FACING MAP DEVELOPERS AND USERS

a. <u>Development of Carrier Band</u>

- At the present time, the broadband deals with a fairly high level computer such as the DEC VAXs, IBM Series/1s, and the HP1000s. Although there is some communication between these computers and, for example, the robots, it is primarily in the file transfer activity where programs are downloaded and, in the event of problems, diagnostics are called down.

- But it is not really meant for real time interrupts for a large number of devices. Hence, the next major development has to occur at the carrier band level where interconnection between the controllers on the devices, such as robots, inspection equipment, etc., will occur.

b. <u>Conformance Testing</u>

- This is a very real and immediate issue, because products advertized as MAP-compatible have to be tested to ensure that all specifications are met. Currently MAP products are tested at the Industrial Technology Institute (ITI) in Ann Arbor (MI).

- Products are tested for individual compliance to the MAP standards and for interoperability of vendors. However, current tests are not as refined as they should be. Also, there is no agreement yet on the appropriateness of the test organization, test scenarios, and a governing body that is going to be in charge of implementing the standards as agreed to by ISO or IEEE.

c. Economics and the Competition

- The incentive to install MAP and other plant networks will clearly be driven by economics. According to Foxboro Company, the costs of MAP networks are high today--around $5,000 per connection. Proprietory networks such as DECnet can offer a much less expensive solution, but when MAP interfaces become available as VLSI devices by the end of this decade, costs are expected to drop rapidly.

- Some sources say prices per connection could fall below $500 once the Japanese, Korean, and Taiwanese electronics makers begin making the interfaces. At this price, manufacturers will be able to offer MAP interfaces as part of a product rather than as separate devices.

- At the present time, many automatic equipment and computer suppliers already have a large investment in Ethernet networks, and they intend to protect it. For example, DEC has a strategy for continuing use of its proprietary DECnet protocols, which were derived from Ethernet.

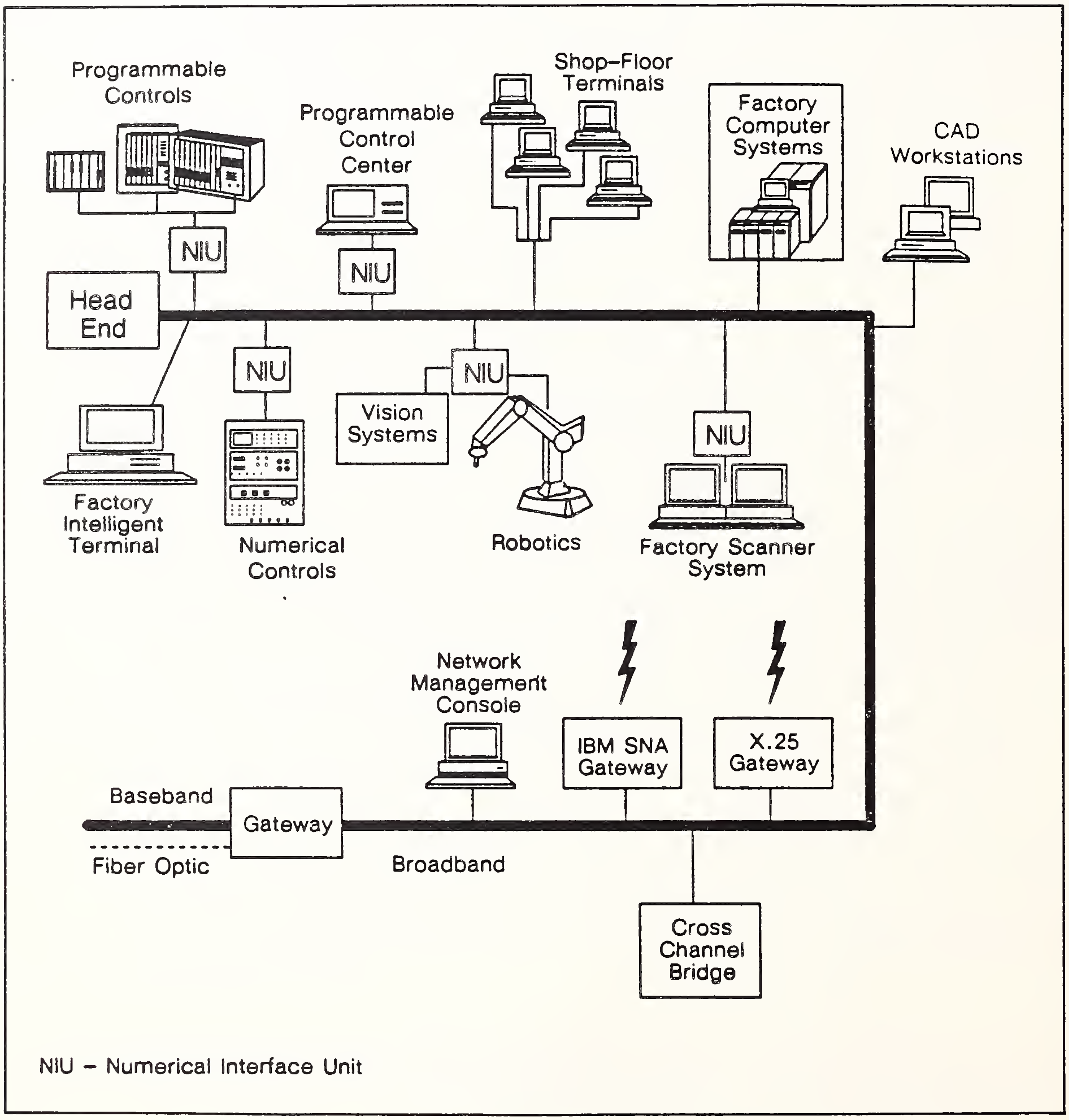
- Applications that need to communicate with non-DEC systems will use MAP, while applications that wish to communicate with DEC systems will continue to use DECnet protocols.

B. NETWORKS

- Exhibit VII-3 shows a typical factory communication system. Three basic types of networks are required for such a system.

EXHIBIT VII-3

TYPICAL FACTORY COMMUNICATION SYSTEM



Source: General Electric

1. CLASS I NETWORKS

- Wide area networks that link different facilities and different host computer systems, gateway to gateway. Examples are IBM's SNA, Digital's DECnet, and CDC's CYBERNET. In general, the speeds for data transmission are not high, but large quantities of data must be transferred. Hence, up to 56kbps or a T1 data link of 1.54 Mbaud may be required for some large installations.

2. CLASS II NETWORKS

- Local area networks (LANs) are in-house communications links that integrate computers, storage devices, other networks, and intelligent devices within a facility. These networks provide the bridges between MIS departments and the factory level manufacturing systems. The type of networks available for this application are Ethernet, Token Bus, and GEnet.

3. CLASS III NETWORKS

- This type ties together all the manufacturing machines and input devices on the shop floor. MAP, which has been discussed previously, is an example of such a network. The type of connection to be used in the network is primarily dependent on the type of media to be used.

- Twisted pairs, coaxial cable, shielded multiple twisted pairs, and fiber optics are the major choices available. In most cases, the only real decision that a purchaser must make is the use of fiber optics. Fiber optics has a significant advantage over conventional cabling since it is not susceptible to extraneous electronic noise which is usually present in the factory environment.

- Fiber optic cabling also has a very high transmission rate. The only negative aspect is that it currently costs more than other alternatives. The type of transmission system to be used is generally specified in the Class I networks by the vendors.

- However, in the Class II systems, two types of transmissions are possible: baseband, generally utilized when only digital data is to be communicated over the network, and broadband, used when a mix of analog signals, such as video, voice, and other forms of data, is to be transmitted. These transmission schemes also allow for different types of link connections.

- The most significant issue in selecting a network configuration is the type of connection. The choice of the proper connection will determine how the network will respond during peak loads. In general, there will be a variety of devices tied into the network, and each may require different types of connections.

- Exhibit VII-4 shows connection types used in a typical system: loop ring, switch, multidrop bus, and star connections. Each type of connection has different advantages, and some support much high data transfer rates depending upon the number of users on the system.

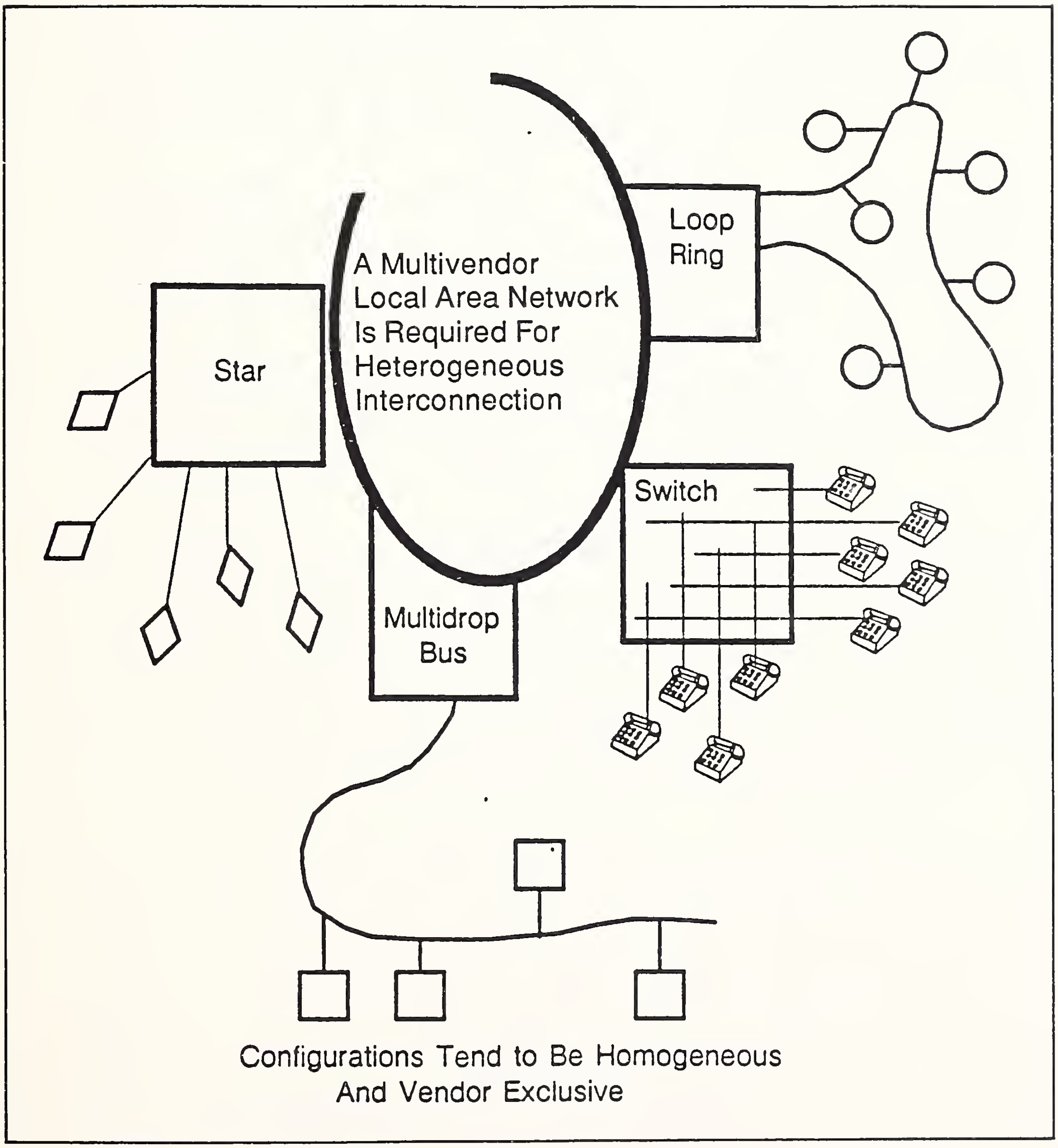
- An interesting feature of computer processing networks is the distribution processing within the system. If the processing capability is distributed throughout the network, then each of the computers in the network shares in the computational load. The advantage of this concept is in system reliability, response time, and overall system performance.

C. MARKET FORECAST

- Exhibit VII-5 shows the projected growth of the three types of LANS: baseband, fiber optic, and broadband. Total revenues will increase tenfold from $45 million in 1986 to $450 million in 1991.

EXHIBIT VII-4

TYPICAL NETWORK CONFIGURATIONS

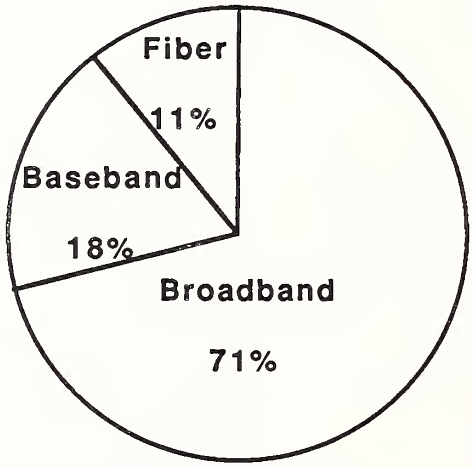


Source: IBM

EXHIBIT VII-5

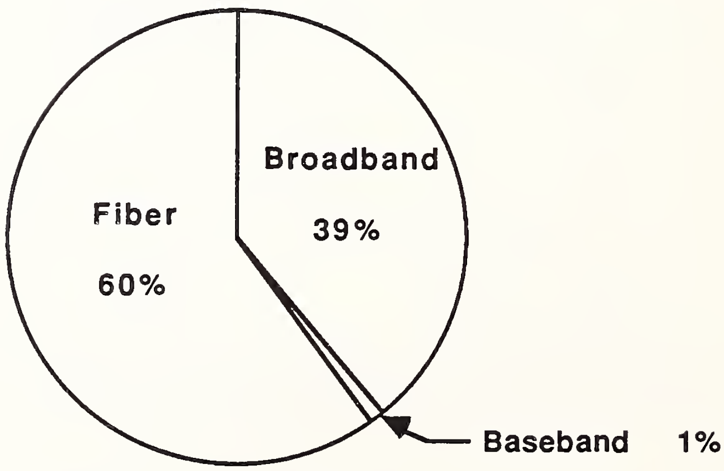
LAN REVENUES IN MANUFACTURING

1986



Total = $45 Million

1991



Total = $450 Million

- Baseband LAN's penetrated the manufacturing market initially with equipment for process and production control using point-to-point LAN systems. These systems have been well received and proved remarkably stable and error free, contributing greatly to user confidence in LANs.

- Advances in process and production control combined with technological improvements in LANs led to an increasing interest in expanding the role of LANs, with particularly high interest in the video capabilities of broadband for process surveillance, plant security, and related applications.

- The relatively higher initial cost of the broadband system has slowed its acceptance in this category initially, but installations will rise dramatically once the costs drop significantly.

- The high growth rate of broadband LANs will be fueled by their application as a backbone or central spine connecting the existing factory floor and work area baseband LANs.

- Fiber optic LANs are particularly well suited to manufacturing environments, but the exceptionally high cost of these systems has prevented much growth. This situation is likely to remain the same for another two years, when the lower cost and strong marketing thrust of the Japanese firms will begin to have an impact. Many American subsidiaries of Japanese firms will be used to showcase the capabilities of the fiber optic LANs in manufacturing.

- Today, more than 200 LAN vendors offer products for the factory, the back office, and the computer center. Most offer carrier-sense, multiple access, collision detection protocols (or CSMA/CD), although IBM and AT&T are likely to offer token-passing protocols. Ungerman-Bass (Net/One), DEC (DECnet), Xerox (Ethernet), Corvus (Omninet), and Wang (WangNet) offer turnkey systems based on CSMA/CD. Board-based CSMA/CD products are offered by 3-COM, Novell, Xerox, Intel, and ABLE.

D. KEY PLAYERS

- Several traditional factory automation equipment suppliers such as Allen-Bradley, Gould, Honeywell, and Hewlett-Packard have announced products that will conform to parts of the MAP standard.

- Semiconductor manufacturers Intel and Motorola are producing board-level interfaces to link existing equipment to MAP-based networks. They and other semiconductor makers are working on VLSI implementations of the interfaces to bring the cost of interconnection down.

- Several smaller companies, such as Charles River Data Systems, Concord Data Systems, and Industrial Networking, are scrambling to develop network interfaces and software for what is anticipated to be a rapidly growing market. Proprietary products such as DECnet, GEnet and SNA are offered by their respective manufacturers (DEC, GE, and IBM).

VIII CIM CASE STUDIES

VIII CIM CASE STUDIES

A. FIRESTONE

1. COMPANY PROFILE

- Firestone is a major U.S. tire manufacturer headquartered in Akron (OH). The company has 11 plants worldwide. Due to the extremely price-sensitive, competitive nature of the tire business, factory automation is a "must" for maintaining market share.

- Firestone corporate put together a study team from corporate engineering and spent over $1 million studying the Albany plant for automation. After extensive research, it was decided that the Decatur (IL) plant was the better pilot project; it was the most profitable and thought to be the most forward-looking with the best management. These qualities were believed to make the overall automation job easier with a higher potential return on investment.

- Through the automation project, which is now nearly complete, Firestone has reaped unexpected benefits. Several major automobile makers have chosen to purchase Firestone tires over competitors, believing that Firestone's automation strategy helps ensure the company's long-term industry success.

2. CIM EXPERIENCE

- In late 1984, Firestone wrote a detailed specification that it presented to system integrators for bids. The idea was to benefit from an independent's view rather than request bids from biased hardware/software vendors. Systems Control, the U.S. arm of SCICON, a division of British Petroleum, was chosen. The original specification called for no down time at the affected plant and required the removal of the roof to install the automation equipment. Systems Control saw an opportunity and changed the original specification drastically, presenting a project that would accomplish all that Firestone wanted at a significant savings.

- In the first quarter 1985, Firestone contracted with Systems Control to undertake a project to primarily reduce the manpower, increase productivity, and control inventory in the plant. This project was unusual for Firestone in that:

    - It was a large project--about $21 million.

    - It was coordinated by an outside systems integrator.

- The Decatur (IL) truck tire plant produces about 30,000 tires per day. The area to be automated was the "final finish" area where already processed tires are taken for inspection and balancing, then put on pallets and shipped to the warehouse.

- In the inspection area, a robot picks up a tire and presents it to a human inspector, rotating it, and turning it. The inspector then pushes a disposition button that rates the tire as good or bad.

- If good, the tire goes for several other tests for uniformity and balance. Twenty-four programmable logic controllers (PLCs) operate the conveyors and communicate with the host computer. A palletizing robot (by Mid-West

Conveyors) then stacks the tires by size or type on a pallet, and wire-guided AGVS bring the pallets to the warehouse, drop off the tires, and return the pallets.

- The warehouse itself is not yet automated and is not part of this project. Besides the robots, conveyors, and AGVS, Systems Control installed three HP 1000 computers; one for backup and the other two for real-time control and gathering of information. Firestone required that the computers be HP since they already have a large base of HP 1000s and 3000s installed.

- They origionally required that the programming be done in Fortran. Systems Control prefered C, but at the time there was not a good C compiler available from HP. (There now is one for the Spectrum 1000 to be shipped in 12/86.) Both companies finally settled on Pascal.

- All of the automation equipment has now been installed in the plant and the first phase of the project is complete and being debugged. Although the project is presently on schedule, when Systems Control originally examined the schedule they found that Firestone was overly optimistic on timing.

- Project conclusion is expected in mid-1987, with an ongoing maintenance management contract for one year after completion. An ongoing training program on all equipment and its maintenance is a key part of the project. This component alone is worth about $1 million.

3. RESULTS

- The project is a success for Firestone in that it reduces the labor force by 105 people, which at an average wage (with benefits) of $40,000/year is a $4-million-a-year quantifiable savings. Other company benefits are more difficult to quantify, but the company has already seen the marketing value of the automation in the shape of new, substantial business.

- The next phase of automation for Firestone is to repeat the process at the other major plants that have "final finish" components. The company has chosen to continue to automate this section of the manufacturing process rather than developing an automated storage and retrieval between the warehouse and final finish due to political aspects of control that exist between these two groups.

- The lessons to be learned from this case study are as follows:

  - Firestone was willing to let a systems integrator control the entire project.

  - Systems Control was successful in the bid stage because they were able to go beyond the narrow confines of the client's own specification and design a better solution with unique advantages.

  - Systems Control immediately rewrote the schedule to make it more realistic, and then kept to it.

  - Firestone, approaching the end of a very successful (though partial) automation project, has been careful to recognize the need to accommodate internal political realities, proceeding with a repeat of what has proven to be a success in one plant with an identical system for other plants. Sooner or later, however, these political problems will have to be addressed if the company is to go beyond partial, isolated automation and begin implementing full CIM.

B. MILTOPE

1. COMPANY PROFILE

- Miltope (an abbreviation for military peripherals) produces ruggedized tape and disk drives for military battlefield conditions. It was a spin-off of Potter Instruments that went bankrupt in the 1970s. The total 1986 company revenue is about $70 million and is growing at about 30% per year.

- To develop a CIM approach to their manufacturing needs, a committee met for 13 weeks at Miltope using IBM's Application Transfer Study (ATS) methodology. The Melville (NY)-based company is now working with the SUNY Farmingdale and Stonybrook campuses requesting a state grant to define a "poor man's CIM" which, for most small companies, means pulling together their islands of automation in a way to optimize their manufacturing goals.

2. CIM EXPERIENCE

- In 1975, Miltope was a company of 50 people needing an inventory system. Since they were a small company without a DP department, they asked IBM for a recommendation for a useful easy-to-use system. IBM recommended an IBM System 32 and the inventory control module for MAPICS, which was the beginning of Miltope's CIM project.

- Since then, the company upgraded to first a System/34 and now has a System/38, all the while building MAPICS modules on top. With the full MAPICS system installed, Miltope is now installing a bar-code data collection system.

- In 1983, management decided that to remain competitive the company would need to install a CAD/CAM system. CADAM was chosen as the product, and mechanical CADAM was initially installed. Of interest is the fact that most small companies install standalone CAD systems only and "paint pictures." Miltope realized the need to generate mathematical models for manufacturing and the need for a manufacturing data base.

- In 1984, Miltope added CADAM's electrical CAD/CAM package (since they also design printed circuit boards for itself, it uses Daisy for logic analysis and, more recently, a gate array).

- To Miltope, CIM is very simple. In its first phase it is connecting MAPICS and CAD/CAM (there is no automation equipment on the shop floor to integrate), and presently it is integrating its bill of materials (BOM). In phase two it is are seeking to integrate all of the different data bases that serve one or another of the manufacturing processes.

- Procedurally, Miltope operates as follows:

  - Product design is accomplished using the CAD part of CAD/CAM.

  - IBM's TIF (The Information Facility), a 4GL, is used to manage the parts data base (a type of component library).

  - This component library can bring the text for the engineering parts list automatically into MAPICS's bill of materials.

  - The graphics that reside on the CADAM library are pulled out and attributed to the component as a detail of CADAM drawing. The user can also generate drawings from the same library.

- Miltope runs NC machines off of the CADAM data base for milling machines using CADAM's animation facility.

3. RESULTS

- Miltope has been working on the concept of a "global data base" for four years and has many more years to go. It is attempting to integrate:

  - The manufacturing data base.

  - The engineering data base.

  - The preferred parts data base.

  - The marketing data base.

  - MAPICS bill of materials all into one data base with a query system attached to the front end.

- The company knows that CIM is an ongoing project. It has been constantly enhancing CAD/CAM for the past four years and MAPICS for the past nine years, and will continue to do so.

- To procedurize this evolution, a committee of plant representatives meets weekly at Miltope with participation from the following to discuss the pros and cons of present and future automation solutions:

  - System users.

  - CAD designers.

  - CAM programmers.

  - Systems people.

  - Management.

- In the near future, Miltope will build a ruggedized PC. It will first design an automated factory (just as IBM did with their Pro-Writer Division) and then produce the product. Miltope believes that building a factory from the "bottom up" with the product design in mind is a more efficient project long term versus redesigning existing plant and equipment.

C. LENNOX INDUSTRIES

1. COMPANY PROFILE

- Lennox Industries is a privately held company headquartered in Dallas (TX) Texas, that manufactures air conditioning and heating systems. It is a multidivisional corporation with seven manufacturing locations.

2. CIM EXPERIENCE

- In 1986, Lennox began its CIM implementation. The centralized MIS department was the key force in convincing management of the need for JiT and flexible manufacturing to remain competitive.

- The CIM approach that Lennox chose is accepted as a companywide concept, and all seven manufacturing locations will proceed in the same direction. A corporate steering committee meets monthly to discuss the project with data gathered by MIS on a weekly basis.

- The CIM plans will not be modified in any way by this committee. Lennox Industries now has a full implementation of COPICS, including rough cut capacity planning, and master scheduling. As a front-end CAD system, the company uses Anvil 4000 tied into the mainframe COPICS system and is presently working on bringing bills of materials from Anvil into COPICS. The entire system will be "up and running" as of January 1987.

3. RESULTS

- Since the aforementioned configuration is being implemented in seven different plants, MIS has determined that training is a critical element for system success. Consequently, each factory is being educated on how to use the system prior to its installation.

- Lennox is also going entirely to JiT scheduling. They are presently working intimately with IBM on the JiT system, changing several areas within COPICS code. Lennox speculates that IBM may incorporate much of their JiT work into IBM standard COPICS code.

- One of the major COPICS modifications involves changing it to be a one data base approach. Although the data base presently will evolve around IMS, Lennox expects the company to utilize DB2 in the near future. A prime motivator for this single data base approach is the fact that the company operates purchasing on a corporatewide basis and needs to be able to consolidate demand on a national basis. Backup is with Comdisco in Grand Prairie with hotlines into that facility from their seven largest plants.

- Lennox management is convinced that a mechanism is necessary to assist planning (especially capacity planning). The company has a comprehensive time-phase distribution system in which corporate gives manufacturing requirements to factories. The factories realize that those at corporate need to know what the capacity of plants are so they can be properly loaded. Consequently, the planning modules of COPICS are vital.

- The company is still using Martin Marietta's MAS MRP system but is phasing it out. Internally, Lennox had experienced some negative feedback from their accounting department relating to its CIM activities. The accountants wanted nine different cost fields and could only turn in actuals on two or three of them. This situation, however, has been alleviated.

D. GENERAL DYNAMICS

1. COMPANY PROFILE

- General Dynamics (GD) is a major aerospace company. Its Fort Worth plant has 22,000 employees and about $2 billion/year revenue. This plant is responsible for the building of the F-16 aircraft.

- GD participates in an Air Force contract from Wright Paterson that involves a government program to reduce manufacturing costs. The aim of sponsoring automation projects is twofold:

    - Benefit the government by providing better quality products at less cost and in a more timely manner.

    - Benefit the participating company by adding to the "bottom line."

2. CIM EXPERIENCE

- In 1974, General Dynamics formed a committee composed of representatives from MIS, finance, and other departments of the company to determine a plan of action to move toward automation. The objective was the lowering of costs to remain more competitive in the marketplace.

- Since then, the company has implemented many automation projects, including robots, machine tools, CAD/CAM, and MRP--most done internally. In early 1985, General Dynamics began its flexible manufacturing system automation project. It had hoped to be in production by now, but encountered problems with machine tools that needed design reworking. Completion has been rescheduled for early 1987.

- Westinghouse Integration Group was hired as the prime contractor by GD to supply the flexible machining system to the Fort Worth plant. Westinghouse is combining various hardware vendors products with its own control subsystem using a distributed control philosophy with a proprietary highway to distributed Intel units.

- The process involves, first, delivering materials on pallets to the machine tools, and second, after the parts have been cut, taking them off the machine and through the post-machining operations such as testing. The plant is to be a "lightly-manned" operation. For aircraft companies such as General Dynamics, complete automation of the manufacturing process will be impossible until well into the 21st century.

- The company first needs a product "designed for automation" which is at least two generations of aircraft away. With current designs, partial automation of the production process is possible, but the final product is designed to be assembled by hand. Consequently, for GD, the aircraft to be produced in the mid-1990s will be the first where automation needs impact the design process, and in the 2010 timeframe, a plane will be developed for the first time in which automation is the key to design.

- The current scheduling system is based on ART, an expert system shell by Inference Corporation. Originally GD specified that, as part of the distributed system, the central processor complex (host) was to be a cluster of DEC VAXs. Westinghouse tried to build the system around that configuration, but found it was unworkable when they got ART. It has since installed a Symbollics machine as a development station and is still not sure what the final "run-time" hardware product will be.

- Inference recently demonstrated to Westinghouse ART for a VAX written in C (which is in optimization stage), but Westinghouse will wait until the developmental effort is complete to make the final determination on hardware type.

3. RESULTS

- With ART used for scheduling, the rest of the control system is micro-based. The actual material control is done by a"station interface unit" coded in Pascal. Data storage is done in the central computer complex and supports a user transaction and reporting system. There is also a connection through an Ethernet link to the central General Dynamics data processing center.

- By the conclusion of the present automation project, GD will be producing complete parts exclusive of painting. This will include the installation of:

  - Robotic load and unload stations.

  - An ASRS.

  - Vision system for road blocks.

  - Final inspection operation.

- Although GD feels that the results of its CIM efforts are not quantifiable, it knows they are of strategic importance. In the near future, the company will be internally working on integrating all systems from the shop floor, to the scheduling systems, to other relevant departments within the company. CIM will continue to be an ongoing project.

E. RANK XEROX

1. COMPANY PROFILE

- Rank Xerox is the European arm of worldwide Xerox Corporation. The plant in Vernay, The Netherlands, is a producer of low-priced copiers.

- In the late 1970s, with intense Japanese competition, Rank Xerox decided to establish a JiT inventory system to assist them in remaining a viable industry participant.

2. CIM EXPERIENCE

- Prior to beginning the CIM project, Xerox had installed a Honeywell host with internally-developed software. It also had standalone financial systems. Consequently, since the overall objective was to find a real time, on-line, fully-integrated system to link the manufacturing operation to the financial data, it was necessary for the company to link the MRP system through the batch-related system to the financials. The ensuing product has the material flow immediately recorded in the General Ledger, enabling cash flow forecasts.

- The company installed the Xerox MRP system and created an interface that allows production floor operators to use a terminal at their individual station and request material when needed creating the MRP system's response to demand. The end result is a flexible issuing and receiving process on the production floor.

- Further interfaces have been developed between the MRP system and an automated crane, shuttle cars, and AGVS.

3. RESULTS

- In the area providing a direct edge over competitors, Xerox's CIM project produced the following benefits:

    - Unit manufacturing costs, in terms of labor and overhead, have been lowered over 30%, making them about equal to comparable producers.

- In two years, manufacturing output increased 40%. Consequently, the company could deliver 100% of ordered copiers as well as spare parts.

- Xerox increased the features in a new line of copiers while decreasing list price by 40%.

- Raw material inventory was decreased by 75% which saved an estimated $20 million per year in inventory holding costs as well as decreasing the material transport bill by 20%.

• The company was also able to decrease the number of people in accounts payable by 30%, while at the same time doubling the number of invoices processed per day. This saved the company several hundred thousand dollars per year. Rank Xerox believes that their installed automation solution encompasses all the facilities and systems that they will need for the near future.

F. TELEMATICS

1. COMPANY PROFILE

• Telematics is a privately held company located in Fort Lauderdale (FL) that builds products for the package switching segment of the data communications market. 1986 revenue is expected to be about $20 million and employees total 175. The company has one other site in London.

2. CIM EXPERIENCE

• The company is only four years old. From the start, it recognized that a major key to corporate growth was the control of the information flow and it set out with the intention of integrating all the departments in the corporation. A number and nomenclature system was developed to support this goal.

- The CIM responsibility lies with a steering committee comprised of representatives with information system backgrounds in the manufacturing and finance departments. This committee coordinated the CIM plan four years ago and continues to oversee it.

- At the automation project's inception, it was decided that microcomputers would play a major part in the overall plan. Telematics began with 8-bit microcomputers but soon switched to 16-bit micros. They now have developed 20 software modules internally to run with dBASE II that include:

  - Accounts payable.

  - General ledger.

  - BOM.

  - Materials management.

  - Order processing.

- These modules run on standalone micros, of which the company has about 20. In the near future, Telematics will run these applications on dBASE III+ (which is a LAN version of dBASE II) and increase its number of micros to 30. There are other automation entities within the company, the most significant being a CAD system by Valid Logic. With the installation of the corporate LAN, the CAD system will be able to be linked through a gateway since it has an Ethernet capability.

3. RESULTS

- Future automation plans include better communications with the London office, which for Telematics will be less of a problem than for most companies since they compete in that market.

- Telematics has many ways to justify its CIM investment. However, since the company automated from the beginning, it does not have past internal benchmarks for comparison. The company can compare itself to industry averages for revenue per employee comparisons, head count, and inventory averages of similar size manufacturers. It feels it is on the high end of the competitive spectrum in most areas.

G. AMHOIST - AMERICAN HOIST AND DERRICK CO.

1. COMPANY PROFILE

- Amhoist is a designer and manufacturer of heavy crane equipment based in St. Paul (MN). Its products are custom designed and consist of large castings, structural members made from steel plate, and barstock.

- Because of the high cost of materials and castings, inventory control and the ability to deliver products with short lead times are the key elements for success in this business.

- Revenues for the company are running at about $125 million, 50% of which comes from domestic markets and the remainder from overseas. Competition is very stiff, particularly from foreign suppliers such as the Japanese. The company has about 10 major competitors, which have eroded Amhoist's profitability over the last few years. As a result, streamlining the company's operations and automating the design and manufacturing were recognized by senior management as being key to Amhoist's survival in the long run.

2. CIM EXPERIENCE

- The first stage of automation that Amhoist's management decided to pursue was the engineering/design department with an appropriate CAD/CAE system. The decision to proceed with this phase of the program was taken in January 1982, and it was two years before the chosen CAD/CAE system was delivered and training commenced. Annual budget for this project was set at about $400,000, and total project cost was about $1.5 million.

- The central goal of the design automation phase was the establishment of a geometric data base which would have the following features:

  - 3D wireframe.
  - Surface models.
  - Solid models.
  - Finite element graphics.
  - Conventional orthographics.
  - Isometric views and perspectives.
  - Exploded views.
  - Drawing formats.
  - NC tool paths.
  - Component attributes and lists.

- In addition, the data base was to provide multiple usage by functional discipline (structural, mechanical, electrical and hydraulic, manufacturing--including NC and DNC, and Technical Publications) and increase productivity.

3. RESULTS

- Since Amhoist's management was partially responsible for the CAD/CAE installations, justifying it was not a major problem. Automation of the design department and shop floor was viewed from a strategic/competitive perspective and as key to the company's long-term survival in the marketplace. Management, quick to recognize its own limitations, hired an expert and gave him the authority to implement the automation concepts.

- The CAD/CAE installations at Amhoist have been successful. The intent of the company is to continue into the next phase of greater computer control of the NC machines on the shop floor.

- The major problem that Amhoist encountered was getting up to speed on using the 3D graphics package. Tight delivery schedules combined with difficulties in learning the package itself caused users to stick with the manual drafting system. The tendency was to utilize the CAD/CAE system on low-priority jobs and gradually gain confidence in using the system.

- Some of the specific results achieved were:

  - Reduced engineering drafting time by 50% after minimum training.

  - Improved accuracy on engineering drawings.

  - Improved overall image of the company from the customer's perspective.

- Engineering lead times reduced by as much as 75% on certain types of design jobs.

- The CAD/CAE installations lowered the bid prices on standard products. Amhoist recovered its investment in about 2-1/2 years; the CAD/CAE installation decreased the product delivery time from concept through production. The major effort in the group technology area was in the use of the Birsch code and classification system for identifying parts that belong to similar or like families. The system, when fully operational, could result in savings of as much as $1 million/year, easily justifying the cost of the CAD/CAE system.

- It took considerable training and practice to develop a high skill level on the CAD/CAE system. Estimates ranged from 500 to 1,000 hours of practice on the sytem. Taking a 3D model, extracting a part, and obtaining a corresponding engineering drawing was a serious problem. It was difficult to convince engineering management to use the CAD/CAE systems when production schedules were critical and the number of available operators and hours of workstation time were limited.

- Operators were at widely different skill levels, and the tendency was to use only the top notch operators for high-priority jobs. This greatly limited the use of the system.

- The company uses the following computer equipment:

  - An IBM 4341 with 150 user terminals (used for business computing and MRP).

  - An IBM 4331 for engineering scheduling, finite element analysis, and safety analysis for cranes.

  - A CDC Cyber 170/825 with 11 graphic workstations and 1.4 Gbytes of disk space (CAD/CAE).

- A separate IBM 4341 with 150 terminals for data collection and various types of programmable controllers.

- The principal software products used include CDC's "ICEM" (Integrated Computer and Engineering Management with 3D), AMAPS from Comserv for MRP II and all accounting functions, CDC's Engineering Data Library (EDL) flexible data manager, Birsch Bern's Code and Classifications system "Total," and IBM's DBOMP. NC programs are coded in APT, then converted to Compact II.

H. MAGNETIC PERIPHERALS INC. (MPI)

1. COMPANY PROFILE

- MPI is a subsidiary of Control Data Corporation (CDC). The Twin Cities Division (TCD) of MPI is involved in designing and manufacturing magnetic disk drives. The products include 10 different types of drives varying in capacity from 80 to 679 Mbytes.

- TCP employs 5,000 people and has three local manufacturing plants. MPI's annual sales are about $1 billion. The evolution of CIM in the company started five years ago when a CYBER 170-720 CAD/CAE system was installed. There was a recognition on the part of senior management that the disk drive business was getting to be very competitive and implementation of at least some of the concepts of CIM were needed to shorten the time needed for new product development. The need was evident for the establishment of a design management control system. This resulted in the implementation of the engineering data library (EDL).

- The budget for CIM at TCD was divided into two parts--mechanical design and electrical design--with a combined budget of about $600,000. Total project cost for the CAD/CAE installation was estimated to be about $1.5 million. It took about four years from the time of initial equipment acquisition in 1981 for the system to become operational in 1985.

2. CIM EXPERIENCE

- The objectives of MPI in implementing the CAD/CAE system are shown in Exhibit VIII-1. The principal objective was to develop an application management system with:

  - Analytical 4 modeling capabilities, such as geometric modeling, design/drafting, and finite element modeling and analysis.

  - Appropriate manufacturing interfaces such as developing data for control of NC machines and preparing the product for release to manufacturing.

  - Appropriate interface to the Engineering Data Library.

  - Technical publication capabilities.

- Computers used included:

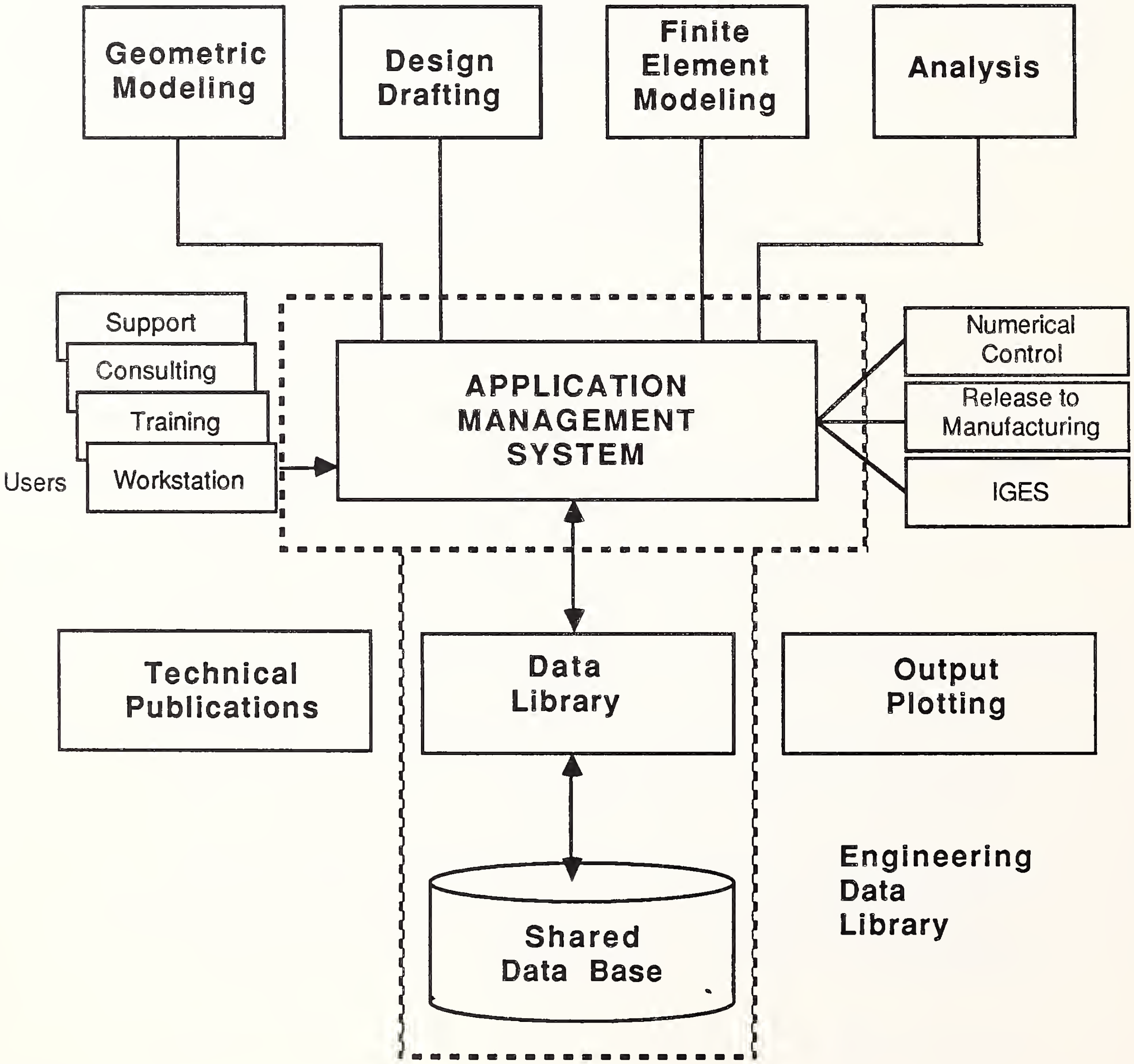
  - Control Processing Computer--Cyber 170/730 dual CPUs used for engineering, manufacturing, and MRP.

  - Scientific Computer--IBM 4341 CPU linked with Cyber 170 used for engineering analysis system compatibility studies and micro code development.

  - CAD/CAE Computer--CDC Cyber 170/730 with 24 graphic stations.

EXHIBIT VIII-1

MPI OBJECTIVES



- Database Computer--Cyber 170/730.

- Other systems include Apollo Idea 1000, engineering workstations for electronic designs and schematic entry.

- The software products include CD2000 (mechanical drafting, detail part drawings, assembly drawings, manuals, manufacturing process document), Unistruc (finite element modeler, mesh generation, pre/post processor), Ansys (Finite Element Analysis, Structural Dynamics, Thermal analysis, MIDAS's Aids (digital circuit simulation, gate arrays), and Cyberspice (analog/digital circuit simulation, analog chips).

3. RESULTS

- The company has improved substantially its ability to expedite the design and fabrication of disk drives. The company's image has improved, and employee morale has been raised.

- Solids and 3D wireframe modeling packages are fully operational; however, the 3D graphics package proved to be more difficult to implement than originally expected. Engineering drafting time has been reduced by over 50%. The productivity improvement for smaller drawings improved by 3 to 1, and for E-size drawings by 2 to 1.

- The productivity improvement for ECOs has been nearly 10 to 1. This large ratio is explained by the fact that the draftperson need not redraw any constant portions of the drawing. Also, there has been an improvement in accuracy on engineering drawings and a reduction in engineering lead times on certain types of design jobs.

- Total project cost was recovered in three years. The generation of 3D data bases takes approximately twice as long as 2D data bases. Consequently, this type of data base is not used nearly as much as 2D data bases. The inital version of the 3D design package provided with the CAD/CAE system was not satisfactory and its use was discontinued until the system difficulties were remedied. This caused a delay in bringing the system up to operational level.

- If the company were to reimplement CAD/CAE today, its personnel feel that implementation should be done in the engineering design organization and not in the drafting group.

I. DUNCAN ENTERPRISES

1. COMPANY PROFILE

- Duncan Enterprises is a family-owned business in Fresno, California, that manufacturers liquid colors, molds, kilns, and brushes for ceramic hobbyists. The company has over 250 employees and revenue in the neighborhood of $20 million.

2. CIM EXPERIENCE

- In the late 1970s, Duncan Enterprises began its major automation project to become more competitive. It saw automation as the competitive advantage that it needed to remain viable in the ceramics market, 75% of which is located east of the Mississippi.

- Duncan Enterprises has an IBM 4341 computer system running COPICS software and several dozen 3278 display terminals. The company modified COPICS by writing special front-end and back-end codes that circumvent the need to key in part numbers.

3. RESULTS

- The systems benefits affect almost every area of Duncan. Several tangible savings include:

  - The year that COPICS was purchased, inventory was reduced by $1 million.

  - Material requirements, planning, and ordering has achieved savings of over $250,000 per year in raw materials purchasing and $200,000 per year in inventory carrying costs.

- General savings to Duncan include:

  - On-line display of formulas takes into account the uneven nature of the raw material included in each color. Consequently, engineering changes can be made per batch which helps insure consistency with the various color hues.

  - The accuracy of the inventory system with COPICS lets manufacturing know if the needed supplies in inventory are on hand before beginning a certain job.

  - Customer order servicing can centralize order information on orders from Duncan's several hundred distributors.

- This centralization also aids marketing who can use the same data reformated for their needs to view the customer histories by geographic region, size of firm, etc. This can be used to develop marketing strategies and information, as well as for the development of new products. Duncan brings over one dozen new products to market each month.

J. COLEMAN COMPANY

1. COMPANY PROFILE

- Coleman Company Inc., Wichita, Kansas, is a major manufacturer of camping and water sports products. The company has been very agressive with acquisitions in the near past, sometimes acquiring a new or medium-sized subsidiary every month. The O'Brien subsidiary is located in Seattle, Washington, and manufactures water skis, sailboards, and industrial water tanks.

2. CIM EXPERIENCE

- In the early 1980s, Coleman determined that a sophisticated data processing system would help the parent run the subsidiaries from the Kansas headquarters while allowing the individual companies autonomy.

- O'Brien has installed an IBM System/36 and MAPICS. This is supplemented with a data passthrough that allows O'Brien to use IBM 5251 terminals to emulate IBM 3270 workstations using an IBM 3705 controller attached to Coleman's main IBM 3083 in Witchita. Users in O'Brien can switch from the System/36 to the remote 3083 with three keystrokes.

3. RESULTS

- O'Brien reports that by using MAPICS they can keep a large amount of the plant processing in-house as opposed to using the resources of the Witchita parent. This means a more timely preparation of special reports with current data and more efficient product development, manufacturing, and delivery.

- In the near future, the company plans to do almost all of the O'Brien processing in-house and be able to cancel the dedicated communication link to Coleman headquarters that costs O'Brien several thousand dollars per month. The line would be replaced with a dialup system for occasional inquiry.

IX ISSUES AND TECHNOLOGY TRENDS

IX ISSUES AND TECHNOLOGY TRENDS

A. MANAGEMENT COMMITMENT

- A major capital-intensive project such as CIM will not succeed without the total support of the senior management in the organization, particularly the CEO.

- Top management enthusiasm for CIM is frequently hampered by the term computer integrated manufacturing itself, and more specifically by the word computer. Many executives still view the computer as an enemy and not as an ally and an asset.

- Too many executives view manufacturing in the narrow sense of the term to mean production only. The emphasis has to shift from the shop floor level to a strategic level. Getting top management to think more strategically about manufacturing is key to obtaining their support for CIM.

- CIM proposals from functional managers are typically couched in non-strategic terms and have overemphasis on tools such as computers, machines, and systems and not enough emphasis on end results such as gaining competitive advantage.

- Corporate managers require frequent reminding that corporate business strategy objectives should always drive all internal functional strategies, such as manufacturing strategies. This way there is a linkage between business strategy objective to each functional strategy objective. The implication is that if an organization wants to achieve a certain business strategy objective, it must excel at some specific task in manufacturing.

- Many executives tend to view manufacturing decisions such as vertical integration, production technology, plant location, capacity, production systems, labor force composition, etc. as one-time decisions that, once made, need little reconsideration--maybe a perfunctory review every five or ten years. In reality, making decisions on these items is an ongoing process as technology, costs, and global competitive conditions change.

B. JUSTIFYING CIM

- Justifying automation in the face of low production volumes is a problem for most small to medium businesses in the U.S. They have the option of waiting to automate until production volumes are high or, like their Japanese counterparts, make the necessary upfront investment in CIM that would drive unit manufacturing costs down and volumes up through the resulting market expansion. However, due to short-term profit pressures, they have chosen the former rather than the latter.

- Corporate managers thinking is tied to old-fashioned investment formulas such as return on investment (ROI), return on assets (ROA), and other short-term financial measures that neglect consideration of strategic benefits (such as flexibility and reduced new product development lead time) and long-term competitive success.

- Another problem faced by manufacturing companies that want to automate is in their treatment of capital costs. High front-end expenditures traditionally experienced in a new plant startup, such as building construction and installation of basic machinery, are normally amortizee over a three-year period.

- With automation, companies are faced with a similar situation of high front-end costs but, unfortunately, a much longer productive life. So if the amortization could be spread over a longer timeframe, it would mean less of a negative impact on the company's income statement and make the financial justification of automation easier.

- The recent revision of the tax code, where many of the incentives for capital investment in plant and machinery have been eliminated, may cause the slowdown of factory automation and make it even more difficult to justify CIM.

C. INDUSTRY STANDARDS AND INTEGRATION

- Industry standards are necessary if products from several vendors are to communicate easily within the hierarchy of CIM equipment; however, the lack of it is a major readblock to CIM. General Motors, for example, has thousands of pieces of automated equipment but only 15% can communicate.

- GM, frustrated by the task of automating its factory operations, set out to develop a standard industrial LAN. Known as the manufacturing automation protocol (MAP), it is a token passing broadband network married to open systems interconnect, a seven-layer LAN model developed by ISO. While the development of this protocol is far from complete, it represents a major step forward to assure interconnect compatibility among equipment from different vendors.

- Comprehensive conformance testing of MAP-compatible products to the standard is a very real and immediate issue. Currently, products are tested only at the Industrial Technology Institute (ITI) in Ann Arbor (MI). The products are tested for individual compliance to the MAP specifications and for interoperability of vendors.

- However, current tests are not as refined as they should be. Also, there is no agreement yet on the appropriateness of the test organization, test scenaries, and a governing body that is going to be in charge of implementing the standards as agreed to by ISO or IEEE.

- The costs of MAP-networks are high at the present time, as much as $5,000 per connection. Proprietary networks, such as DECnet, can offer a much less expensive solution. However, when MAP interfaces become available as VLSI devices by the end of the decade, costs are expected to drop rapidly.

- Another major software standards issue is in the applications programming arena. Robots now have over 12 programming languages. The Japan Robot Industry Association (JRIA) has given a high priority to formulating specification for an international standard programming language for robots.

- The central idea behind the integration of CAD/CAE applications that is universal of most companies is the idea of a common data base. Of all the 3D modeling techniques, solid modeling might be the key to the common CAD/CAE data base. But if solid modeling is to be the key, it must provide the missing ingredients to support the many CAD/CAE functions.

- There are two basic requirements for the common CAD/CAE data base if it is to provide for complete CAD/CAE integration. The first requirement is that the format and contents of the data base be agreed upon between the different engineering and manufacturing functions.

- The second requirement is that the product definition contained in the common CAD/CAE data base must be complete and unambiguous enough to support all the applicable CAD/CAE applications. This product definition is made up of geometric data along with an associated set of non-geometic specifications.

- If the solid model is to be the key in integrating CAD/CAE applications, some of the applications that it must aid are:

  - Mass properties analysis of individual parts and assemblies of parts.

  - Automatic checking for part interferences and clearances.

  - Realistic display of parts and assemblies, including exploded views, section cuts, hidden line removal, and color shaded display.

  - Association of dimensions and tolerances with the geometry of the model.

  - Automated quality assurance checking using the geometric model and its associated dimensions and tolerances.

  - Generative process planning through automatic recognition of important features of the solid geometric model.

  - Automated or generative NC. Also, verification of NC data by comparing the orignial engineering created model to a model generated by NC data.

  - Automated tooling and fixture design.

  - Robotics work cell design allowing for automatic checking of potential interference and optimization of object placement and orientation.

- However, solid modeling has not reached its CAD/CAE integration potential as yet. Some of the most technical problems include:

  - Difficult access to the solid model data base.

  - Sparse recognition of defining model features.

- Limitations in model size.

- Difficult extraction of geometry for NC work.

- Absence of dimensioning and tolerancing data.

- Limited capabilities to query model.

- In addition to these technical problems, there are implementation problems such as:

    - Complicated and awkward user interfaces.

    - Shortage of modeling tools.

    - Slow interaction speed.

    - Need for large computing resources.

    - Difficult editing of geometry.

- Most companies lack the organizational structure or staffing that gives any one individual the charter to pull together the entire CIM picture. Proposals for parts of the CIM solution come from many different sources within the company.

- Thus, top management never gets to see a total CIM program, its total cost, or, in particular, its total benefits. Often, top management may want to support CIM, but they simply are overwhelmed by multiple solutions. They do not know which of the many solutions offered by their people, consultants, or vendors to accept.

- There is a lack of technical knowledge and skills in most organizations to tackle automation. Automation, because it involves multiple disciplines, demands broader skills of supervisors who must understand mechanical and electronic equipment, software concepts, etc., on a factorywide basis and who need to be coaches and communicators to the work force.

- Top managers are too isolated from the tremendous pace of technological change occuring in the world today. Not only are they unaware of progress in manufacturing in other industries and countries, but they often do not appreciate the progress, or the lack of it, evident in their own design centers, plants, or distribution centers.

- U.S. companies need to develop new methods of training and communicating with their manufacturing organizations. Education of broader segments of the work force and a partnership with labor is required.

- There is a lack of truly relational data base management systems. This causes the user company to set up too many data bases through the CIM system, and the management of these distributed databases is difficult.

- Future manufacturing operations will be highly dependent upon software-driven technologies. However, current manufacturing software possesses severe limitations. Another weakness is insufficient programming capabilities both inside and outside user companies. Accentuating the problem is the inability of central computer staffs to understand and satisfy manufacturing floor needs.

D. CAD/CAE TECHNOLOGY MARKET

- The theme behind workstation technology trends is greater performance for lower price. The average workstation by 1991 will have the following characteristics:

- 32-bit machine with 10 mips speed.

- 1-16 Mbytes of memory.

- 5-1/4 inch disk drive with 400 Mbytes of storage and modular packaging.

- At the high end of the line one can expect to see the workstation to have a 32-bit processor with 20mips speed, 16-32 Mbytes of memory, and Gbytes of disk storage.

- CMOS will be the dominant chip technology. By 1991, we can expect to see as many as 1 million transistors on a CPU chip and 4 million transistors on a memory chip. From the current storage capacity of about 20 million bits per square inch, we can expect to see an increase to 100-200 million bits per square inch by the early 1990s.

- Optical storage will be commonplace. It will be low cost, with read/write capability, have high area density, and be removable.

- There is no end in sight to cost improvement of workstation products and consequently of price/performance ratios.

- Generation of true 3D displays will be used extensively for visualization of the design. The addressability of the displays will be greatly improved and the brightness levels will be sufficient to operate them in normal light. The use of higher resolution displays and faster refresh rates will eliminate the flicker problem.

- Workstation vendors will offer software tools integrated across applications. Not only will the trend to integrate engineering, design, and manufacturing continue, but inter-application integration will become increasingly important. Most users have CAD/CAE needs that span application sectors.

- As users become more sophisticated, they will look for workstation products that meet the total needs of their application and that provide interfaces to other applications.

- Vendors will offer integrated office automation software. As the CAD/CAE workstation becomes a personal tool, users will want to meet all their business needs as well as their design needs.

E. FACTORY AUTOMATION TECHNOLOGY

- Today's systems are frequently equipped with various sensors for machine monitoring, parts measurement, and counting. They are frequently tied in with inventory control systems and other aspects of CIM. Future data collection systems will provide the data necessary to monitor, control, and optimize the entire operation of the factory.

- All the hardware and software items are available to collect and process production data, but few installations complete the loop. Once the number of closed loop systems becomes significant, this trend will accelerate rapidly as the cost of data collection is shown to payout in dramatically reduced scrappage and lost machine time.

- Closing the local process control loop is an essential step in the evolving philosophy of fixing the process instead of the product. The closed loop provides real time control which allows immediate feedback to the process and to any deviations from the acceptance standards and initiation of corrective procedures to fix the problem immediately before the next part is produced.

- Adaptive Control Systems perform three basic functions: measure on-line machine variables in a process in real time, compare these measured outputs with other established values, and nodify the machining activity by changing one or more variables to improve or optimize performance.

- More importantly, these systems perform these functions automatically. Hence, the demand for these systems is on the rise due to renewed interest in automation. The key element of adaptive control is their ability to sense machining conditions. For example, with the information gathered with adaptive control, the host computer can determine if the cutter is dull and should be changed and the time it has actually spent in cutting or if the spindle motor horsepower is degenerating. Also, to run the batch manufacturing shop on an around-the-clock basis, so as to improve facilities utilization and keep inventory moving, systems must be able to respond to unexpected events, such as extra stock, hard spots in the material, and premature tool wearout.

- Even though adaptive control technology has brought about significant improvements in the machining process, optimization is an unrealistic goal at the present time. Significant optimization through adaptive control is about 5-10 years away. Manufacturers will not see increased optimization until all the available sensors for tool wear, forces, and gages for workpiece dimensions are in operation at the same time.

- Sensor technology is moving toward semiconductors. It will replace many larger, more expensive, and less accurate and unreliable macrosensors such as pressure and temperature gages. As this evolves, sensors will have calibration "curves" resident in software, minimizing initial expense and subsequent recalibration problems. Honeywell has developed a "smart transmitter" for pressure measurements.

- This transmitter is fully "communication ready" for all the non-linearities of individual sensors throughout their entire operational range of temperature and pressure. The corrections are stored digitally, and not only provide the necessary corrective factors, but extend the useful range of most sensors while reducing their cost because each need not be carefully compensated or selected.

- Machine vision systems are moving from the research laboratory to the factory floor. Many firms are marketing these systems ranging from the simple to the highly complex. Vision systems eliminate the problems of human fatigue and boredom present in most inspection jobs. It also frees humans from work in hazardous environments such as welding and painting. In other settings, it does things that human vision simply cannot do, such as see in small or restricted areas or perform precise measurements in real time.

- Vision systems can be categorized according to how images are processed. Binary systems translate each point of the image into black or white, while gray scale systems allow numerous different shades of gray to be assigned to the image points.

- 3D technology that is capable of accurately determining depth is available. A major application of this technology is in robotic seam welding. The vision system locates the seam, tracks it, and measures its width and depth. It then guides the robot in performing the weld. This technology is also applicable to a variety of material handling and manufacturing processes, including drilling, routing, painting, and loading and unloading.

- General Electric sometime ago introduced BinVision, which can acquire randomly-oriented, overlapping parts from bins or other work surfaces. This system can accomodate up to four cameras and thus work with four parts simultaneously at a typical cycle time of 5 to 20 seconds, including image processing and robot transfer. Product sizes and shapes can vary within certain limits, but the parts must be opaguqe, relatively rigid, under 17 pounds in weight, and reflective.

- Though a tremendous potential exists for the use of expert systems on the manufacturing floor, the whole concept is still in its formative stages. It is only recently that expert systems have moved from the laboratory to the day-to-day applications of the real world. An example of the use of these systems in manufacturing is the case where a CNC machine malfunctions and the computer is notified.

- The computer interrogates the data base and receives a complete list of possible alternative actions. The appropriate command is then given to the CNC machine controller to move the work to another available machine, await repair, or take another course of action. This type of decision is commonly referred to as an "active data base" decision. The logic has been stored a priori in the data base; however, it will contain the current status information on the equipment for which the decision is being made.

- An example of an expert system that is currently available for the manufacturing floor is called PICON, developed by LISP Machine Inc. of Andover, Massachusetts. It is presently in use at several Fortune 500 companies. The emphasis of the PICON package is to provide a tool for serious plant implementations. In each case some program customization is required to fit the particular plant. Also, in each case the knowledge base must be constructed. PICON reduces this time to construct knowledge base by a factor of 50 over the conventional non-AI techniques.

- Modern distributed systems bring thousands of plant measurements to a central control room, where they are available for display to an operator. An expert system, added to the distributed system, can apply some intelligence to this flow of information to provide the operator with less, but more intelligent, information concerning plant conditions.

- One example is a shutdown of an automotive plant. In most cases, it is impossible to diagnose the source of the plant shutdown quickly. A plant shutdown of an hour or so typically equates to several hundred thousand dollars of lost opportunity. A real time expert system can quickly diagnose the problem and in a matter of minutes can offer possible bypass/corrective alternates to minimize the shutdown period.

- Another application of PICON is to detect measurement integrity or process integrity problems. One example is to calculate a material balance around a process and to compare it to measured flow. A discrepancy could indicate a measurement failure or a process failure, such as a leak.

- Yet another interesting application of PICON is process startup and shutdown. These operations are done infrequently but require considerable expertise, and errors can be very costly.

- In summary, the PICON, at present, is used for:

  - Process monitoring/optimization.

  - On-line scheduling in FMS.

  - Equipment/process fault detection including quality degradation in transfer lines.

  - Intelligent robots.

  - Simulation of large and complex manufacturing and chemical processes.

  - Early warning systems for equipment faults.

F. LOGISTICS AND DATA BASE MANAGEMENT MARKET

- With the rapid fall in prices of the personal computer and increase in its performance, there is a strong trend towards a distributed processing environment both on the factory floor as well as in the engineering department. Exhibit IX-1 shows a network of computers each with its own data base which can be easily accessed through a PC.

- The PC can also access data from other data bases as well as the corporate data base. This trend is strongly influenced by IBM which is pushing to make the PC the common building block.

- As the power of the microcomputer continues to increase, the MPCS applications will increasingly utilize such processors in lieu of minicomputers. During the next five years, there will be polarization at both ends of the spectrum, the large users opting for mainframes and the mid-sized and small users opting for the micros. Some of the more powerful micros will replace the minicomputers of today.

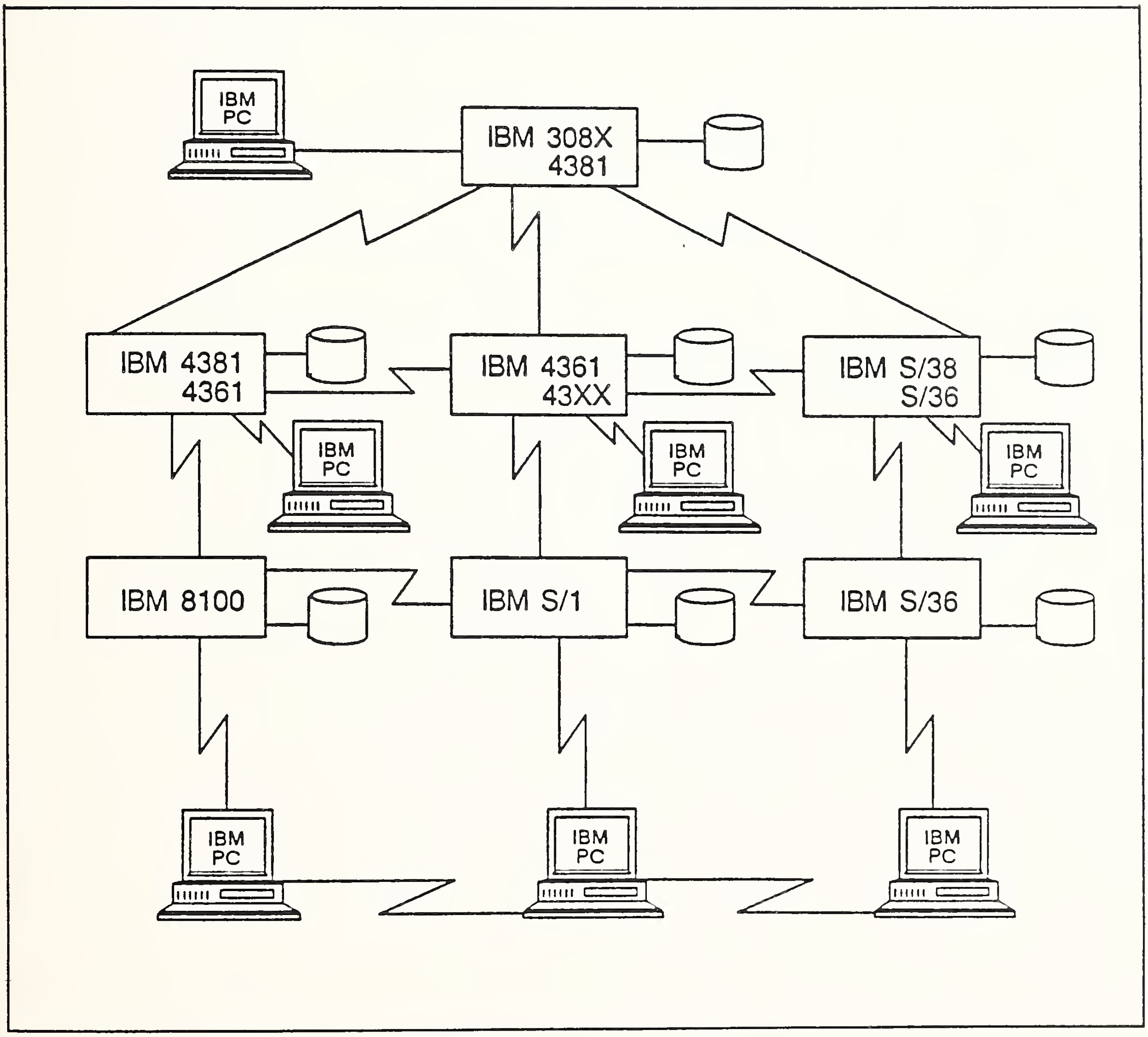
- Shop floor control systems will provide real time information to management on what is happening in the overall system. This will provide the ability for management to act upon current information instead of past information.

- Automated inspection will become increasingly controlled by microprocessors and will be real time systems, thereby increasing the software needs of this market.

- Quality control in general and automatic inspection in particular will become recognized as absolute requirements.

EXHIBIT IX-1

INTELLIGENT WORKSTATIONS



Source: IBM

G. THE FACTORY COMMUNICATIONS TECHNOLOGY

- The problem with interconnectivity today can best be described by Exhibit IX-2. There is a multitude of equipment and protocols, old and new, that are totally incompatible with each other. The strategic direction in which the solution to this problem is headed is shown in Exhibit IX-3.

- IBM's proposed strategic solution to this problem is shown in Exhibit IX-4. Here, IBM's three offerings--the Token Ring cabling system, PC LAN, and the industrial LAN--are all interconnected. This trend in the industry to seek total communication solutions is bound to continue if CIM is to be a reality.

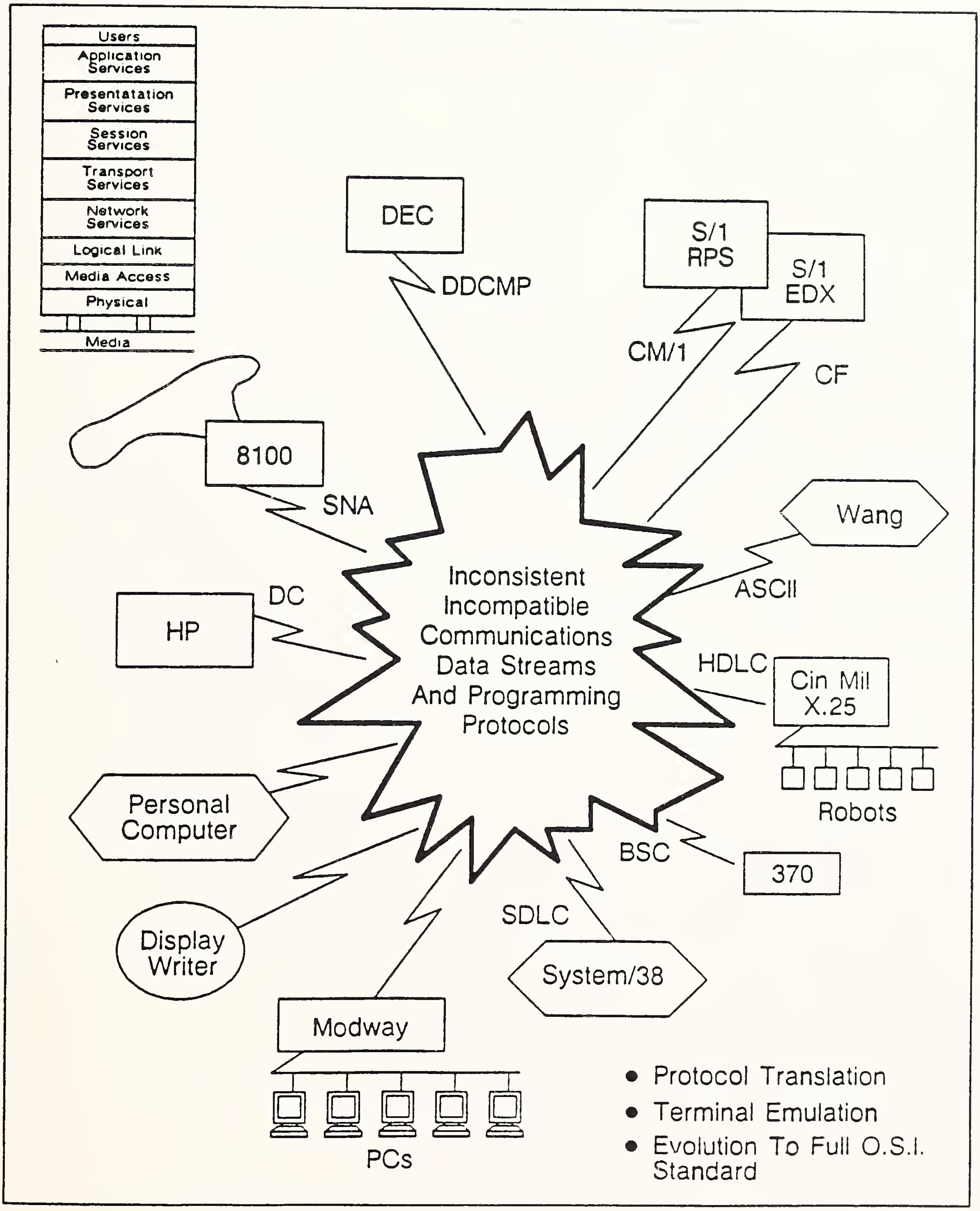
- Manufacturing automation protocol (MAP) will continue to gain momentum, but it will be some time before all seven layers are implemented. The bottom, or foundation, layers of the reference model are already well understood. These deal with the "connection" aspect of multicomputer interoperability. There are different implementations at these two levels: Ethernet, broadband token bus, and baseband token ring protocols are examples.

- The concern now is with the two uppermost layers: the presentation and application levels. It is these layers that make application processes and their associated data bases intelligible to one another at physically separate sites. There are, as yet, no complete defined and accepted standards for connection of different computer makes and types. There are, however, computer-specific solutions, such as IBM's "Advanced Program-to-Program Communications" offering based on IBM's LU 6.2 protocol, a variation of which can be expected in MAP.

- Conformance testing of vendors' MAP-compatible products to MAP specs began at ITI (Industrial Technology Institute), Ann Arbor (MI), one year ago. The trend to set up more of these centers to meet the demand for testing a proliferation of MAP compatible products is likely to continue.

EXHIBIT IX-2

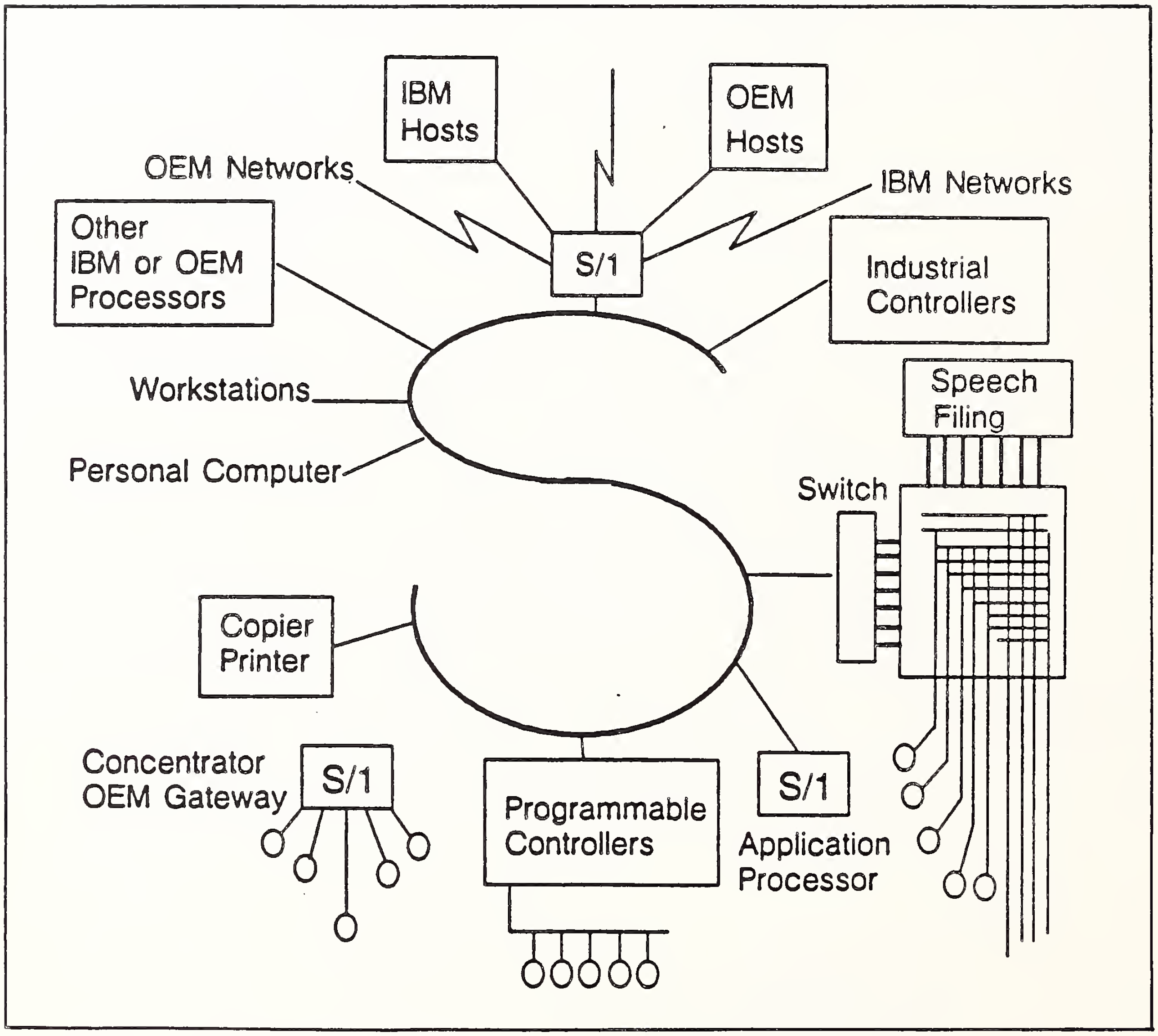
THE PROBLEM



Source: IBM

EXHIBIT IX-3

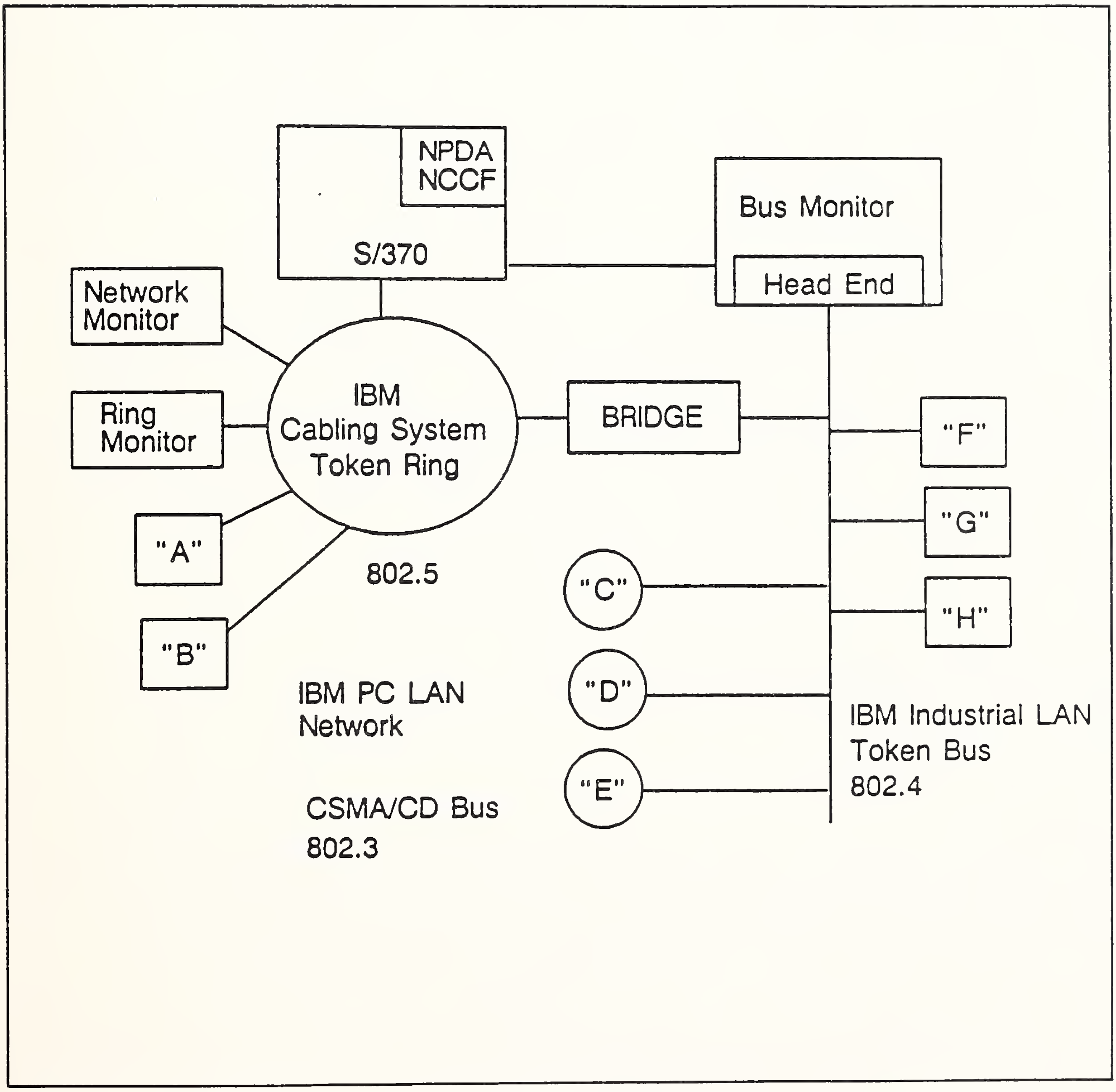
STRATEGIC DIRECTION



Source: IBM

EXHIBIT IX-4

IBM'S STRATEGIC SOLUTION



Source: IBM

- The trend toward applications software, data base, and data communication interfaces to be able to work in concert with one another will continue. Advances in process and production control combined with technological improvements in LANs have led to an increasing interest in expanding the role of LAN with particularly high interest in the video capabailities of broadband for process surveillance, plant security, and related applications. The relatively higher initial cost of the broadband systems has slowed their acceptance in this category initially, but installations will rise dramatically once the costs drop significantly.

- The high growth rate of broadband LANs will be fueled by their application as a backbone or central spine connecting the existing factory floor and work area baseband LANs.

- Fiber optic LANs are particularly well suited to manufacturing environments, but the exceptionally high cost of these systems has prevented much growth. This situation is likely to remain the same for another two years, when the lower cost and strong marketing thrust of the Japanese firms will begin to have an impact. Many American subsidiaries of Japanese firms will be used to showcase the capabilities of the fiber optic LANs in manufacturing.

H. CONCLUSIONS AND RECOMMENDATIONS

- The manufacturing market will continue as a large and attractive opportunity for vendors of computer-based products and services. However, the market is expected to change rapidly over the next few years as new applications and new technology-based solutions emerge.

- To be successful in this market, vendors must remember that the manufacturing industry sector has had a history of propensity to build versus buy.

Vendors should expect this attitude to continue to be prevalent. For software and turnkey vendors this means a strategy that includes the ability to customize the product. Such a decision must be a conscious, not opportunistic, one.

- Professional services vendors should evaluate the commercial systems integration (CSI) opportunity. Large, complex systems such as those expected in the manufacturing industry will be an enormous opportunity over the next five years. However, there will also be many opportunities for vendors to waste their time on "big deals" that never happen or whose decision cycle will be continually extended. Sales activity should be carefully monitored to determine any patterns in these procurements in order to adequately plan and deploy the sales resource.

- Sales campaigns should be structured around two central themes:

  - Cost reduction ("this sector must be competitive to survive").

  - Time savings (translated to cost and the ability to respond to user needs and to competition).

- In the manufacturing planning and control arena, there is a great deal of demand for linking these "back office" systems to the engineering and design and shop floor operations. There is also demand to replace the older back office systems with more up-to-date architectures that will allow connectivity. This is the real target for applications software developed around data base systems and is also a good starting point for participation in CIM.

- In the CAD/CAE area, there is a demand for linking CAD/CAE systems to the shop floor. In some instances this will translate into a need for an interface, in others for an integration project.

- An emerging demand is in the area of computer-aided maintenance management (CAMM). This is a high-potential opportunity for both software and turnkey vendors to develop systems for analyzing and scheduling maintenance in the plant. The predictive maintenance function is a logical enhancement to complete offerings in this area.

- The demand for process control systems solutions is widespread and has created an opportunity for professional services vendors to develop interim systems for scheduling and inventory management.

- Another need in the process control area is for LAN and Gateway systems to connect the multitude of existing peripherals located in the plant.

- The opportunities in shop floor control are predominantly for materials handling, hardware-oriented vendors. Because of this, information services vendors should consider joint venture relationships with hardware vendors who need applications software, installation support, and custom software development.

- While opportunities seem to be available for turnkey vendors, there are associated risks due to the potential demand for customization of these highly complex processes.

- The moving target labeled "CIM" presents many opportunities supported by enormous demand that will attract the very large competitors. Most information services vendors should develop strategies to partner with these very large vendors.

- Commercial Systems Integration (CSI) is expected to be a very large market. The practice of using CSI-type procurements has been employed successfully by the federal government for a number of years and would be a good model to emulate in the private sector.

- Expertise in any of the following CIM components would make an attractive potential partner for the strategy of teaming with one or more of the very large vendors.

  - Computer-aided design.

  - Group technology.

  - Manufacturing information systems and software (particularly data bases).

  - Automated materials handling systems.

  - Industrial robots, including vision systems.

  - Network integrators.

  - Expert systems and artificial intelligence vendors.

- There are also corresponding opportunities with small- to medium-sized manufacturers where the competitive pressures may be less severe.

APPENDIX A: DEFINITIONS

APPENDIX A: DEFINITIONS

A. MANUFACTURING-SPECIFIC DEFINITIONS

- Bill of Material (BOM). A listing of all subassemblies, parts, and materials that go into an assembled part (showing the quantities of each).

- CAD/CAE. The integrated applications of CAD and CAE.

- Capacity Requirements Planning. The translation of open shop orders and planned shop orders into hours of work by time period and work center.

- Computer-Aided Design (CAD). Applications of computer and graphic technology to engineering, design, and drafting.

- Computer-Aided Engineering (CAE). The use of the full range of software and systems to model, simulate, and analyze a product before construction of production models.

- Computer-Aided Maintenance Management (CAMM). Systems for analyzing and scheduling maintenance in manufacturing plants. The predictive maintenance functions would be the next logical development.

- Computer-Integrated Manufacturing (CIM). Integration of separately automated factory functions. These functions include MRP II, CAD/CAE, DSS, process control, ATE, and robotics. CIM is a philosophy of operations requiring management commitment.

- Electronic Data/Document Interchange (EDI). The use of a communictions network to transmit and receive electronic business transactions between multiple locations on an intra- or inter-company basis.

- Finite Element Analysis. As used in this report, includes all tasks involved in structural analysis using finite element methods--mesh generation, pre-processing, finite element analysis processing, and post-processing.

- Group Technology. The application of classification and coding technology to search a data base for information on similar parts and to apply this to CAD and CAM tasks.

- Material Production Schedule. An anticipated build schedule that drives the MRP systems.

- Manufacturing Resource Planning (MRPII). An extension of MRP where MRP is integrated with financial planning, a simulation capability, and other functions on a closed-loop basis for the planning of all of the resources of a manufacturing company.

- Master Production Schedule. An anticipated build schedule that drives the MRP systems.

- Nesting. Software to automatically or interactively arrange patterns for parts within stock material boundaries.

- Numerical Control (NC). Fixed sequence control of machine tool programs. (Also see DNC - Direct Numerical Control.)

- Shipments. The dollar equivalent of products shipped by a manufacturing establishment. Will usually be approximately equal to revenue.

- Shop Floor Control. Control of the progress of each customer order or stock order through the operations of its production cycle and the collection of data about actual completion status.

- Value Added. The portion of product shipment values originating in that industry; includes factors such as labor costs, depreciation, various business expenses, and energy costs. It is basically the difference between shipments and raw or input materials costs.

B. OTHER DEFINITIONS

- Data Base Management System (DBMS). A software system that allows a user to structure a data base by defining the data, its organization, and the association between data elements. It also includes a data manipulation language (for accessing, sorting, merging, etc.) and controls for concurrent use (security, request, queuing, etc.). Functions as a common interface to multiple applications.

- Distributed Data Base. A data base that is physically located at multiple sites, with each site having a part of the total data base. The sites are usually linked to a central site and have access to each other.

- Distributed Processing. Multiple computers simultaneously processing elements of a CAD task.

- Management Information System (MIS). A DP system specifically designed to provide business managers with company, financial, project, or program data.

- Networking. The interconnection and control of remotely located systems and devices over communications lines.