Computer Integrated Manufacturing Markets

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COMPUTER INTEGRATED MANUFACTURING MARKETS

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COMPUTER INTEGRATED MANUFACTURING MARKETS

EXHIBITS

I INTRODUCTION

A. PURPOSE

- The purpose of this report is to identify the Computer Integrated Manufacturing (CIM) market size and directions, the technological barriers which are inhibiting the industry's evolution and growth and to analyze the strategies which vendors may pursue to take advantage of the emerging industry standards and market opportunities.

- This report is produced by INPUT as part of the Market Analysis and Planning Service Program (MAPS).

B. METHODOLOGY

- The information for this report was obtained from a variety of sources:

  - Vendor interviews--INPUT conducted over 15 in-depth interviews with the leading vendors of factory automation systems and integrated manufacturing systems. Appendix A details the questions that were posed to marketing and product planning executives at these companies.

- User interviews--INPUT conducted interviews with large manufacturers such as GE who are spearheading the implementation of CIM technology, and 20 interviews with mid-sized companies whose factory automation plans are still in their inception.

- Consultants--the opinion of INPUT's own specialists and outside manufacturing consultants were considered.

- Secondary sources--INPUT's library of periodicals was used for background information.

C. SCOPE

- The scope of this report is limited to a discussion of the evolving manufacturing integration technologies and information services vendor strategies. Although Chapter III describes standalone factory automation product markets to clarify the components of CIM, the analytical emphasis is on the new integrated offerings emerging from these domains, rather than on the separate "islands of automation" themselves.

II EXECUTIVE SUMMARY

- This executive summary is designed in a presentation format in order to:
  - Help the busy reader quickly review key research findings.
  - Provide a ready-to-go executive presentation, complete with script, to facilitate group communication.
- The key points of the entire report are summarized in Exhibits II-1 through II-6. On the left-hand page facing each exhibit is a script explaining its contents.

A. COMPUTER INTEGRATED MANUFACTURING DEFINED

- Computer Integrated Manufacturing (CIM) is both an integration technology and a production philosophy. The philosophy is aimed at increasing the efficiency, quality, and flexibility of manufacturing operations through the integration of separately automated factory functions.

- These include: manufacturing resource planning (MRP II systems), computer aided design and engineering (CAD/CAM/CAE systems), process control and quality testing (programmable/numerical controllers, ATE), machine tooling and assembly (robotics), and decision support systems (PCs/micro-mainframe links).

- The major trend accelerating the demand for CIM is the United States' declining share of worldwide manufacturing markets and the commitment on the part of major domestic manufacturers to regain lost productivity through improved production processes which require functional and technological integration.

- "Just in time" inventory control and production systems are representative of the new type of manufacturing processes U.S. companies are employing to reduce overhead, improve asset management, and quality control. "Just in time" requires flexible automation and new product/process definitions to facilitate communications and data exchange. This entails CAD/CAM and MRP II data bases which utilize group technology (a coding and classification scheme), local area networks that interconnect the office and shop floor, VLSI circuitry, and other technologies.

- "Just in time" and Computer Integrated Manufacturing techniques can be implemented effectively by both process and discrete manufacturers. However, the process technology is most suited to job shop environments where repetitive manufacturing already exists. Exhibit II-1 summarizes the main functional and technological components of CIM.

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COMPUTER INTEGRATED MANUFACTURING DEFINED

FUNCTIONAL INTEGRATION	TECHNICAL INTEGRATION
Manufacturing Resource Planning	MRPII Systems
Computer Aided Design and Engineering	CAD/CAM Systems
Process Controls	Programmable/Numerical Controllers/ATE
Machine Tools	Robotics
Decision Support	Microcomputers, Micro/Mainframe Links

B. SIZE AND STATUS OF THE CIM MARKET: INTEGRATING ISLANDS OF AUTOMATION

- INPUT estimates the size of the total market for factory automation systems as $9.2 billion, and that only about 5% or $485 million of those expenditures are specifically related to CIM products. Most of these expenditures were for the computer aided manufacturing (CAM) portion of the CAD/CAM market, selected MRP II modules, and local area networks (LAN).

- A major barrier to the growth of CIM markets is the lack of compatibility that exists among available hardware and software systems and the desire of most manufacturers to preserve their investment in their installed systems. The absence of communication and data base/data definition standards means that comprehensive CIM solutions cannot be packaged and marketed on a broad commercial basis by any one vendor at this time.

- The current CIM is comprised of partial solutions being offered by vendors who have either:

  - Interfaced their system with other manufacturing technologies on a customized basis.

  - Integrated a broad array of manufacturing functions into their product data base (e.g., CAD vendors recent forays into CAM).

  - Physically linked shop floor and engineering systems through point-to-point telecommunications.

- Exhibit II-2 provides the market segment penetration achieved by CIM and the 1984 market size in millions of dollars.

SIZE AND STATUS OF THE CIM MARKET: INTEGRATING ISLANDS OF AUTOMATION

MARKET SEGMENT	PERCENT OF CIM PENETRATION	1984 VALUE ($ Millions)
CAD/CAM/CAE	14%	$350
MRP II	5	73
Business Applications		
- Cross Industry	3	23
- Vertical	5	28
LANs	5	12

(Not Integrated Yet: Process Control and Robotics)

C. THE STRUGGLE FOR COMMUNICATION STANDARDS: MAP TAKES THE LEAD

- The future direction of Computer Integrated Manufacturing will be dramatically influenced by MAP. MAP is not a product, it is a collection of standard network protocols being proposed and lobbied for by a General Motors task group founded in 1981 for the sole purpose of establishing telecommunications standards which would facilitate low-cost networking. Exhibit II-3 defines MAP's current status and significance.

- General Motors will rely on the task force recommendations to interconnect the 200,000 intelligent devices it expects to have operating its plants by 1990. This is an integral part of project Saturn, the company-wide network being developed by GM's CDS subsidiary.

- The MAP protocols which have been specified so far are limited to physical interconnection and transmission issues (layers one to two of the Open Systems Interconnection, or OSI, reference model) and call for broadband token bus network access. There are only two network products available which conform to these standards: Concord Data's Token/Net and Allen Bradley's Vistanet. Ethernet networks are not MAP compliant.

- General Motors and the MAP committee have set a four year timetable in which it expects to complete its specifications for higher level communications protocols (layers four to seven of the OSI model) relating to data base and data definition software. These standards will be much more difficult to establish, however.

- The significance of MAP is that it is backed by a large body of manufacturers (over 150) who have adopted it as their standard for manufacturing telecommunications and that it is a dynamic standard; it is already expanding to include the particular networking needs of robotics and numerical control equipment, via local area networks.

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THE STRUGGLE FOR COMMUNICATION STANDARDS: MAP TAKES THE LEAD

- **MAP Status**
  - **ISO Compatible**
  - **Broadband Token-Bus**
  - **Originally a General Motors Task Force**
  - **Standard for Layers 1 and 2 of OSI**
- **MAP Is Significant**
  - **Backed by 150 Manufacturers**
  - **Direction for Manufacturing Telecommunications**
  - **Will Encompass Robotics and Numerical Control**

D. VENDOR APPROACHES: LANs STRESSED

- Well established vendors such as Digital Equipment Corporation and start-up ventures such as Concord Data Systems and Industrial Networking Incorporated (GE/Ungermann Bass) are highlighting the telecommunications aspects of CIM (see INPUT's forecast for CIM-related LAN sales in Exhibit II-4).

- The LANs these vendors are now designing (MAP- or Ethernet-based) are unique insofar as they permit messages to be automatically transferred from a minicomputer host to shop floor programmable controllers and machine tools.

- In the past this type of data exchange was handled either manually or via point-to-point communications. The increased carrying capacity and speed of shop floor LANs puts vendors of these networks at the center of the CIM stage.

- INPUT estimates growth in the manufacturing portion of the LAN market will jump from $12 million to $265 million over the next five years.

- Farsighted LAN vendors are designing MAP-based networks which incorporate VLSI integrated circuitry (with attendant reductions in cost) as well as interconnections to token ring and Ethernet systems.

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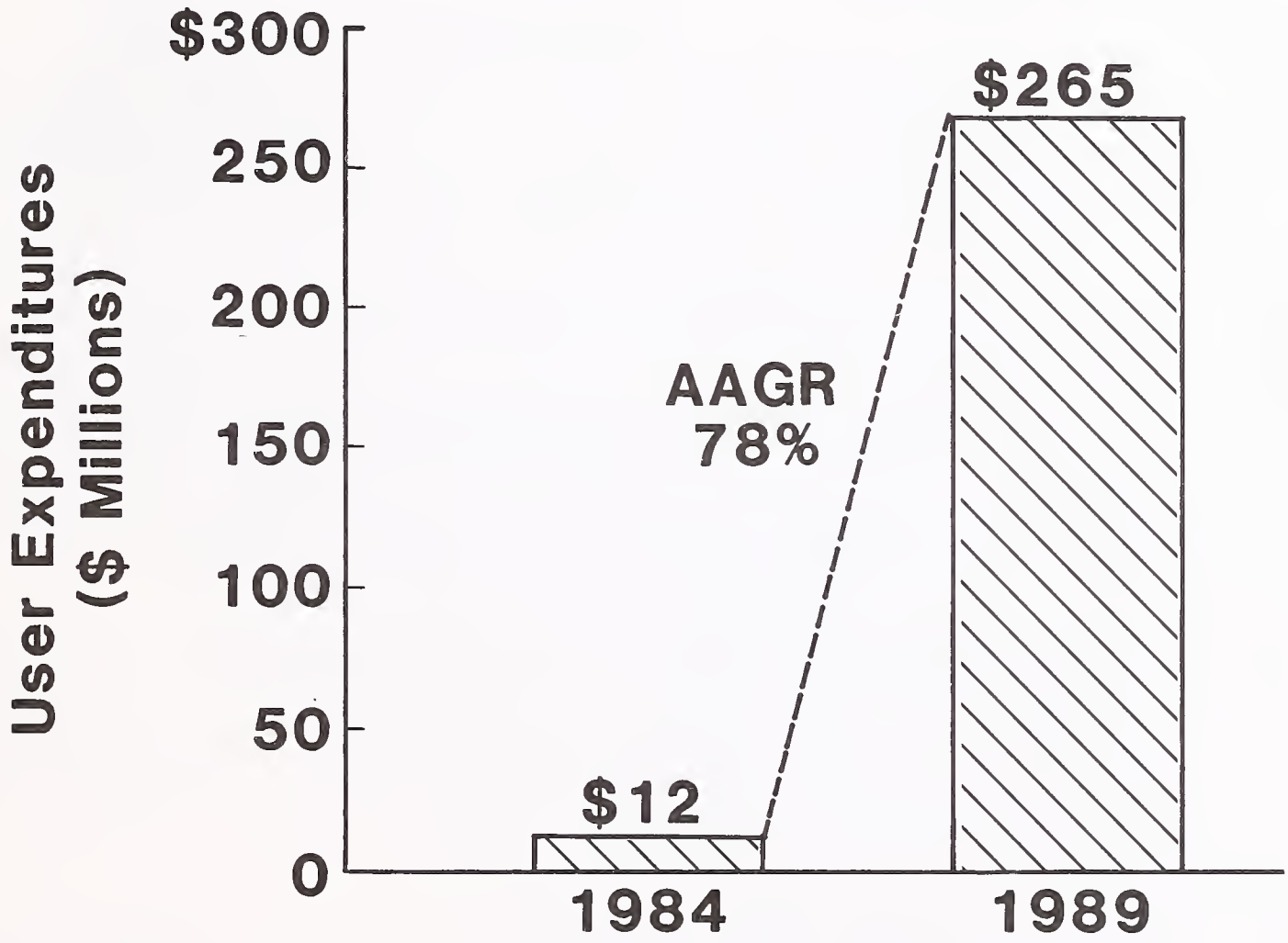
VENDOR APPROACHES: LANs STRESSED



E. TOTAL SOLUTION VENDORS

- Major vendors such as IBM, GE, and McDonnell Douglas Automation Corporation are positioning themselves as total solution suppliers of Computer Integrated Manufacturing solutions by amassing the key standalone technologies needed by the manufacturing industry, as well as by developing the necessary software interfaces.

- IBM and GE/Ungermann Bass (INI) have MAP-based, token access networks under development. INI's LAN should be out by the end of 1985; IBM's is not expected before 1986.

- Of all the total-solution vendors, IBM has the most potent factory automation effort underway. The company has the dominant share of the CAD/CAM and MRPII market (24% and 40% respectively) and is gearing up to expand its presence in robotics. The IBM 9000, PC AT, and 5080 graphics workstation further consolidate IBM's position from a hardware standpoint.

- The primary strength of the total solution strategy is its comprehensiveness (See Exhibit II-5). Manufacturers would generally prefer to buy packaged CIM from a single reputable vendor if possible. However, this strategy requires a huge capital investment which few suppliers can afford.

- INPUT believes that IBM will dominate the market for factory system and integrated applications. However, IBM is technologically weak in certain areas (particularly in terms of its integrated offerings) and badly in need of third-party support in others. CIM niches can, therefore, be exploited by vendors who have superior software products and network solutions, or complementary application strategies.

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TOTAL SOLUTION VENDORS

- Major Vendors:
  - IBM
  - General Electric
  - McDonnell Douglas
- Total Solution Strategy:
  - Comprehensiveness
  - Sole Source Supply
  - Huge Marketing Investment

F. THE CIM VENDOR R&D DILEMMA

- There are four strategic product directions which independent CIM vendors can pursue as the MAP protocols evolve (seeExhibit II-6). They may:

  - Build network technology that is structured around the existing MAP protocols and commit to research and development in anticipation of forthcoming MAP specifications for higher level protocols.

  - Design software solutions which move beyond the communications issue to facilitate the intercomputer dialogue through common data definitions, data base recoding/reclassification schemes, and/or application interfaces.

  - Design customized network technology that is compatible or different to MAP protocols, but which takes advantage of the immediate need for shop floor integration (and has the potential to set its own standard).

- Although all of the above options entail risks, INPUT recommends that CIM vendors work closely with the MAP committee, try to anticipate future protocol specifications, and direct their product strategies to assure compatibility.

- INPUT does not recommend that vendors wait for MAP to fully evolve before extending their product strategies, given the actual length of time it may take for higher level protocols to be established, and the contribution individual vendors can make to MAP through their research and development work.

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THE CIM VENDOR R&D DILEMMA

- Options
  - Develop MAP-Based Network Technology?
  - Develop Proprietary Network Technology?
  - Develop Custom Interfaces?
  - Abort CIM Projects Until Higher Level Protocols Are Specified?

III CIM COMPONENT MARKETS

- A brief synopsis of the standalone factory automation product markets are included in this chapter to place the components of CIM in perspective.

A. THE MRP II MARKET—TRENDS

- Manufacturing resource planning software addresses the plant manager's need for systems to plan and track production schedules. The technology has evolved from a simple method of material requirements planning in the 1970s (MRP I) to a comprehensive master manufacturing ressource planning production schedule (MRP II) monitoring raw materials, work in process, finished goods, manpower and equipment capacity planning, and vendor schedules.

- Trends in the performance requirements of MRP II systems include real time capabilities, integration with standard DBMS packages, micro-based modules, and transportability.

- From a CIM perspective, "just in time" manufacturing, which strives for minimal inventory levels and short production runs, could be antagonistic to the logic of traditional MRP II systems, which are designed to keep track of large amounts of inventory and work in process. However, farsighted MRP II vendors are adapting their systems by developing simpler planning modules and interfacing their data base structures with design/engineering and process

control functions. In this latter context, an MRP II data base would expand to become a centralized factory management information system.

- As shown in Exhibit III-1, INPUT estimates that the market for MRP II systems will grow from $1.5 billion in 1984 to $4.2 billion by 1989--at an average annual rate of 33% per year. Leading vendors in the MRP II market include IBM, ASK Computers, Hewlett-Packard, Comserv, NCA Corporation, Cullinet Software, and Management Science America. IBM and ASK Computers have the first and second largest shares of the market, respectively.

B. THE CAD/CAM/CAE MARKET AND TRENDS

- Computer-aided design, manufacturing, and engineering systems have emerged as the major engineering productivity tool of the 1980s, facilitating productivity improvements of 3.6 to 1 on average.

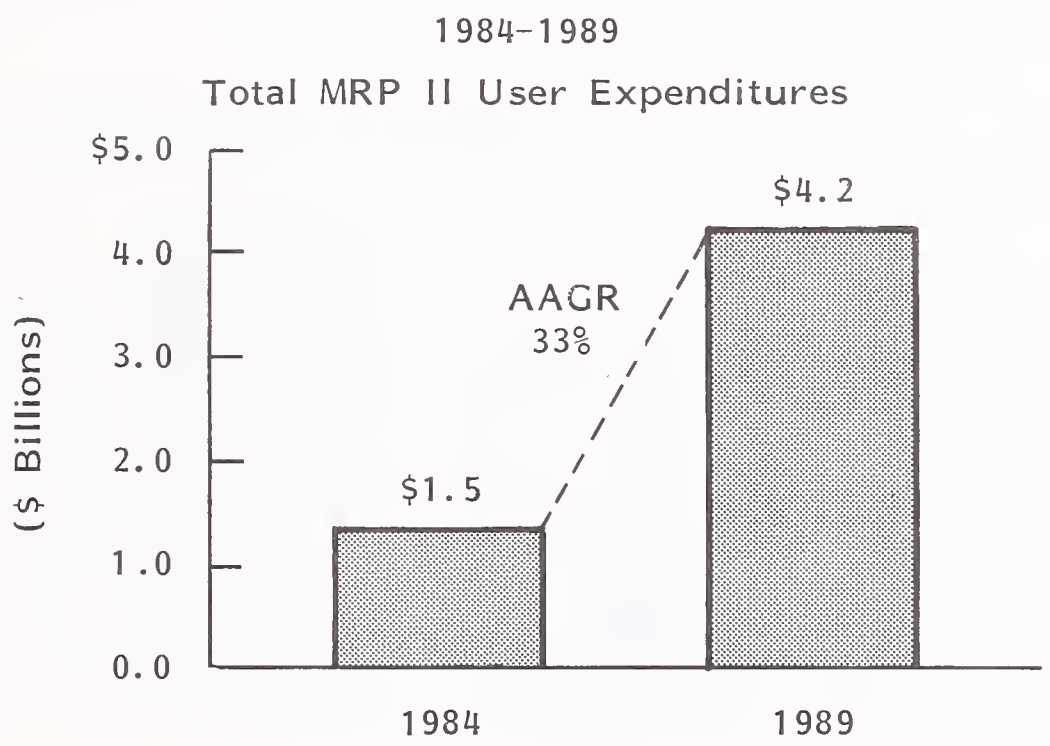
- CAD/CAM applications can be divided into seven separate functional areas: design and analysis (concept design), drafting and documentation (assembly drawings), production programming (location/parts verification), manufacturing engineering (routing), industrial engineering (machine time standards), facilities engineering (plant layout), and reliability engineering (quality control).

- Since their introduction in 1969, CAD/CAM systems have mostly been used for the first two functions (CAD). However, in a CIM context, systems will be increasingly employed to manage the physical implementation process (CAM) as well as to facilitate of the product design (CAE).

- As shown in Exhibit III-2, the market for CAD/CAM systems is projected to grow from $2.5 billion in 1984 to $9.5 billion in 1989, at an average annual

EXHIBIT III-1

MRP II USER EXPENDITURES AND
VENDOR MARKET SHARE

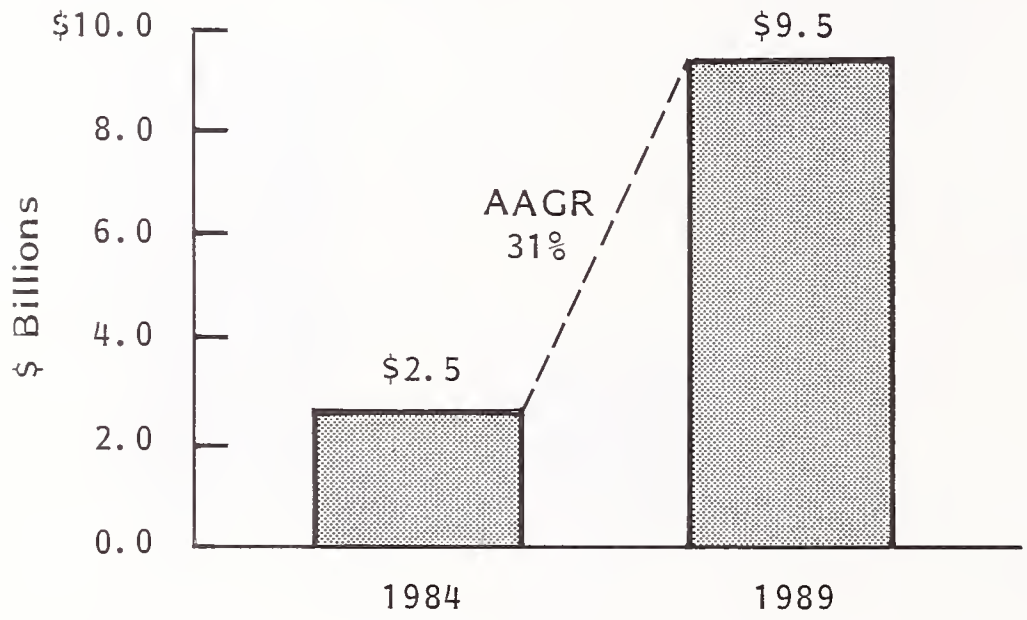


($ MILLIONS)

VENDOR	TOTAL REVENUES	MRP II PRODUCT REVENUES	MARKET SHARE
IBM	$42,000.0	$585.0	40.0%
ASK Computers	76.7	72.0	5.0
ComServ	24.0	18.5	1.3
NCA Corporation	24.0	15.0	1.0
Cullinet	131.4	11.0	0.8
MSA	141.8	8.0	0.5
Hewlett-Packard	N/A	N/A	N/A

EXHIBIT III-2

CAD/CAM TOTAL USER EXPENDITURES AND
LEADING VENDOR MARKET SHARES



1984 Market Share
U.S.A. Only

IBM	24%
Computervision	10
Intergraph	12
CALMA	8
McAUTO	4

growth rate of 31% per year. Leading CAD/CAM/CAE vendors include IBM, Computervision, Integraph, CALMA (GE), and McDonnell Douglas. IBM has the largest share of the market, accounting for about 24% of total user expenditures.

C. MATERIAL HANDLING SYSTEMS

- Material handling systems facilitate the flow of material within a manufacturing operation from design through assembly. They are engineered to move material with fewer handling of steps over shorter distances using less expensive means. Automatic storage and retrieval systems, bar code/automatic scanning devices, and carousels are primary examples of material handling products. Primary vendors in this market sector include Litton Industries, Jervis, Webb, and Republic Steel.

- In a CIM environment, material handling systems will be needed that are smaller, more flexible, and able to accommodate lower inventory levels and compact lot sizes.

D. ROBOTICS

- Robots are programmable, multifunction machines that facilitate manufacturing assembly. Robots are used primarily for routine and repetitive jobs and can be categorized into four functional groups:

  - Arc welding.

  - Finishing and coating.

- Small parts handling.

- Vision integrated.

- Sales of small parts-handling and vision-integrated robots are growing above the industry average.

- Although the long-term outlook for the robotics industry remains favorable--sales in early years did not meet expectations, reflecting resistance on the part of users to the costly, unfamiliar product technology as well as the weak economy.

  - U.S. suppliers shipped $190 million of robotics equipment in 1982, $240 million in 1983, approximately $375 million in 1984, and are projected to generate revenues of $900 million in 1989. In 1984 only one vendor was profitable.

- The most important trend in the robotics industry as it relates to CIM is the move to make robots more intelligent and adaptable to a flexible factory environment. This work will be demonstrated in primarily three areas:

  - Communication with the environment: this entails increased sensory perception, particularly visual perception.

  - Communication with other machines: this entails networking.

  - Communication with people: this will require "natural language" front-ends and other artificial intelligence applications.

- Primary robotics suppliers include GM Fanuc, Cincinnati Milacron, Westinghouse Unimation, Automatix, Devilbiss, Asea Inc, IBM, and GE.

- General Motors' recent investment in four vision companies, Automatix, Diffracto (privately held), Robotic Vision Systems, and View Engineering (privately held), highlights the importance of machine intelligence and gives substantial clout to the relatively unknown private concerns. INPUT's market share estimates for U.S. based robot suppliers are listed in Exhibit III-3.

E. PROCESS CONTROL: NUMERICAL CONTROLLERS/TEST EQUIPMENT

- Process control covers a broad spectrum of factory tools which are used to monitor and adjust a production process to assure that specifications are met.

- Numerical controllers, programmable controllers, embedded microcomputers, automatic test equipment, can all be categorized as process control devices.

- Programmable controllers are the predecessors of numerical controllers performing engineering diagnostics by accepting input from sensor devices such as push buttons and relaying output to devices such as stepper motors.

- In a CIM environment, programmable controllers will be fed by sensors with embedded microprocessor boards which can collect, recode, analyze, and transmit data regarding manufacturing conditions.

- Primary U.S. suppliers of numerical control tools are Litton Industries and Bendix. Leading U.S. suppliers of programmable controllers are Allen Bradley, Square D, Gould Modican, Bailey Controls, Texas Instruments, Foxboro, and Westinghouse. As Exhibit III-4 reveals, INPUT estimates the combined product markets will grow to $8.0 billion by 1989.

- Automatic testing equipment is a quality control system used to measure the performance of integrated circuits and electronic assemblies such as printed circuit boards. ATE equipment is now being used to test off-line components as well as assembly parts.

EXHIBIT III-3

ESTIMATED MARKET SHARE OF TEN LEADING U.S. BASED ROBOTICS SUPPLIERS

VENDOR	1984
GM Fanuc	20%
Cincinnati Milacron	17
Westinghouse/Unimation	10
Automatix	9
Devilbiss	6
ASEA	5
IBM	5
General Electric	4
Prab	4
Intellidex	3

1984 total Market Size: $375 Million

EXHIBIT III-4

1984-1989 TOTAL USER EXPENDITURES FOR PROCESS CONTROL MATERIAL HANDLING AND ROBOTICS
($ Millions)

	1984	1989	AAGR
Process Control			
Numerical	$ 900	$1,800	15%
Programmable	600	2,000	27
ATE	1,200	4,000	27
Total	$2,700	$8,000	24%
Material Handling	780	1,600	15
Robots	375	900	19

- The leading U.S. suppliers of ATE systems include Hewlett Packard and Tektronix. INPUT expects the ATE market to grow from $1.2 billion in 1984 to $4.0 billion by 1989. Exhibit III-4 displays INPUT's total user expenditure estimates for process control, material handling, and robotics markets between 1984 and 1989.

F. DECISION SUPPORT SYSTEMS

- Decision support systems generally refer to computer programs and tools which allow the collection, synthesis, analysis, and reporting of information in such a way that informed decisions may be rendered based on suggested trends or data correlations. Such systems usually comprise an inquiry language facility, a data base, and a problem processor.

- In a CIM context, DSS systems can be linked to a mainframe DBMS that maintains, updates, and distributes information relating to all aspects of the manufacturing process. Existing manufacturing DSS systems are usually not so comprehensive and are rarely linked to proprietary MRP II and CAD/CAM data bases.

- The available DSS products are being marketed by MRP II and CAD/CAM vendors and are included in INPUT's estimates of these product markets.

IV NEED FOR CIM

A. THE DOMESTIC MANUFACTURERS DEMISE

- The demand for CIM is not simply a technological progression, but rather an outgrowth of fundamental economic changes which have caused domestic manufacturers to experiment with new manufacturing process theories and the technologies necessary for their implementation.

- The economic impetus for CIM relates to the steadily declining position of the U.S. in worldwide manufacturing markets. The rate of increase in the productivity of the U.S. manufacturing sector collapsed from a positive 3.5% in the mid-60s to negative growth in 1979, 1980, and 1982.

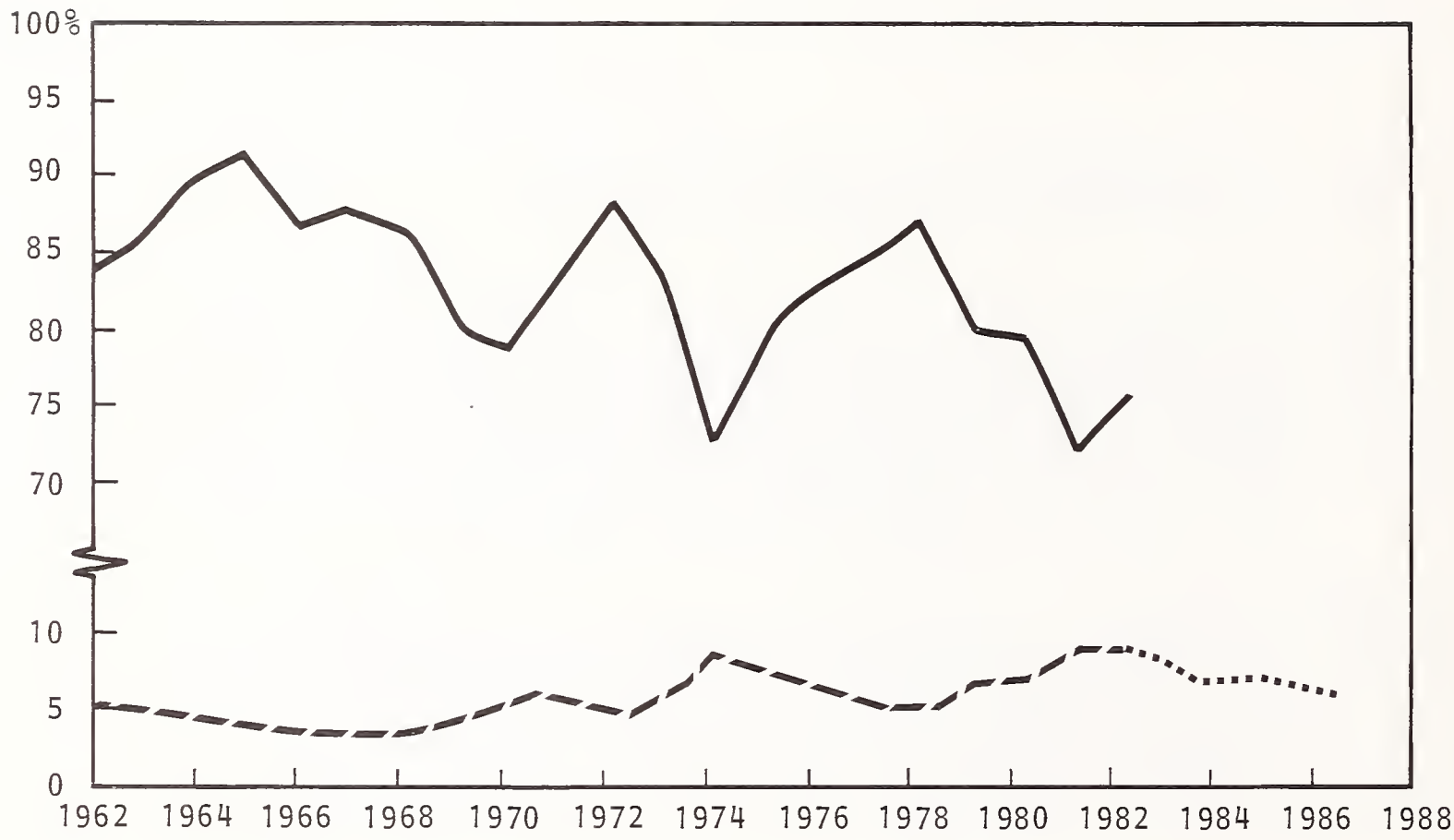
- While most dramatic in the steel, automobile, consumer electronics, apparel, and machine tool industries, the decline is also reflected in measures that cut across the overall economy.

- For example, between 1966 and 1984 the U.S. merchandise trade balance deteriorated both in absolute terms and as a percentage of GNP from +1% to -2%. The manufacturing capacity utilization rate also dropped from 92% to 75% (see Exhibit IV-1).

- The United States' chief competition is coming from traditional European rivals and, more recently, from five East Asian nations, including Japan, Taiwan, South Korea, Hong Kong, and Singapore.

EXHIBIT IV-1

U.S. MANUFACTURING CAPACITY UTILIZATION RATE
AND TOTAL UNEMPLOYMENT RATE (1963-1983)



Manufacturing Capacity Utilzation Rate (Federal Reserve Series)

Total Unemployment Rate

Council of Economic Advisers Forecast

- Recent interviews with managers of competitively successful technology-based German and Japanese firms have identified a strong pattern of commitment to the development of advanced process technology. By contrast, U.S. manufacturers over the past decade have failed to scrutinize the competitive aspects of their production processes both on a managerial and technological level. In fact, U.S. capital investment as a percentage of GNP was less than 20% that of France and West Germany during the late 1970s, and less than 200% of Japan's.

- Led by domestic manufacturers such as General Motors, North American business leaders are now responding to the dilemma by committing to improved production methods which require functional and technological integration.

- The Japanese "just in time" inventory and production system (also called stockless production of Kanban) is representative of the new manufacturing philosophy American companies are attempting to employ. KANBAN refers specifically to the version of the system pioneered by Toyota and companies of the Toyota group during the past 25 years.

- Although it is generally recognized that KANBAN must be adapted to work effectively in the more complex American culture, the basic tenets of the asset management theory are being adopted.

- Exhibit IV-2 demonstrates the results of "just in time" production as practiced by several of Japan's "Class B" manufacturers (Toyota has identified 10 Japanese companies as being "Class A" in the practice of KANBAN and 30 or 40 other companies as "Class B"). The exhibit also details Toyota's productivity (a Class A manufacturer) in hood and fender press plants relative to the U.S.

EXHIBIT IV-2

RESULTS OF STOCKLESS PRODUCTION IN JAPAN

Class "B" Companies

COMPANY	DURATION OF PROGRAM	INVENTORY REDUCTION (Percent of Original Value)	THROUGHPUT TIME REDUCTION (Percent of Original Value)	LABOR PRODUCTIVITY (Percent Increase)
A	3 Years	45%	40%	50%
B	3 Years	16	20	80
C	4 Years	30	25	60
D	2 Years	20	50	50

Toyota Motor Company Comparisons (1978)

Productivity Comparisons in Hood and Fendor Press Plants

	TOYOTA	AMERICAN PLANT	SWEDISH PLANT	WEST GERMAN PLANT
Set up Times (Hours)	0.2	6.0	4.0	4.0
Setups Per Day	3.0	1.0	-	0.5
Lot Size	1 Day Use	10 Day Use	1 Month Use	NA

- A more specific explanation of the differences between "just in time" production and traditional methods, as well as the technological developments it requires, are further described in the next two sections.

B. REVITALIZING PRODUCTION: TRADITIONAL VERSUS "JUST IN TIME" MANUFACTURING

- Traditional process technology has divided people, equipment, and procedures into workflow patterns of five generic types: project, job shop, batch, assembly, and continuous flow.

- A job shop represents the end of the continuum where processes are organized to produce more customized goods. The small batches of high volume products produced by a customized circuit board manufacturer serves as an example.

- To reduce the marginal cost of production, work flow patterns in a job shop send different orders through a set of common operations and then to other less standard tasks. Consequently, a job shop typically requires large amounts of in-process inventory, making any specific job or bottleneck difficult to locate.

- At the other end of the spectrum is the continous flow process used by oil refineries, high volume chemical plants, and food processing operations. Production in this environment is highly standardized, requiring only a few inputs and material flow that is predetermined and continuous rather than discrete. Although process manufacturers are usually efficient, they use dedicated high technology equipment which is programmed to the assembly sequence causing the production cycle to be relatively inflexible.

- Historically, as firms have moved toward more standardized process technologies, their distinguishing capabilities have shifted from flexibility and customization (job shop) to product reliability, predictability, and cost (flow). The nature of these operational differences is further outlined in Exhibit IV-3.

- The primary aim of a "just in time" production process is to build an operation where the trade off between quality/flexibility and efficiency/reliability need not be made. Just in time production aims to develop a factory which is as cost efficient as a flow operation but also offers the flexibility of work flow patterns in a job shop.

- "Just in time" manufacturing processes can, therefore, result in performance improvements for both job shop and process manufacturers. However, it is most suited to job shop environments where repetitive manufacturing already exists.

C. THE IMPLICATIONS FOR HIGH TECHNOLOGY APPLICATIONS

- Implementation of just in time (KANBAN) processes that will allow both flexible and efficient operations require profound structural changes within manufacturing organizations relating to the following:

  - Inventory scheduling and planning.
  - Run rates and set-up times.
  - Material handling.
  - Equipment and plant layout.
  - Intra- and inter-company communications.

EXHIBIT IV-3

DIFFERENCES BETWEEN JOB SHOP AND FLOW OPERATIONS

CHARACTERISTICS	JOB SHOP	FLOW
Material Requirements	Difficult to Predict	Very Predictable
Work in Process	Large	Very Small
Size of Facility	Small	Large
Process Flow	Few Dominant Flow Patterns	Clear + Inflexible Patterns
Type of Equipment	Mostly General Purpose	Specialized Dedicated High Technology Equipment
Bottlenecks	Shifting Frequently	Known and Stationary
Set-Ups	Frequent	Rare and Expensive
Speed of Process (Unit/Time Period)	Slow	Very Fast
Run Lengths	Short	Long

- Exhibit IV-4 summarizes the technological implications which are further discussed below.

1. INVENTORY PLANNING

- The KANBAN process designs products that the customer wants only at the rate the customer wants them: "to order" rather than "to stock," "just in time" rather than "just in case."

- The strategy eliminates costly inventories as well as the need for complex production planning since lead times become shorter. The implications of this methodology relate most specifically to manufacturing resource planning (MRP II systems).

2. RUN RATES AND SET UPS

- Producing only at the market rate of demand and without producing inventory, means making parts and products in small quantities. The strategy requires flexible equipment that can be programmed to switch instantaneously from work on one part to work on another. Flexible set ups also require that the physical process of changing tools and attachments require little time and that plant layout accommodate a straight line flow of physical material to final assembly as quickly as possible.

- Flexible automation presupposes data base designs that will permit data independence and information exchange between distinct applications--particularly engineering and production. "Group technology" coding for CAD/CAM and MRP II data bases, as well as CAD/CAM shop floor interfaces are relevant to this objective.

EXHIBIT IV-4

"JUST IN TIME" OPERATIONAL AND TECHNOLOGICAL REQUIREMENTS

JUST-IN-TIME PROCESS REQUIREMENT	RELATED TECHNOLOGICAL REQUIREMENT
• Minimal Inventory Levels	• Simpler MRPII Planning Modules
• Straight Line Workflow Flexible Set-Ups and Run Rates	• "Flexible Manufacturing Systems" • Relational DBMS and Group Technology • CAD/CAM, Shop Floor Integration
• Economic Material Transport for Smaller lot Sizes	• Lighter, More Flexible Automation Storage and Retrieval Systems
• Real-Time Communications Between Work Stations Vendors and Suppliers	• Shop Floor LANS with Gateways to Office LANS • ULSI Technology • Common Data Base/Data Definition Software

3. MATERIAL HANDLING

- In a stockless environment, parts usually leave the last operation of a supplier one at a time and enter the first operation of the user one at a time. The approach assumes that more economical transport of material is feasible--a suggestion that is most applicable to automatic storage and retrieval vendors.

4. COMMUNICATION

- A priority for a system as tightly linked as stockless production is skilled teamwork and instant communication.

- The purpose is not only to establish connections between planning and design functions or design and shop floor work centers, but rather to have the entire organization function as a unified team so that throughput, asset turnover, and quality controls are optimized.

  - In Japan, "visibility boards" originally provided information to help coordinate the efforts of linked work centers.

  - Domestically the technical issue of how to connect separately automated factory functions is a major CIM barrier and is directly linked to the relative success of individual (and frequently incompatible) vendors in any one area.

  - The typical manufacturer today could be using IBM hardware data base management systems for business applications, DEC/VAX equipment for CAD/CAM, Data General microcomputers for shop floor data collection, and Wang for process control and office automation.

- Although two or more suppliers of factory automation equipment may unite to form a customized interface (as in fact is happening), these vendor-specific solutions cannot be broadly applied and are very costly.

V THE COMMUNICATIONS BARRIERS TO CIM AND THE EMERGING STANDARDS

A. THE OSI MODEL

- The end-user need for telecommunication standards which would not only physically link distinct systems but also logically hide the effects of incompatible data structures, has given birth to several organizations committed to setting national communications standards. These organizations include the American National Standards Institute (ANSI), the International Standards Organization (ISO), the International Telephone and Telegraph Consultative Committee (ITTCC), the Electronic Industry Association (EIA), and the Computer Business Equipment Manufacturers Association (CSMA).

- In 1977, the International Standards Organization spearheaded the national effort for inter-vendor communications by proposing a seven-layer reference model for network architecture. The model is referred to as Open Systems Interconnection (OSI) and has been accepted by most designers as a basis for network development. The OSI sorts the multifarious functions of a network into seven layers, each representing a group of related data processing and communications steps that can be carried out in a standard way to support all applications.

- The set of functions assigned various steps of the communications ladder range from physical and data link (steps one and two) to the way particular

applications such as file transfer (step seven) are handled. Two networks that implement approved protocols at all layers can theoretically exchange information transparently across different syntaxes.

- Although progress with the model has been made, existing networks only supply protocols for the lower two or three layers of the seven. In addition, the committee that defined the lower level standards, the Institute for Electrical and Electronic Engineers (IEEE 802), allowed for more than one way to build a network depending on its purpose. The IEEE 802 gave layer one distinct protocols for broadbased and baseband networks, and for collision detection (802.3), token bus (802.4), and token ring access methods. The operative difference between token passing and collision detection is that token passing guarantees access to the network in a limited amount of time.

- Ethernet, which was a joint venture between DEC, XEROX, and Intel in 1980 was chosen by the IEEE as the basis for the layer one CSMA/collision detection physical link. This meant that the 18,000 DECnet nodes which Digital Equipment had installed at factory sites, as well as the Ethernet Installation of other LAN vendors, were already in conformance with protocols adopted for OSI's first two layers.

- However, General Motor's recent stand that token bus protocols represent the suitable network technology for automated factories rather than CSMA/collision detection means that the direction of manufacturing telecommunication is likely to move away from Ethernet toward token access LAN technology.

B. GENERAL MOTORS AND MAP

- In 1981, General Motors independently fueled the clamor for OSI standards by appointing a task force to select an existing or emerging standard protocol for each of the OSI seven layers. GM's involvement was designed to identify a

more cost effective way of connecting the 200,000 intelligent devices in automating its manufacturing plants by 1990. A study of appropriate requests for new automation revealed that up to 50% of the costs were related to communications and that a large portion of this went toward system software and hardware interfaces to connect proprietary systems.

- The proposed solution which emerges from the task force is called MAP (manufacturing applications protocol). Since its introduction in early 1984, the backing for MAP has been swift. The MAP user group grew in four meetings to more than 450 people representing 150 companies, including such potent names as McDonnell Douglas, Boeing, the U.S. Air Force, Eastman Kodak, John Deere, DuPont, GM, and Ford. Like GM, these companies are "actively soliciting" all their vendors to implement MAP protocols in their products.

- With regard to the current specifications, GM initially concentrated on IEEE project 802 and the emerging ISO/NBS (National Bureau of Standards) specifications. It is now detailing an encoding protocol that operates in layer seven of the OSI and a standard which would allow a MAP model to communicate outside its own net.

- MAP will be demonstrated in a five-step process spanning the next four years. Step one is complete. This was the demonstration of multivendor connections (DEC and IBM) and terminal emulation (VT 100 and 3270) via a centralized computer node (IBM Series 1). No network was used.

- Step two (current status) has added a local area net (Concord Data Systems Token/Net) to achieve multivendor connections over a broadband, backbone network with gateways to programmable controllers (Gould, Allen Bradley).

- Future steps will add gateways to wide area networks (1985), reduce layers one to four to hardware and add more makes of equipment (1986), and achieve plug compatibility by a majority of suppliers (1988).

- GM is said to have a staff of 70 working to make sure its schedule is met. If recent moves are indicative, GM could invest in two or three LAN suppliers within the next few years to facilitate its development.

- GM has MAP commitments and requests for participation in the company's 1985 Autofac presentation from the following firms:

  - Advanced Computer Communications.
  - Allen Bradley.
  - American Robots.
  - AT&T.
  - ASEA.
  - Automated Industrial Systems.
  - Charles River Data Systems.
  - Concord Data Systems.
  - Codex.
  - Digital Equipment Corporation.
  - Industrial Networking Inc. (GE/Ungermann Bass).
  - Intel.
  - Interactive Systems/3M.

- IBM.

- Machine Vision.

- Motorola.

- NCR.

- Northern Telecom.

- Rolm/IBM.

- Siemens.

- Stratus.

- Tandem.

- Westinghouse.

- Itel.

- The Industrial Technology Institute of Ann Arbor (MI) is lobbying to become the independent certification lab for MAP-compliant products.

C. THE SIGNIFICANCE OF GENERAL MOTORS AND MAP

- General Motors influence in the manufacturing industry, and its contribution to the CIM in particular must be considered from several angles:

- First, the support MAP has garnered from the manufacturing community as well as from myriad hardware, software, CAD/CAM, robotics, and process control vendors, indicates that the protocol specifications will set the basic direction for telecommunications in manufacturing. The major manufacturers committed to MAP are listed in Exhibit V-1.

- Second, MAP's influence should quickly broaden into manufacturing domains outside of telecommunications. For example, GM is looking at the relationship of MAP to EID 1943 (the standard that governs numerical controls) and is talking to the Robotics Industry Association to explore robot programming on controls via LAN.

- Third, having announced its intention to spend approximately $40 billion to bring CIM into its two plants by 1988, GM may not only determine the direction of factory telecommunications through MAP, but also influence which independent vendors in the material planning, design engineering, process control, and machine tool segments will emerge as preeminent.

- Fourth, although the MAP standard will facilitate intervendor network communications, it is important to remember that existing protocols are limited to physical interconnection and transmission layers (one to four) and that compatible data base and data definition software is necessary for a higher level intercomputer dialogue.

- Fifth, it is important to remember that while a timetable for completion of higher OSI levels has been set for the next four years, these protocols require common data definitions and will be much more difficult to establish.

- Sixth, for the MAP protocols which have been specified, there are only two products commercially available: Concord Data Systems Token/Net and Allen Bradley's Vistanet.

EXHIBIT V-1

MAJOR MANUFACTURERS COMMITTED TO
MAP AND LOBBYING FOR ITS DEVELOPMENT

McDonnell Douglas	MAP Committee Chair
General Motors	Vice Chairman, MAP Technical Direction
Dupont	Vice Chairman, MAP Standards Activity
Boeing	Vice Chairman, MAP Program Activity
Kodak	Vice Chairman, MAP Membership

- Finally, although MAP standards are likely to set the basic direction for shop floor telecommunications and manufacturing system development--the market is large and multifarious, and a few distinct network protocols, such as Ethernet, should coexist with MAP protocols.

- In summary, there are four strategic product directions which independent CIM vendors can pursue relative to the emerging MAP standards. They may:

  - Build network technology that is structured around the existing MAP protocols and commit to research and development in anticipation of forthcoming MAP specifications for higher level protocols.

  - Design software solutions which move beyond the communications issue to facilitate the intercomputer dialogue through common data definitions, data base recoding/reclassification techniques, and/or application interfaces.

  - Design customized network technology that is compatible or different to MAP protocols, but which takes advantage of the immediate need for shop floor integration and has the potential to set its own standard.

  - Abort computer integrated manufacturing development work until all the MAP specifications are revealed.

- Although all the available options entail risks, INPUT recommends that CIM vendors work closely with the MAP committee, try to anticipate future protocol specifications, and direct their product strategies to assure compatibility.

- INPUT does not recommend that vendors wait for MAP to fully evolve before extending their product strategies, given the actual length of time it may take for higher level protocols to be established, and the contribution individual vendors can make to MAP through their research and development work.

VI THE AVAILABLE SOLUTIONS AND VENDOR STRATEGIES

- The following provides more specific examples of the technologies which unique vendor groups are offering to take advantage of "just in time"/computer-integrated manufacturing needs and the vendor/commitments to MAP.

A. THE NETWORK CIM VENDORS

- Well established vendors such as Digital Equipment Corporation and start-up ventures such as Concord Data Systems are highlighting the telecommunications aspects of CIM. The local area network these companies are designing are unique insofar as they permit messages to be automatically transferred from a minicomputer host to shop floor programmable controllers and machine tools.

- In the past, this type of data transfer was handled either manually or via point-to-point communications. The increased carrying capacity and speed of shop floor LANs therefore puts vendors of these networks at the center of the CIM stage.

- Concord Data Systems Token/Net and Allen Bradley's Vistanet are the only commercially available shop floor networks which comply with the existing MAP specifications. Concord's Token/Net is a broadband token passing bus network that uses CATV-compatible coaxial cable. The network can operate

at speeds up to 5 mbps and can accommodate cable lengths of 20 miles or more. Token/Net has been installed at 20 manufacturing sites including General Motors, Ford, Dupont, and John Deere.

- At the MAP demonstration at the NCC last October, Concord's product was used to link an IBM Series I to a DEC VT 100 and IBM 3270 terminals. It showed how gateways could be used to connect the host to shop floor programmable controllers by Gould and Allen Bradley. Concord is working on the development of VLSI interfaces that will allow MAP protocols to be implemented as integrated circuits and used in robots, machine tools, and other devices. The company has recently joined some of Gould AMI to develop a 3-chip set that will provide these features.

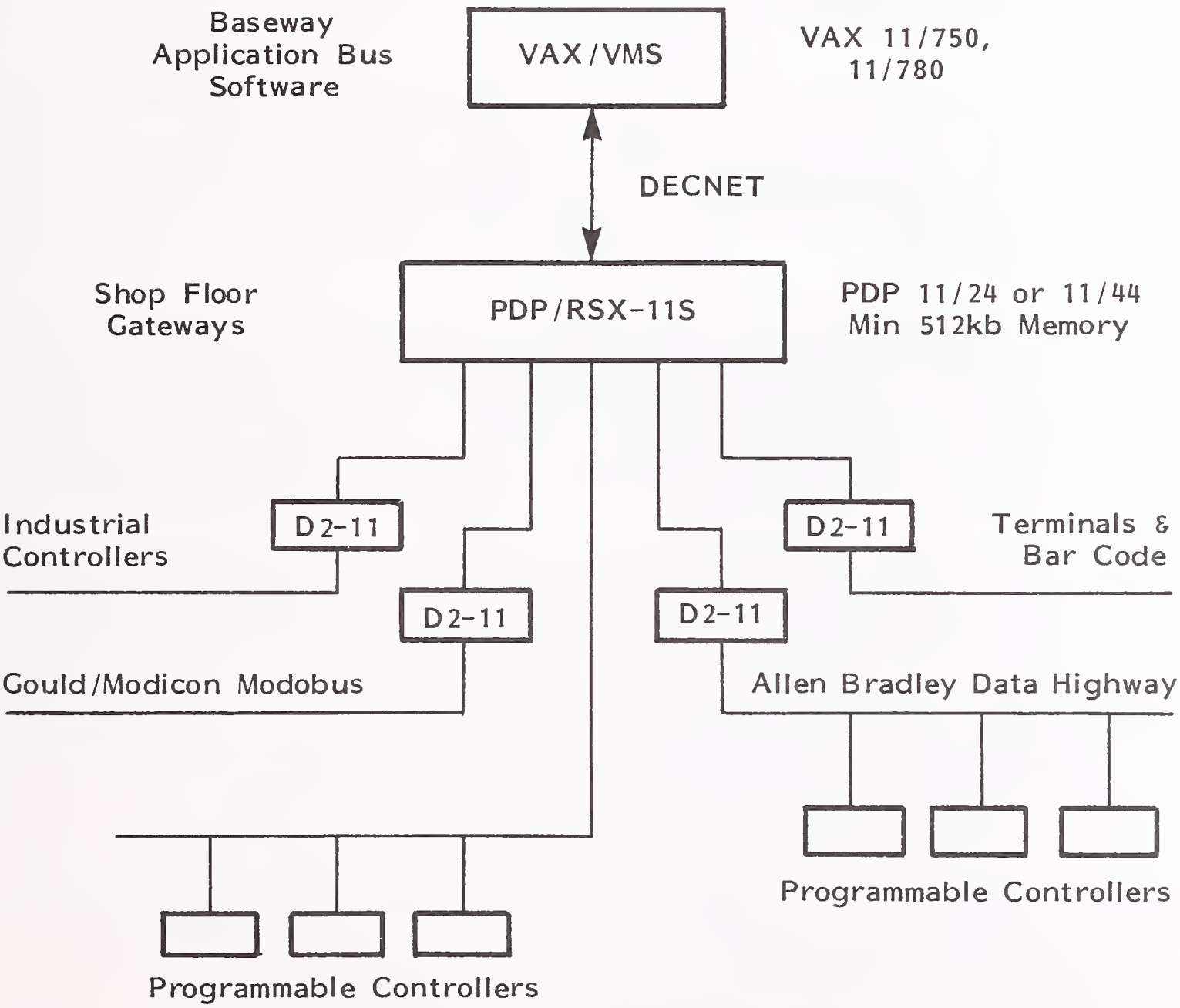
- DEC's "baseway" network consists of three separate software components. The shop floor gateway ($4,000), the applications bus ($18,000) and the programmable device support which is a menu-driven program for loading documenting and maintaining ladder logic programs. Exhibit VI-1 displays the Baseway configuration. The gateway software runs on a PDP-11 with the RSX-11S real-time operating system. It collects, translates, and uploads inputs from shop floor devices which are sent via DECnet to the applications bus. The bus resides on a Vax running VMS. Baseway was commercially released in early 1985, and DEC has made approximately 35 installations to date.

- AT&T and IBM have also expressed their intention to enter the market for MAP-based LANs and will undoubtedly command a pervasive market share. AT&T is reportedly working with EDS on network development which will focus on the links between factory and office automation. IBM is expected to announce an 802.4 network as well as a 4 mbps star-radial LAN within the next few years.

- General Electric has formed a joint venture with Ungermann Bass to develop factory LANs based on both Ethernet and MAP protocol specifications. The

EXHIBIT VI-1

BASEWAY SOFTWARE/HARDWARE CONFIGURATION



joint venture is called Industrial Networking Incorporated and should have its first 802.4 product out in 1985.

- The primary shortcoming of the existing MAP products and the challenge to future network vendors relate to cost. MAP was founded to facilitate low-cost networking and yet Token/Net and Baseway are rather expensive (Token/Net costs $500 to $2,000 per connection depending on the configuration). An average system running five to ten nodes could cost anywhere from $25,000 to $100,000.

- This high connection price is due in part to the fact that network hardware is based on medium-scale discrete components. Future generation networks should incorporate VLSI (very large-scale integration) with attendant reductions in cost.

- It is also significant that many of the existing 802.4 networks lack real time capabilities and provide the best interfaces to the suppliers products (e.g., Baseway to DECnet and Vistanet to Highway 1). Vendors must try to increase their network speed and broaden the range of intelligent devices supported.

- Finally, networks are needed to connect the floor with material planning and accounting functions so that the manufacturing communication loop is closed from purchasing all the way through design and assembly. This will entail "internetworking" (e.g., the ability of a MAP network to communicate with devices outside its own net).

- We estimate that the market for shop floor and other manufacturing telecommunications networks will represent about 22% of the total LAN market by 1990 or $265 million.

B. THE CAD/CAM/CAE CONTRIBUTION

- Whereas network vendors are focusing on the telecommunications aspects of CIM, CAD/CAM vendors are attacking the underlying software issues which must be addressed for true integration to be achieved. Accordingly established CAD/CAM/CAE vendors such as Intergraph, Computervision, and Daisy Systems, as well as start-up ventures such as Automation Technology Products and Metagraphics are strengthening their foothold in the CIM market by pursuing the following integration strategies:

  - CAD + CAM: Further integrating CAD design functions with the physical implementation process utilizing coding and classification schemes such as group technology.

  - CAD/CAM host to CAD/CAM workstation: Designing CAD/CAM system architectures which permit graphics processors and engineering workstations to access host resources and/or perform local 3-D simulation and analysis.

  - CAD/CAM and MRP: Interfacing CAD data base software with MRP II planning functions.

  - CAD/CAM to CAD/CAM: Developing interface technology that is in compliance with the International Graphics Exchange System (IGES) and employing network system technology which is MAP based.

- Integraph Corporation and Computervision are two CAD/CAM vendors which have addressed requirements one and two. Integraph has released software modules which automatically generates NC tool paths and is also developing off-line programming and processing capabilities for robots which should be available in 1985.

- From a workstation standpoint, Intergraph's Interpro 32 and forthcoming Microvax CAD are significant offerings given the wide range of engineering tasks they perform functioning either as a terminal to an Intergraph host or as a standalone Microvax running unit.

- Computervision's manufacturing applications also include graphic numerical machining and robot programming. Its most significant workstation product, released in May of 1984, is called Factory Vision/3000. Factory Vision is actually a Sun microcomputer running UNIX. The product is unique as it can access data bases created on Computervision's CAD/CAM systems, as well as text information from non-Computervision mainframe computers.

- Start-up CAD/CAM vendors with significant technologies under development include Automation Technology Products (ATP) of Campbell (CA) and Metagraphics of Woburn (MA). ATP's CIMplex product incorporates unique communication and DBMS capabilities for monitoring reporting of engineering and manufacturing tasks. Metagraphics has a new approach to the old program of converting parts drawings on microfiche to the CAD data base.

- The primary advantage of the CAD/CAM vendor approach to the CIM market is its software orientation. CAD/CAM is one of the few manufacturing technologies where distinct factory functions have actually been "integrated" into a common data base management system rather than "interfaced" via dedicated applications programs. The increased manufacturing productivity and flexibility that results from this type of integration favorably positions CAD/CAM vendors to leverage their installed base through the sale of additional modules.

- The primary difficulty the dedicated CAD/CAM vendors will confront as they embark upon their strategy is the incompatibility that exists between their data base software and outside vendors, and the limitations this imposes upon them in terms of marketing a more comprehensive solution incorporating links to MRP II systems and other CAD data bases. Although all the major CAD

vendors are developing IGES interfaces, these specifications only address the requirement for geometric data exchange.

- Exhibit VI-2 lists leading CAD/CAM vendor revenues.

- As Exhibit VI-3 shows, INPUT estimates user expenditures for CAD/CAM integrated applications will grow from $350 million in 1984 to $3.9 billion by 1989, representing 42% of the total 1989 CAD/CAM market versus 14% of the 1984 market.

C. THE MRP II VENDORS

- Vendors such as ASK Computers, Management Science America, NCA Corporation, and Comserv regard their material resource planning systems as the top-down solution to CIM needs. Rather than attempting to build common automated systems from scratch or rewrite the code of several incompatible systems, these vendors urge manufacturing managers to rally around one centralized MRP II data base that is linked to:

  - Factory floor data collection terminals and sensor devices.

  - CAD/CAM systems.

- Although most MRP II vendors are initiating their strategy through joint agreements with individual CAD/CAM process control and material handling vendors, prototype products will be used to develop generic system interfaces.

- ASK Computers appears to be the MRP vendor which is furthest along with its CIM product development. Exhibit VI-4 reveals ASK's scheduled release dates for CAD/CAM, automatic storage and retrieval, and process control interfaces. ASK has agreements to develop the related products with Computervision, Daisy Systems, and White Data Systems--among others.

EXHIBIT VI-2

CAD/CAM VENDOR REVENUES
($ Millions)

	TOTAL SALES INTERNATIONAL AND DOMESTIC		TOTAL SALES U.S.A. ONLY	
	1984	1983	1984	1983
IBM	$700	$425	$600	N/A
Computervision	447	317	246	165
Intergraph	347	220	288	200
GE/CALMA	235	210	200	168
McAUTO	108	70	92	55

EXHIBIT VI-3

CIM USER EXPENDITURES FOR CAD/CAM
1984-1989
($ Millions)

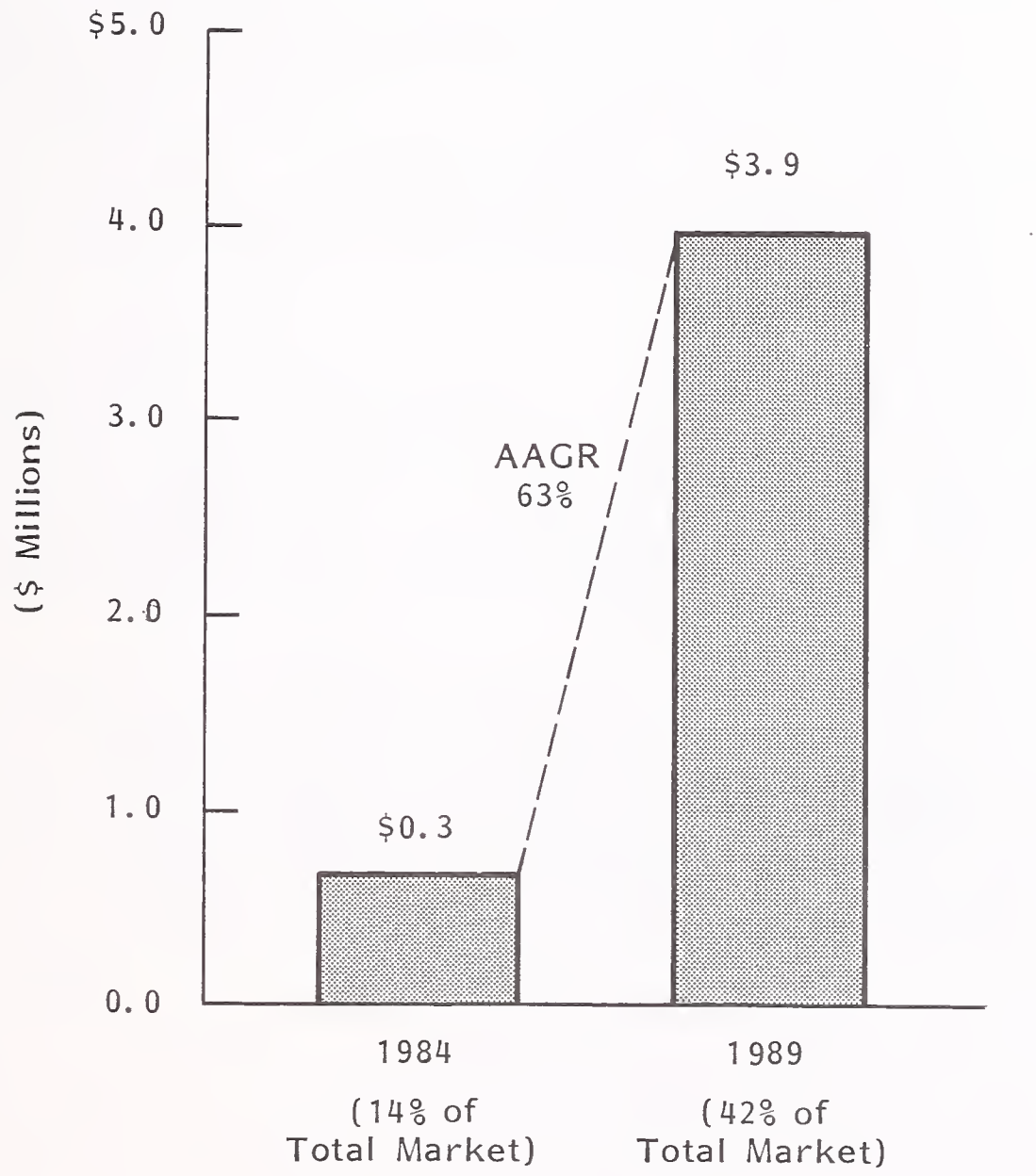


EXHIBIT VI-4

MRP II INTEGRATED OFFERINGS

COMPANY	CIM PRODUCTS	PRICES	AVAILABILITY
ASK Computers	CAD/CAM/CAE Interface	$15-25,000	6/85
	Automatic Storage and Retrieval	N/A	12/85
	Quality Management Marketing	$30-40,000	6/85
	Bar Code Monitoring	$3-5,000	3/85
	DSS Software	$3,300	Out
MSA	CAD/CAM/CAE Interface	N/A	N/A
	Bar Code Data Collection	N/A	N/A
	Electronic Purchasing	N/A	N/A
	DSS Software		Out
NCA Corporation	Repetitive Manufacturing Module (RFLX)	$35,000	Out
	Field Service (TRAXX)	$100,000	Out
	Data Collection	N/A	6/85

- Management Science American also has a comprehensive CIM strategy underway, although MSA is a relative newcomer to the manufacturing market and has not yet set firm product release dates. MSA's MRP II system runs on all the popular mainframe data base management systems and the company will therefore address a broad cross-section of the market.

- MRP II vendors approach the CIM arena with several strengths. First, they have control of materials purchasing and production scheduling--key functions which must be integrated with engineering and the shop floor for the "manufacturing loop" to be closed. However, neither the total solution vendors (IBM) nor the dedicated CAD/CAM suppliers have focused on this aspect of CIM.

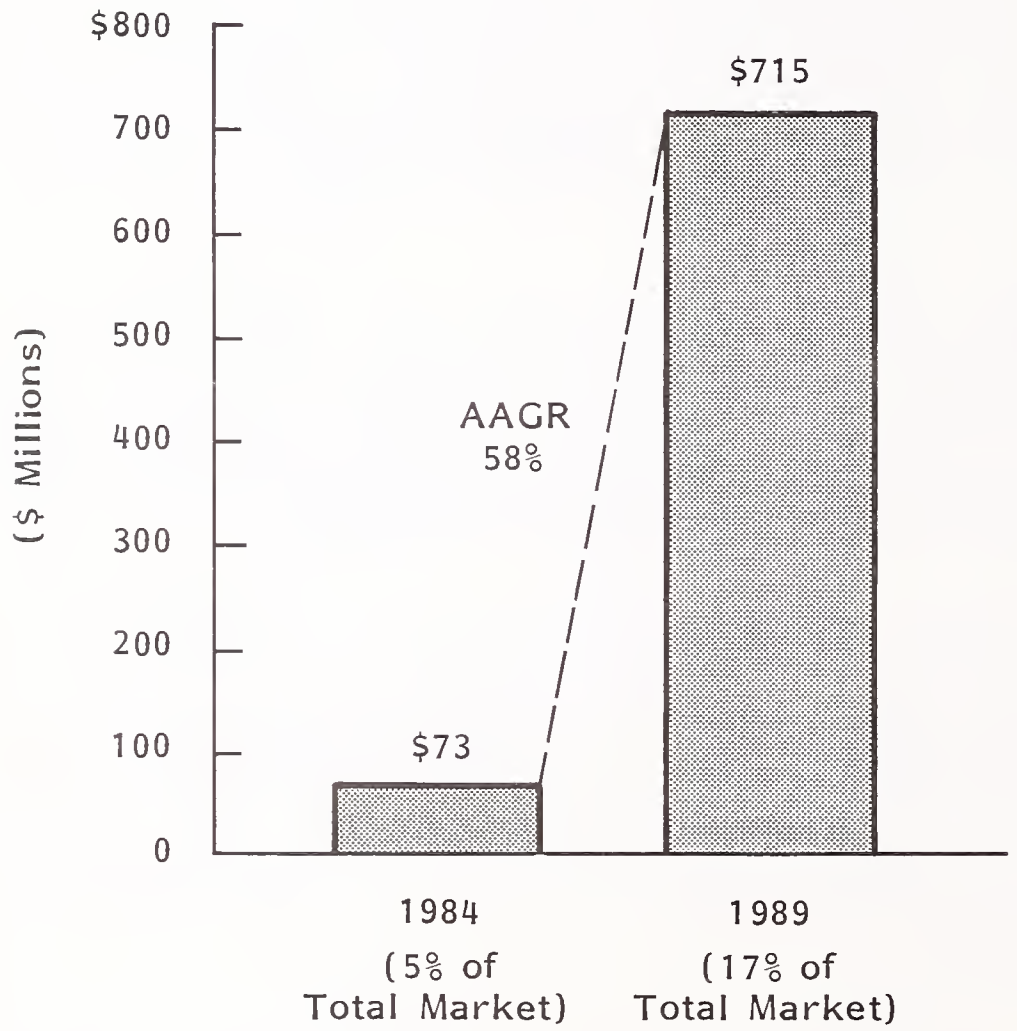
- Second, from a marketing vantage point, MRP II vendors have established relationships with manufacturing managers as opposed to system engineers. These relationships indicate that they will be able to sell add-on CIM products to at least 10-15% of their existing customers.

- The primary obstacle MRP II vendors may confront concerns whether MRP II systems rather than a neutral data base or data base machine should serve as a manufacturer's central management information system. This problem could be compounded if MRP II vendors do not adapt their system to address "just in time" requirements for lower levels of inventory and shorter production cycles.

- INPUT conservatively estimates that 17% of MRP II revenues will be related to integrated applications by 1989. The projection is shown in Exhibit VI-5.

EXHIBIT VI-5

CIM USER EXPENDITURES FOR MRP II
1984-1989



D. THE TOTAL SOLUTION VENDORS

- Major U.S. corporations, such as IBM, GE, and McAuto (a division of McDonnell Douglas Corporation) are attempting to dominate the factory automation market by amassing the key standalone technologies needed in the factory as well as by developing the necessary software interfaces and local area networks. Most of the CIM products currently available from the vendors facilitate functional integration between engineering and manufacturing rather than materials planning and marketing.

- IBM, General Electric, and McDonnell Douglas have all expressed their commitment to support MAP standards as they evolve. As indicated earlier, GE has an 802.4 network under development as part of a joint venture it has formed with Ungermann Bass.

- IBM is expected to release a MAP-based LAN (as well as other star radial LANs) within the next few years. McAuto has not indicated an interest in marketing proprietary 802.4 LANs, but has clearly expressed that it will adapt its CAD/CAM product to support both Ethernet and Token access protocols.

- Of all the "total solution" CIM vendors, IBM has the most comprehensive and potent factory automation effort underway. As shown in Exhibit VI-6, the company has generated over three times the manufacturing system sales as GE or McAuto and is taking decisive steps to expand and consolidate its industry position.

- Exhibit VI-7 lists IBM's primary offerings for planning, engineering, and production applications. The company has the dominant position in the MRP II market, the dominant position in the CAD/CAM market, and the seventh largest robotics market share (although it is still in a start-up phase in this sector).

EXHIBIT VI-6

TOTAL SOLUTION VENDORS
1984 ESTIMATED SALES OF STANDALONE SYSTEMS
($ Millions)

	IBM	GENERAL ELECTRIC	McDONNELL DOUGLAS
CAD/CAM	$ 600	$200	$92
MRP II	585	5	0
Robotics	19	15	0
Total	$1,204	$220	$92

EXHIBIT VI-7

IBM's STANDALONE FACTORY AUTOMATION PRODUCTS

APPLICATION	SOFTWARE PRODUCT	MARKET SHARE
Design/Engineering	CADAM CATIA FASTDRAFT SQL	24%
Planning + Control	MAPICS COPICS	40%
Production & Assembly	7500 Robot Series	5%

- Recent significant hardware and software manufacturing product announcements include the following: The IBM 9000, which sells for less than one-half the price of DEC's PDP line of minicomputers, and provides flexible multitasking workstation capabilities, as well as communication links to programmable controllers from Gould and Allen Bradley; the 5080 graphics workstation, which is supported by CADAM/CATIA and CAEDS to provide IBM with its first Raster graphics-based engineering configuration for solids modeling and simulation in mechanical design applications; and the 1984 introduction of the PC/AT which is gaining wide acceptance for controlling and programming robots, numerical controllers, and other factory equipment.

- In spite of this expansive product base, it should be recognized that IBM is technologically weak in certain areas, and badly in need of third-party support in others. For example, MRP II vendors such as ASK Computers should continue to sell effectively against IBM unless the giant bolsters its MAPICS/COPICS product features. In addition, although CAD/CAM/CAE vendors with competitive hardware strategies are being hurt by IBM (e.g., Computervision), companies such as Daisy Systems, who uses the IBM product family at both the minicomputer and workstation level as computer platforms for value-added software, may enjoy an expansion in their served markets.

- Finally, and most importantly, IBM has not yet developed the software interfaces or communication networks that are needed to connect its supermarket of standalone offerings. Although IBM has clearly indicated that its integration strategy will be based on 802.4 network protocols and SQL/DS/DB2 data definitions, the manifestation of the strategy appears to be at least three years off, providing a window for vendors with customized CIM application software solutions and 802.4 LANs.

- GE, like IBM, is seeking leadership in the CIM market. GE is also in a position to supply a broad range of factory automation products from start to finish. However, GE is approaching the CIM market with factory floor experience rather than as a computer manufacturer which INPUT believes puts it at relative disadvantage to IBM.

- GE has made an enormous attempt to automate internally. Since 1980 the company has committed over $3 billion to plant modernization and in 1984 received the industry LEAD award for excellence in the application and development of computer integrated manufacturing, conferred by the Society of Manufacturing Engineers (CASA/SME).

- Several of GE's standalone factory automation products, such as its weldvision robots, have grown out of these internal CIM development efforts. In 1984 GE sold about $16 million of its robotics systems, giving it the eighth largest share of the market after IBM.

- What GE hasn't developed internally, it has tried to make up for through acquisition. For example, in April 1981, GE acquired CALMA from United Technologies, Inc. CALMA designs and markets a full line of CAD/CAM products for mechanical, electrical, and construction markets. The GE subsidiary generated approximately $200 million in revenues in 1984, although sales were below expectations and income from operations was in the red.

- At the Autofact show last October, GE demonstrated an impressive array of CIM offerings, specifically designed to facilitate functional integration. These products, along with GE's standalone factory systems, are shown in Exhibit VI-8. The most significant integrated releases are Factory Scanner ($100,000) and CAPP ($50 to 15,000).

- Factory scanner is a network product designed for the monitoring and supervisory control of plant floor machinery via DEC/VAX computers. The system interfaces with most standard programmable controllers to automatically acquire the data needed for monitoring.

- GECAPP is a computer-aided process planning system also designed for the Digital Equipment family of VAX computers. The system is comprised of packaged modules which facilitate the flow of information between engineering and manufacturing.

EXHIBIT VI-8

GE's STANDALONE FACTORY AUTOMATION PRODUCTS
AND INTEGRATION APPLICATIONS

APPLICATION	STAND-ALONE PRODUCT	INTEGRADED OFFERINGS
Design/Engineering	CALMA	GECAPP, MATS
Production	Weldvision Robots	Universal Robot Controller Robot SIM Factory Scanner
Planning & Control	MRP II	0

- Like IBM, GE needs to broaden its MRP integration application. However, INPUT believes that GE's primary weakness in the CIM market relates less to technology and more to the marketing and packaging of its system capabilities. As indicated by CALMA's poor operating performance, tighter operating controls and management focus are needed.

- McAuto was originally formed in 1960 to support the internal EDP requirements of the aerospace concern. McAuto acquired its Unigraphics CAD/CAM system from United Computing in the early 1970s and began marketing the product to outside manufacturers in 1979.

- Although McAuto's CAD/CAM sales represented about 80% of total domestic revenues in 1984, or about $92 million, the company qualifies itself as a total-solution vendor given the broad experience it has in CAD/CAM numerical control and project maintenance and the level of integration it has achieved through its system design.

- McAuto's unigraphics II is unique insofar as it will run on IBM, DEC, or VAX systems, and can be used with the range of resident DBMS.

- In addition, McAuto pioneered the now growing field of CAD-based robotic cell design and is releasing a host of other products which will broaden the functional link between the engineer and the shop floor. A list of McAuto's forthcoming integrated products are shown in Exhibit VI-9.

- The most significant of these include Plant-Com, UG net, and release control module. UG net is a proprietary local area network that connects Data General and DEC-based Unigraphics systems with non-CAD data bases residing on IBM. Plant-Com (announced in September) is a shop floor data collection system based on the IBM 43XX, Series I and 7546 terminal. Release control module is not available yet, but will be an important tool for process planning and data management/exchange.

EXHIBIT VI-9

MCAUTO'S STANDALONE FACTORY AUTOMATION
SYSTEMS AND INTEGRATED OFFERINGS

APPLICATION	STAND-ALONE PRODUCT	INTEGRATED OFFERINGS
Design/Engineering	Unigraphics II	Release Control Module, PLACE
Production	0	Plant-Com, Moldflow, Masterlink, UG Net
Planning + Control	0	0

- McAuto's CIM strategy is narrowly focused and tightly woven. As a consequence, it is gaining a share in the CAD/CAM market where vendors such as Computervision and GE are losing momentum. However, McAuto's strategy should be bolstered by acquiring an MRP II product or the design of related integrated modules if it is to market itself as a sole source CIM supplier.

E. MARKET GROWTH PROJECTION

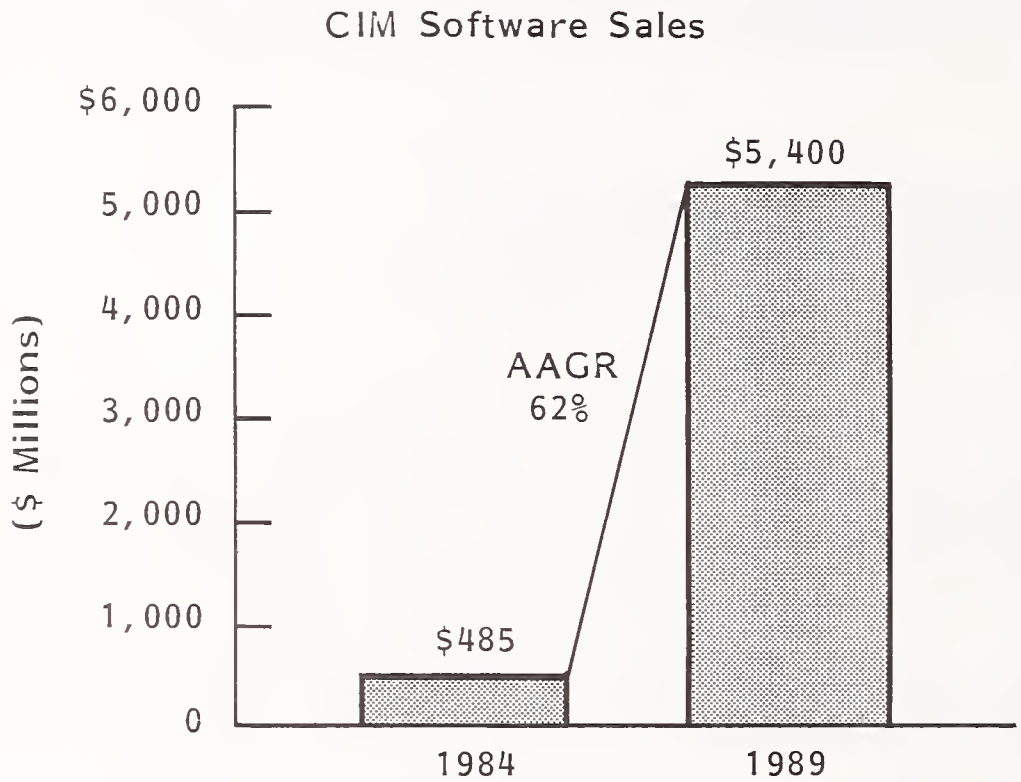
- The market forecast that INPUT projects for CIM software by 1989 is $5.4 billion, at a compound average annual growth rate of 62%. This estimate presupposes that while broadband token access networks will become the standard for shop floor telecommunications, custom software solutions will continue to gain momentum because no one data base or fixed set of data definitions will emerge in that time as the singular solution to factory automation needs.

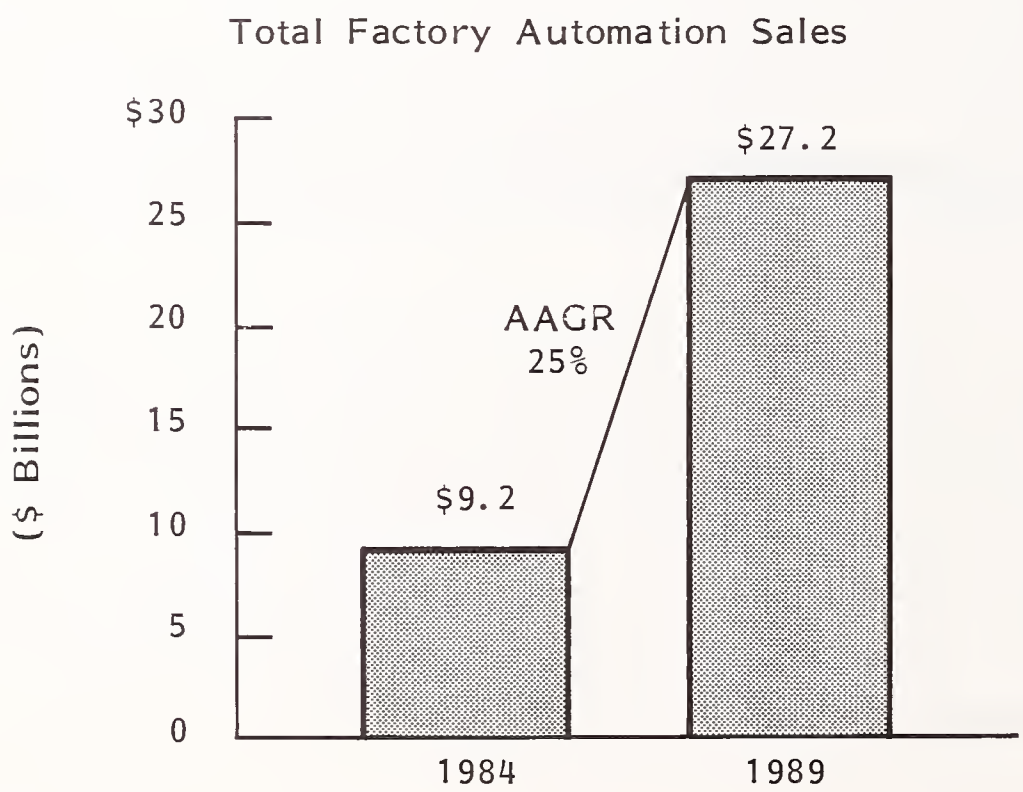
- As Exhibit VI-10 shows, this represents close to 20% of the total market for factory automation systems (including hardware and software) which will grow from $9 billion in 1984 to $27.2 billion in 1989, at a 25% AAGR.

- The manufacturing industry's need for automation technology is acute and the growth opportunities for system vendors are substantial, particularly for those developing integrated applications in compliance with MAP specifications. There are only two risk factors INPUT foresees which could upset this scenario. These include a more timely series of integrated offerings from IBM and/or "automation paralysis" resulting from the collapse of the current standards momentum (i.e., MAP).

EXHIBIT VI-10

THE FUTURE CIM MARKET SIZE AND STATE





1. Are you implementing a "just-in-time" manufacturing program?

   ☐ Yes ☐ No

2. How much do you expect to increase productivity? _____

   _____

3. How much will you spend? $_____

4. Which types would you purchase first given:

	What would you pay?
A. MRP 2 system linked to CAD/CAM	$_____
B. CAD/CAM linked to machine tool systems	$_____
C. Machine tool linked to MRP systems	$_____
D. Micro-mainframe decision support link	$_____
E. All equally important	$_____

5. Do you prefer to purchase from one type of vendor? ☐ Yes ☐ No

   Why? _____

6. Which one would you prefer to purchase these interfaces from?

   Would you purchase more than one? ☐ Yes ☐ No

   ☐ A. Hardware

   ☐ B. MRP

   ☐ C. CAD/CAM

   ☐ D. Communications

   ☐ E. Other _____

7. On a scale of 1 to 5, 1 being low and 5 high, please rate the following factors that will influence your selection of vendor:

   ☐ Reputation/Size

   ☐ Compliance with General Motors MAP protocol

   ☐ Number of function vendor can integrate

   ☐ Depth of integration

   ☐ Cost

   ☐ Availability

8. Would you be partial to your existing vendor? ☐ Yes ☐ No

9. Would you be most partial to a ☐ hardware or ☐ software vendor?

10. Do you endorse GM MAP standards? (Standards for Network Development)

    ☐ Yes ☐ No

About INPUT

INPUT provides planning information, analysis, and recommendations to managers and executives in the information processing industries. Through market research, technology forecasting, and competitive analysis, INPUT supports client management in making informed decisions. Continuing services are provided to users and vendors of computers, communications, and office products and services.

The company carries out continuous and in-depth research. Working closely with clients on important issues, INPUT's staff members analyze and interpret the research data, then develop recommendations and innovative ideas to meet clients' needs. Clients receive reports, presentations, access to data on which analyses are based, and continuous consulting.

Many of INPUT's professional staff members have nearly 20 years' experience in their areas of specialization. Most have held senior management positions in operations, marketing, or planning. This expertise enables INPUT to supply practical solutions to complex business problems.

Formed in 1974, INPUT has become a leading international planning services firm. Clients include over 100 of the world's largest and most technically advanced companies.

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