MARKET ANALYSIS AND FORECASTS

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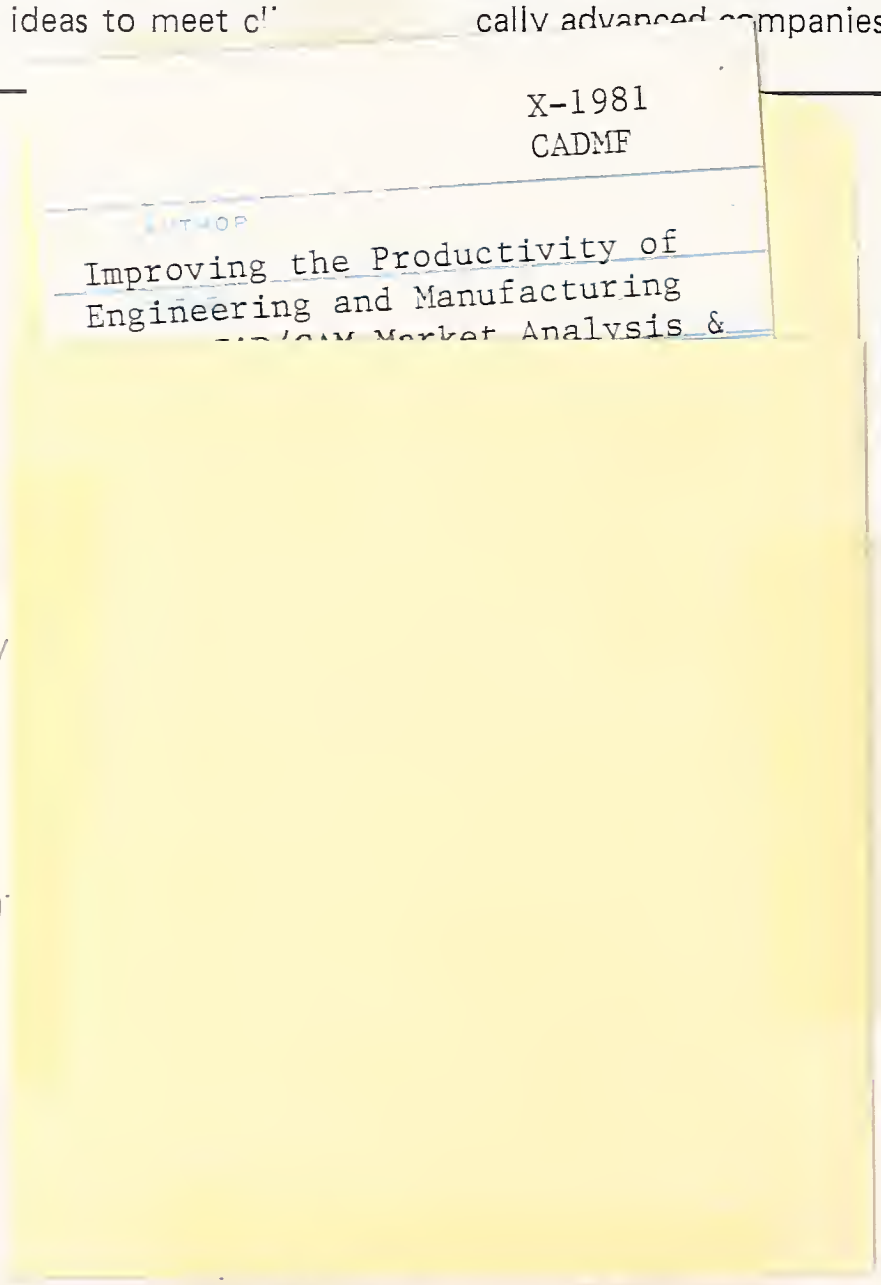

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INPUT Planning Services for Management

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM MARKET ANALYSIS AND FORECASTS

A MULTICLIENT STUDY

DECEMBER 1981

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM
MARKET ANALYSIS AND FORECASTS

CONTENTS

IMPROVING THE PRODUCTIVITY OF ENGINEERING AND MANUFACTURING USING CAD/CAM
MARKET ANALYSIS AND FORECASTS

EXHIBITS

1 INTRODUCTION

I INTRODUCTION

A. SCOPE AND PURPOSE

- This INPUT report is part of a five-volume multiclient study exploring system and service market opportunities for computer-aided design/computer-aided manufacturing (CAD/CAM) systems, and the application of CAD/CAM in the areas of architectural, electronic, and mechanical engineering.

- This volume of the study defines the structure of the CAD/CAM marketplace in terms relevant to the market planning functions of vendor organizations currently marketing, or planning to market, turnkey systems, remote computing services, hardware components, or software systems.

- This study addresses three geographic areas:

  - United States.

  - Western Europe and Great Britain.

  - Japan.

- INPUT estimates that these areas combined constitute over 95% of the free-world market in 1981. "World market" is used in this volume to refer to the areas listed above.

- The analysis of the marketplace and projections for it cover a period of 10 years, starting with the base year of 1980, with major review points in 1986 and 1991. Because of the young age and highly dynamic nature of the CAD/CAM industry, the forecasts beyond 1986 are less reliable than the near term forecast.

- Market cell definition has been constructed to analyze four specific modes of delivery:

  - Turnkey systems (a fully operable hardware/software system purchased from a single vendor).

  - CAD/CAM graphics software offerings (independent software packages).

  - Remote computing services (RCS) offerings in the CAD/CAM graphics markets.

  - Hardware component offerings (including computers, graphics terminals, and peripherals) for CAD/CAM systems where the users are integrating individually purchased hardware components into existing CAD/CAM systems, or developing in-house CAD/CAM systems.

- The study reviews the CAD/CAM marketplace in terms of four major application areas, and reviews current and forecasted purchases within each of those application areas. The four application areas reviewed are:

  - Mechanical.

  - Electronic (including very large scale integrated circuit (VLSI) and printed circuit board (PCB) designs).

  - Architectural/engineering.

- All other application areas including, but not limited to, mapping.

- All user expenditure values over $20 million were rounded to the nearest $5 million; all user expenditure values under $20 million were rounded to the nearest $1 million.

B. ECONOMIC ASSUMPTIONS

- Dollar figures in projections for various years are stated in terms of current dollars in those years and include the following assumptions for inflation:

Period	Inflation Rate
1980-1986	10%
1986-1991	5%

C. DEFINITION OF CAD/CAM

- CAD/CAM is defined as any interactive graphics-based system or application where design, drafting, and analysis are an integral part of the system. Examples include:

  - Turnkey design, drafting, and analysis systems (e.g., Applicon, Calma, or Computervision).

  - Mainframe-based design, drafting, and analysis systems where the user has purchased the hardware and software separately (for example: Lockheed CADAM running on an existing IBM mainframe).

- RCS design, drafting, and analysis systems (e.g., CADD, CD-2000, ANVIL 3000 terminals on an RCS basis).

- Analysis or simulation programs are only considered to be in the CAD/CAM market estimates if the software is integrated with a graphics-based system as described above. Integrated is defined as the close coupling of functions so that data are transferred to other applications or systems and operations initiated without extensive manual involvement.

- Standalone numerical control and robotics applications (for example: UCC-APT and MDSI Compact II) are not considered in INPUT's CAD/CAM market estimates.

- Standalone graphics-based modeling systems, such as Supertab and Patran-G, are not considered in INPUT's market estimates.

II EXECUTIVE SUMMARY

II EXECUTIVE SUMMARY

A. KEY CONCLUSIONS

- INPUT estimates that in 1980 there were more than 22,000 CAD/CAM graphics workstations installed throughout the world.

- Exhibit II-1 shows the distribution of the currently installed and potential installations of workstations in each of the major application areas based upon INPUT's analysis of the application of these systems to the current workforce. The value of the base of currently installed systems is estimated at over $2 billion, based upon a per station cost of $100,000; the 1980 user expenditures on systems in these categories is estimated at $910 million; and 1986 expenditures are projected to reach $5.8 billion.

- Cost per station (on a total system basis) is not anticipated to change significantly from 1980 to 1986. Users and vendors expect the functionality and features of systems to increase dramatically over this period, and do not expect to pay more for these enhanced capabilities.

- INPUT forecasts market growth at an average annual growth rate (AAGR) of 36% from 1980 to 1986 and 31% from 1986 to 1991. The CAD/CAM market is highly elastic and could grow faster than projected as the use of CAD/CAM systems broadens.

EXHIBIT II-1

ESTIMATE OF WORKSTATIONS INSTALLED WORLDWIDE - 1980

APPLICATION	NUMBER INSTALLED	POTENTIAL NUMBER OF WORKSTATIONS	PENETRATION (percent)
Mechanical	9,000	96,000	9%
Electronic	8,000	59,000	14
Architectural / Engineering	3,000	60,000	5
Other	2,000	21,000	10
Total	22,000	236,000	9%

- The market profile is changing rapidly as vendors take advantage of new hardware technology. Turnkey systems that were formerly four to six workstations connected to a minicomputer are now available from single station, standalone units to large-scale mainframes driving 50 or more stations. This makes systems more affordable to a broader range of company sizes.

- The projected growth of the total CAD/CAM market is shown in Exhibit II-2. User expenditures are estimated at $910 million in 1980 and forecasted to grow to $5.8 billion in 1986, and $22.5 billion in 1991. The primary driving forces are:

  - Economic and competitive pressures to increase productivity.

  - Growing acceptance of CAD/CAM technology.

  - Rapidly improving systems cost/performance ratios.

  - Increasing system capabilities.

  - Development of products for all market segments and company sizes.

- The turnkey segment of the CAD/CAM marketplace is by far the largest, with sales representing $670 million of a total of $910 million in 1980, as shown in Exhibit II-3.

  - INPUT estimates that approximately $200 million of hardware components, including captive CPUs used for processing of CAD/CAM systems, were sold in 1980.

    . Much of this equipment was sold to major companies who are actively involved in developing their own systems, and are integrating hardware into these systems which they buy directly from their hardware manufacturers.

EXHIBIT II-2

TOTAL CAD/CAM MARKET GROWTH
($ billions)

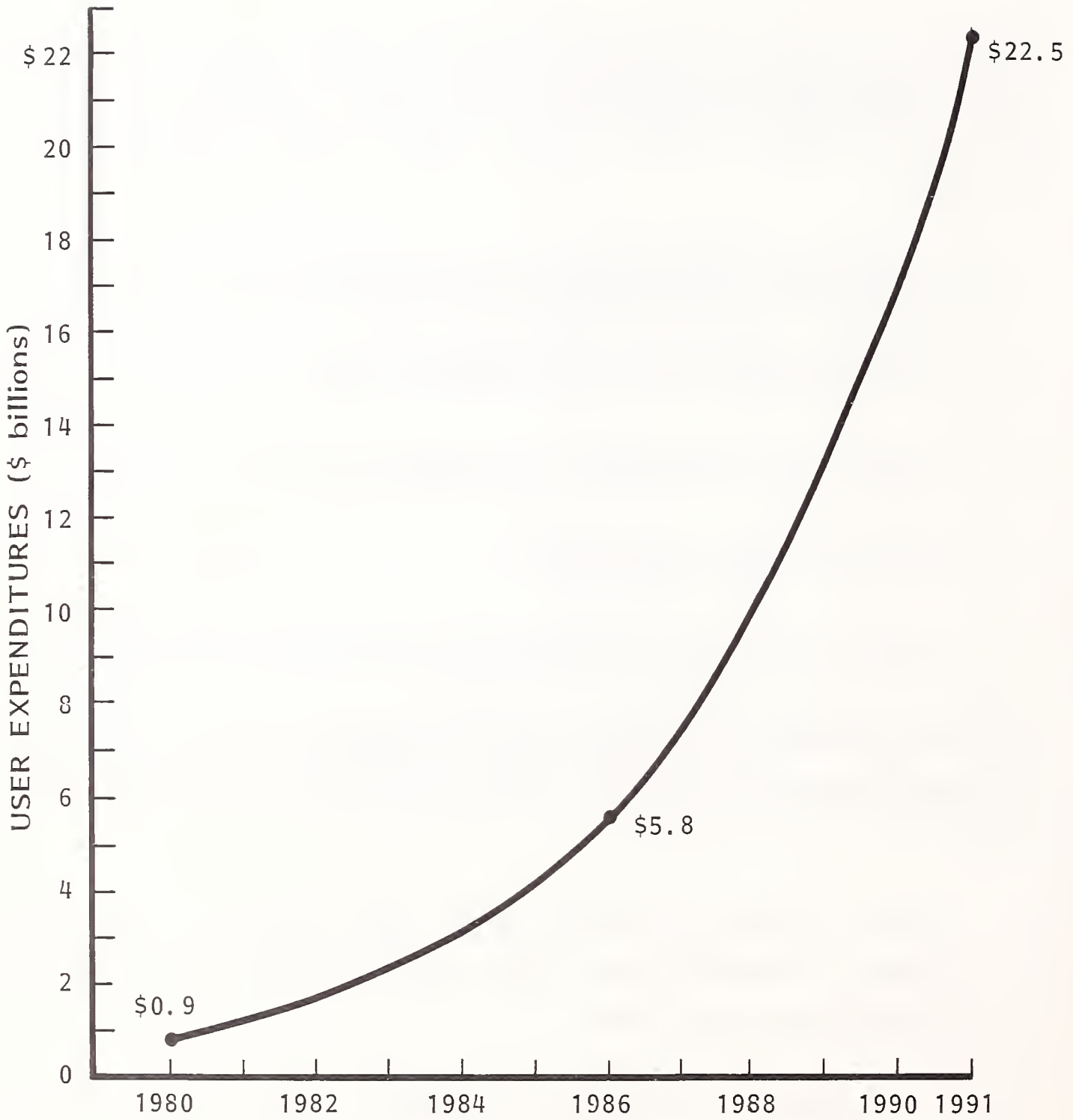
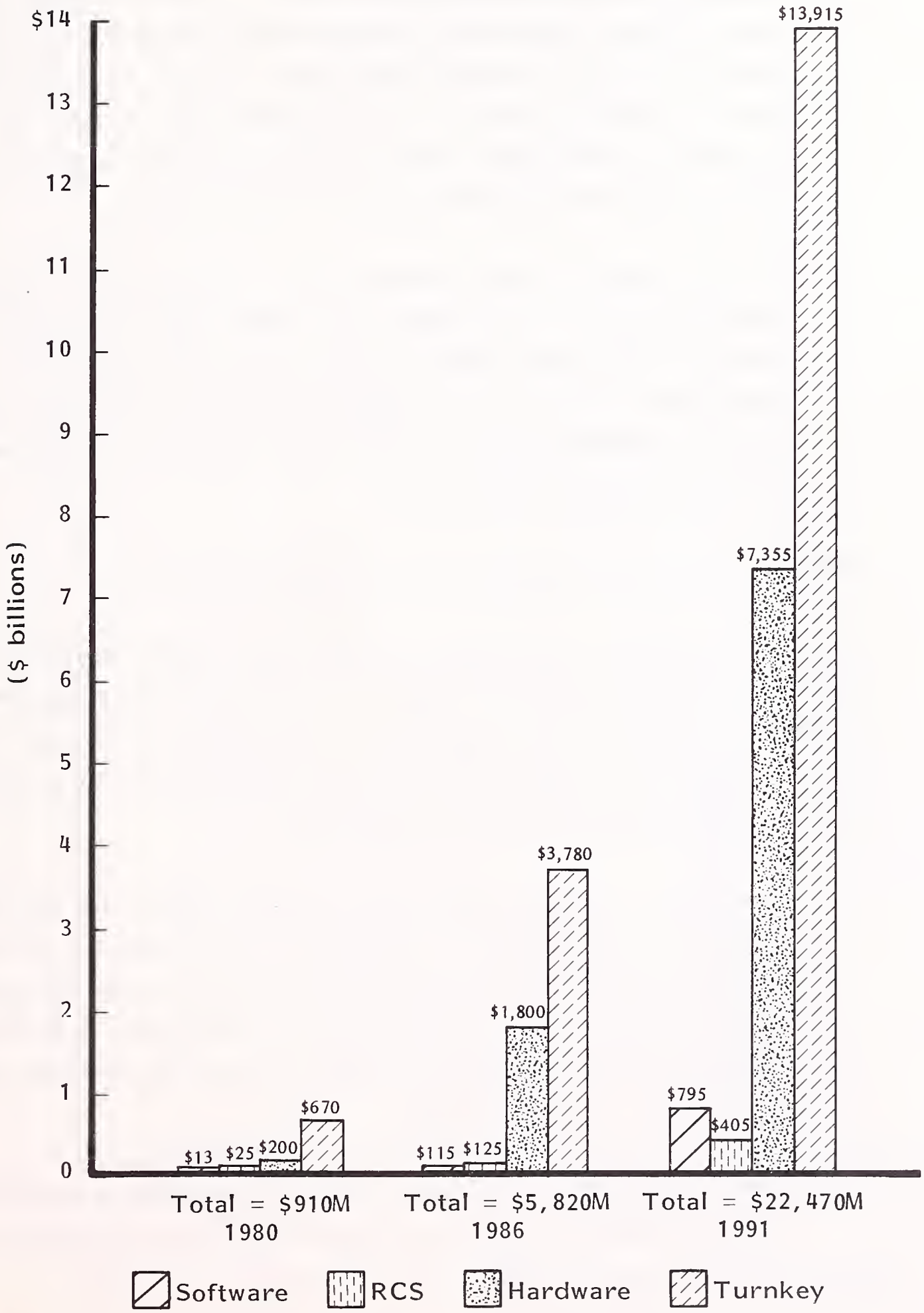


EXHIBIT II-3

USER EXPENDITURES ON CAD/CAM BY DELIVERY MODE



. This segment of the market is projected to increase relative to the other segments over the next 10 years.

- Remote computing services (RCS) revenues in the CAD/CAM marketplace will grow significantly between 1980 and 1986, but will not be a significant factor in overall market growth or size. The availability of low-cost turnkey systems (in the $100,000 range), and the desire of engineering departments to own and operate their own captive systems will preclude more significant growth in the RCS area.

- The full function turnkey manufacturers will experience significant growth trends in their market from 1980, where sales were $670 million, to 1986 where INPUT estimates sales to be $3.8 billion. Large corporations will continue to purchase turnkey systems, but a significant and increasing portion of the market growth will come from the medium and small size companies.

- Expenditure forecasts by application are shown in Exhibit II-4.

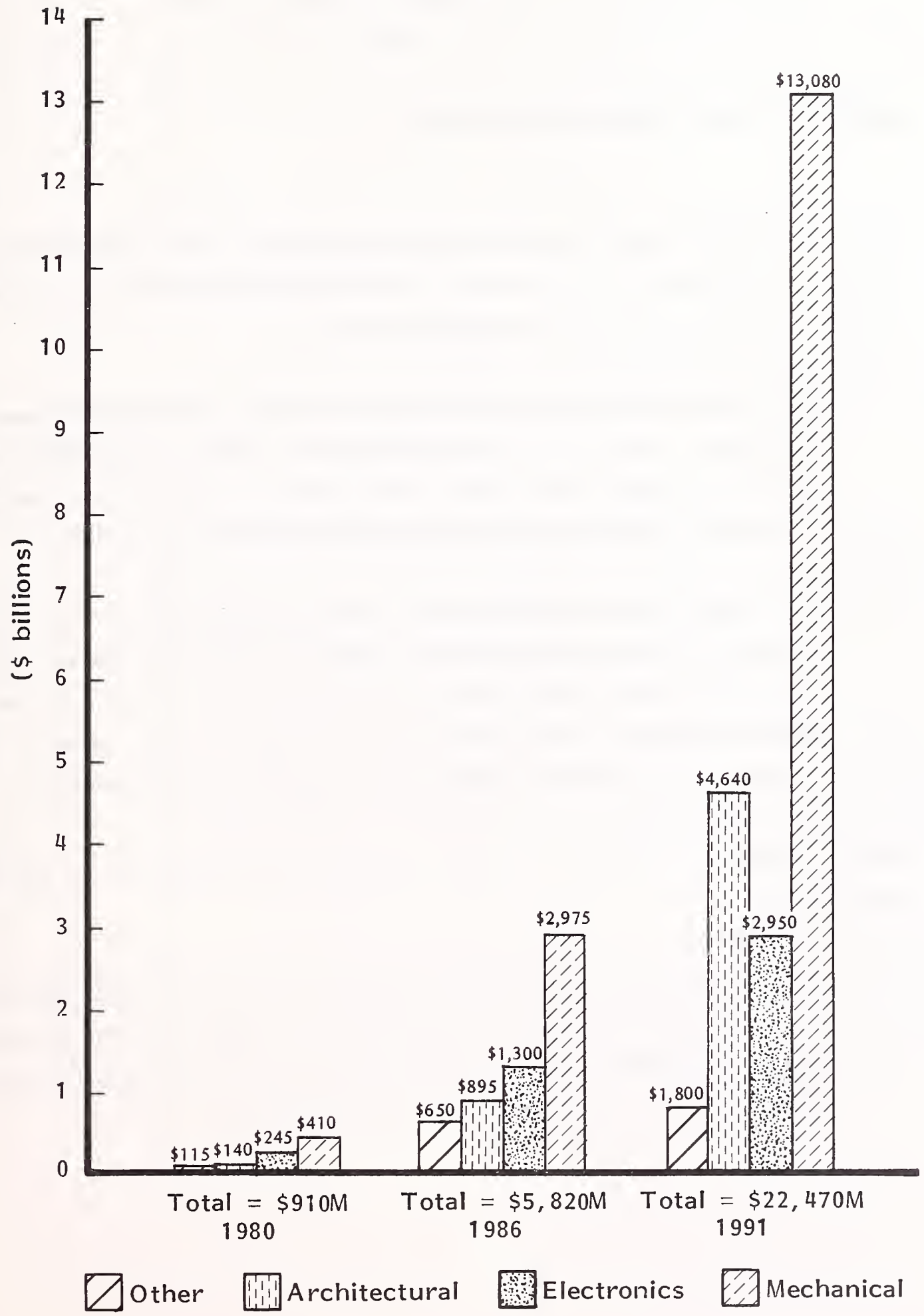
- Mechanical products manufacturers represent the largest segment of the discrete manufacturing sector. Because of the size of this segment, the mechanical portion of the marketplace will continue in its role as the dominant sector of the market, and by 1986 will provide for nearly $3 billion of the total marketplace revenues of $5.8 billion.

  - The primary area of future growth (beyond 1986) in the mechanical segment will come from the integration of CAD/CAM into the entire manufacturing organization, providing for involvement of the manufacturing divisions in the use of CAD/CAM technology. CAD/CAM is presently most prevalent in the design and drafting portions of their operations.

  - INPUT estimates that beyond 1986 the architectural/engineering market will grow at a much more rapid rate of 39% compared to the

EXHIBIT II-4

EXPENDITURE FORECAST BY APPLICATION



electronic market at 18%. This will be due to the higher saturation level of the market in electronics. The architectural market has developed much later than electronics and will owe much of its growth to the acceptance of CAD/CAM by the smaller firms.

B. MARKET STRUCTURE AND ANALYSIS

- Respondent users perform the greatest percentage of their CAD/CAM functions on turnkey systems. These users perceive themselves, for the most part, as being locked into one specific application area.

  - The existing penetration of turnkey vendor companies in selected application areas has provided a basis for future growth which will continue through 1986. Vendors with significant penetration in application areas in 1980 will for the most part maintain their positions.

  - The major exception will be the increasing presence of IBM in the mechanical sector which INPUT attributes to IBM's ability to market large multistation systems which provide for a lower per-station cost in large installations, and which are also seen by the general user community as being well supported and requiring minimal training.

- INPUT estimates that there is a total current market potential for 236,000 workstations.

  - All applications of CAD/CAM technology have not yet been explored. In particular, the expansion of CAD/CAM technology into the manufacturing and production environment will rapidly increase the number of potential users of workstations in the next 10 years.

- Standardization of interfaces between CAD/CAM systems will occur in the mid to late 1980s. However, both the vendor and user communities are unsure what will be the final, adopted standard.

  - As has historically been the case with general-purpose computing, it may become the role of major hardware manufacturers to establish interface standards.

  - Automotive and aerospace corporations will continue to be the dominant factors in development of large CAD/CAM systems using standardized interfaces.

- The increasing complexity associated with products within the electronics segment will result in a move toward a more functionally integrated environment of computer-aided engineering.

  - The need for integration of analysis functions such as design rules checking will result in the integration of larger scale processors into these systems. Associated data base management and project control functions will be brought to play in these systems.

  - Large manufacturers of integrated circuits concerned with VLSI design will become major "user integrators" in that they will become components purchasers who will be developing and implementing software and systems of their own design.

- The architectural/engineering marketplace will continue to have a variety of vendors who share fairly equal roles. Technology from Europe, such as the GDS and BDS systems which McDonnell Douglas Automation Company (McAuto) has obtained from Applied Research of Cambridge, could prove to be a powerful new entrant into this marketplace.

- IBM will continue to grow within this marketplace because of CADAM, and will extend its presence into the major design/build companies who currently represent the major buying power in this industry.

- Low-cost turnkey systems (systems with initial full function capability for under $100,000) will find wide acceptance in the architectural/engineering market. This success will be based upon the large number of small, non-capital-intensive architectural/engineering firms who will find that the use of these systems is more easily justified for their operations. Small architectural/engineering companies will not have a need for integrated CAM functions, and will have minimal needs for intra- or intercompany CAD/CAM communications capabilities.

C. COMPETITIVE ENVIRONMENT

- The 1980 CAD/CAM market is dominated by eight vendors whose revenues account for approximately 80% of total revenues of turnkey systems vendors. INPUT forecasts that the role of these vendors will change significantly over the period 1980 to 1981.

  - Computervision, currently the largest turnkey vendor, had revenues in excess of $190 million in 1981. With the exception of IBM, Calma (now owned by General Electric Company), and McAuto, other turnkey manufacturers have sales far below Computervision's. Funding required for growth levels, as they have historically occurred, will be difficult for these smaller companies.

- The requirement for outside resources in the form of growth capital will necessitate a continuing trend of mergers and acquisitions over the next 10 years.

- Companies with involvement in the high-technology marketplace, and capital sufficient to support such investment will be active participants. These would include Schlumberger and General Electric among others.

- Major Japanese electronics companies such as Fujitsu and Nippon Electric Corporation (NEC) can be expected to enter this marketplace through the offering of new products which they have either acquired or developed internally. This trend has already begun in the Japanese marketplace where Fujitsu has licensed CADAM from Lockheed Corporation.

- Major users of CAD/CAM technology, such as aerospace and automotive corporations, indicate that future purchases will be oriented toward standardization within certain product lines and with vendors who can provide support and resources necessary for major growth.

  - Major customers for large purchases of CAD/CAM technology in the next 10 years will be seeking vendors who can provide confidence that systems and support will be available. Companies with established data processing reputations such as IBM and Control Data Corporation (CDC) will have distinct advantages in these situations.

  - Dissatisfaction with support of hardware and software by current turnkey manufacturers will result in a trend toward evaluation of alternative sources of service, software, and equipment. The advantage will be to major corporations who are geared to support growth, and who have established international field service operations.

D. RECOMMENDED VENDOR STRATEGIES

- Recommended strategies for major turnkey vendors in the 1980 marketplace center around the penetration and increased market presence in existing successful markets.

- Companies successful in the mechanical section of the marketplace should employ strategies for developing fully integrated manufacturing capabilities that will allow major buyers to integrate CAD effectively into their manufacturing and production facilities.

- Companies with successful market experience in the electronics segment should direct product development and marketing activities to developing full computer-aided engineering (CAE) systems.

- Companies with proven products and developed markets in the architectural/engineering marketplace should develop and market products for two specific segments of that marketplace:

  - The architectural/engineering companies in the medium to small ranges who are very price sensitive, and the larger design/build firms whose orientation will be more mechanical and will demand new tools in design and conceptualization.

- Software vendors should establish "beta test sites" in cooperation with large corporations and begin joint approaches to:

  - Learn how new software technologies will be used in major integrated systems.

  - Test system approaches.

  - Learn the languages, needs, and requirements of end users.

  - Explore optimal ways of integrating CAD/CAM technology with traditional MIS functions, design engineering functions, and manufacturing organizations within major end user companies.

- RCS vendors should capitalize on their capability to establish distributed CAD/CAM networks and should attempt to convert major corporations to the

use of their networks in terms of integrating "next higher level" distributed, corporate-wide systems.

- Many multidivisional, multisubsidiary corporations will be seeking to standardize approaches to the use of CAD/CAM technology in the next five years. Appropriate use of pricing techniques, and flexibility in configuration of systems will allow RCS vendors to obtain major clients who could represent significant portions of their revenues. Existence of major users will provide an impressive client list to attract smaller corporations and encourage them to use RCS.

- Vendors of turnkey systems in the under $100,000 category should concentrate on developing specific application capabilities for primary market segments.

  - Vendors should seek to develop reputations in specific market segments, and should concentrate on developing strong client lists which can be used in attracting first-time users.

  - Small system vendors must be able to demonstrate station communication capabilities, and other capabilities such as future expansion into CAM areas (numerical control, finite element modeling, group technology) in order to compete with major turnkey vendors or at least coexist with them in a multi-system installation.

- Mainframe manufacturers should use their influence within major general business system customers to expand the use of their systems into engineering activities such as CAD/CAM.

  - Major users have already made commitments toward the use of mainframe systems in development of in-house integrated systems. The investments made to date will not be discarded and, as such, systems vendors who can "tag on" to existing systems plans and allow for controlled growth for in-house development programs will benefit.

- Minicomputer vendors should continue in areas of strength developed to date, such as use of their equipment in turnkey vendor systems, and should also seek to develop powerful distributed systems capabilities that can be integrated within a single vendor's product environment and within multiproduct environments.

  - The Digital Equipment Corporation (DEC) VAX systems plans, which call for a broad product line of 32-bit machines, are an excellent example of developing a generalized capability for use in a variety of CAD/CAM situations.

  - Vendors who are not supplying systems to systems integrators selling turnkey CAD/CAM systems will have to concentrate more heavily on acquiring and/or arranging for the use of CAD/CAM packages on their systems. An example of this strategy is the effort by Prime to obtain marketing rights to advanced mechanical CAD/CAM capabilities incorporating volumetrics/solid modeling and other such capabilities not commonly offered by existing systems vendors. Components vendors should concentrate on compatibility with systems offered by dominant firms in each of the specific application marketplaces.

  - Plug compatible offerings for use with major vendors' equipment will also be a major trend in the components sector of the marketplace. To date, much of this activity has been in the plotter arena, however, trends already exist for the use of outside display technology in a plug compatible form with large multistation offerings of certain vendors.

III MARKET STRUCTURE AND FORECASTS

III MARKET STRUCTURE AND FORECASTS

A. GENERAL MARKET STRUCTURE

- The CAD/CAM market is segmented according to the following application areas:

  - Mechanical design and analysis.
  - Electronic design and analysis.
  - Architectural/engineering.
  - Other applications.

- For the purpose of this report, the mapping portion of the market will not be covered separately, but will be included in the "other" category.

- INPUT estimates that there are currently approximately 3.4 million engineers in the three geographic areas addressed in this study:

  - U.S. - 1.2 million (source: U.S. Department of Labor)
  - Europe - 1.4 million (source: INPUT estimate)
  - Japan - 0.8 million (source: Nomura Research Institute)

- Approximately 80% of the total engineers are presently in occupational categories that are found in industries that have CAD/CAM applications. This includes aeronautical, civil, electrical, industrial, and mechanical engineers.

- Approximately 70% of the above engineers, or 56% of the total engineers, are in large industries such as discrete manufacturing (selected segments), professional services, government, and utilities.

- Architects and drafters are two occupations which must also be included in the number of potential CAD/CAM system users. These occupations combined amount to approximately 40% of the total number of engineers, bringing the potential user population to 4.6 million.

- As CAD/CAM becomes more widely accepted as a productivity aid, it will penetrate into additional industry segments and involve more occupational categories. The extent of this penetration cannot be estimated at the present time, but has the potential for causing a significant increase in total market potential by the mid-1980s.

- A manpower forecast and occupational utilization model constructed by INPUT resulted in the following estimates for the base year, 1980:

  - Workstation potential 236,000 (5% of potential user population)

  - Workstations installed 22,000

  - Market penetration 9%

- The detailed estimates are shown in Exhibit III-1. The estimated penetration of 9% demonstrates the relatively immature state and undeveloped nature of the market:

EXHIBIT III-1

ESTIMATE OF WORKSTATIONS INSTALLED WORLDWIDE - 1980

APPLICATION	NUMBER INSTALLED	POTENTIAL NUMBER OF WORKSTATIONS	PENETRATION (percent)
Mechanical	9,000	96,000	9%
Electronic	8,000	59,000	14
Architectural / Engineering	3,000	60,000	5
Other	2,000	21,000	10
Total	22,000	236,000	9%

- Only the most sophisticated and long-term users have begun to realize the potential of CAD/CAM systems.

- Most systems today are used for very rudimentary design and analysis functions. Many systems in the architectural and mechanical areas are used for little more than automated drafting.

- Upper management in general is just now beginning to realize the cost savings potential of CAD/CAM and is becoming more receptive to the idea of applying this "new" technology to its operations. Sufficient visibility through various media has given CAD/CAM an aura of credibility which is helping to overcome the initial management reaction to the seemingly high entry cost.

• The CAD/CAM market will prove to be extremely elastic with a sensitivity to cost/performance.

- The average cost per workstation for complete systems is generally not expected to change much through the initial forecast period (1980-1986), so price by itself will not be a factor in encouraging use.

- Most vendors estimated that the cost per workstation would remain constant through 1986 (in current dollars), but the capabilities would increase significantly.

- This trend of level prices but increased cost effectiveness has been proven in the data processing industry to be the key factor in expanded utilization. A similar trend in the CAD industry is clear if one compares the prices and functions of systems five years ago with those of today.

B. MARKET FORECASTS

- The INPUT user expenditure forecast for CAD/CAM is shown in Exhibit III-2.

- The forecast is broken down by application area and delivery mode and shown in detail with discussions of pertinent factors in subsequent sections.

- Forecasts have been developed using vendor performance data (published financial reports) for the base year 1980 and extrapolated based on historical vendor performance and INPUT estimates of trends, growth rates, and other factors. Duplicate revenue caused by vendors selling to other vendors have been eliminated.

- Forecast amounts are stated in current dollars.

- Hardware and software maintenance expenditures are included in the forecasts (except for RCS where they are not applicable) and can be assumed to be approximately 10% of the respective product delivery mode total in 1980, increasing at the rate of approximately 1% per year.

- Yearly forecasts between 1980 and 1986 were derived through straight-line interpolation and are shown as indications only. Year-to-year variances can be expected due to economic conditions, competitive conditions, and other market factors.

C. DELIVERY MODE FORECASTS

- CAD/CAM products and services are delivered in one of the following modes:

  - Turnkey systems.

EXHIBIT III-2

FORECAST OF USER EXPENDITURES ON CAD/CAM -
ALL APPLICATIONS AND DELIVERY MODES
($ millions)

YEAR	USER EXPENDITURES ($ millions)	AAGR (percent)
1980	$910	
		36.4%
1986	5,820	
		31.0
1991	22,470	

- Software products.

- Remote computing services.

- Hardware and components.

- Expenditure forecasts for all delivery modes are shown in Exhibit III-3.

- Turnkey expenditures are broken into two categories - proprietary and nonproprietary.

  - Proprietary turnkey systems are those where the system is only available from a single vendor. The software (and in some cases, the hardware as well) is the proprietary product of the vendor and cannot be purchased separately from the hardware. Typical vendors of proprietary systems are Applicon and Computervision.

  - Nonproprietary turnkey systems are those systems purchased from either a software or hardware vendor who obtains the associated hardware or software from another source and offers it to the end user as an integrated turnkey package; for example, IBM with its hardware and Lockheed CADAM software.

- Exhibit III-4 shows the INPUT estimates of the geographic distribution of the CAD/CAM market forecasts. These estimates are rather broad at the present time due to the dynamic nature of the market and the large number of relatively small vendors. Better forecasting data will become available as the market begins to consolidate in the next one to two years.

I. TURNKEY SYSTEMS

- Turnkey systems were the dominant mode of delivery for CAD/CAM products and services in 1980. INPUT forecasts that this will continue through 1986 and

EXHIBIT III-3

USER EXPENDITURE FORECAST BY DELIVERY MODE, TOTAL CAD/CAM MARKET - ALL APPLICATIONS
($ millions)

DELIVERY MODE	USER EXPENDITURES ($ millions) 1980	1981	1982	1983	1984	1985	1986	GROWTH 1980-1986 (percent)	USER EXPENDITURES ($ millions) 1991	GROWTH 1986-1991 (percent)
Proprietary Turnkey	$555	$ 730	$ 965	$1,275	$1,685	$2,215	$2,915	32%	$10,015	30%
Nonproprietary Turnkey										
Hardware	95	135	185	260	365	510	715	40	3,200	30
Software	20	30	40	55	75	110	150	40	700	30
Total Turnkey	$670	$ 895	$1,190	$1,590	$2,125	$2,835	$3,780	33%	$13,915	30%
Software	13	19	25	40	55	80	115	44	795	47
RCS	25	30	40	55	70	95	125	32	405	26
Hardware	200	290	415	600	865	1,250	1,800	44	7,355	33
Total*	$910	$1,235	$1,670	$2,285	$3,115	$4,260	$5,820	36%	$22,470	31%

*Numbers may not total due to rounding.

EXHIBIT III-4

GEOGRAPHIC DISTRIBUTION OF CAD/CAM USER EXPENDITURES - ALL APPLICATIONS
($ millions)

GEOGRAPHIC AREA AND YEAR	DELIVERY MODE									
	TURNKEY		SOFTWARE		RCS		HARDWARE		TOTAL	
	USER EXPENDITURES	AAGR*	USER EXPENDITURES	AAGR*	USER EXPENDITURES	AAGR*	USER EXPENDITURES	AAGR*	USER EXPENDITURES	AAGR*
1980										
United States	$ 505	-	$ 9	-	$ 14	-	$ 140	-	$ 670	-
Western Europe	135	-	2	-	10	-	40	-	189	-
Japan	30	-	2	-	0	-	20	-	51	-
Total	$ 670	-	$ 13	-	$ 25	-	$ 200	-	$ 910	-
1986										
United States	2,650	32%	75	42%	75	32%	1,170	42%	3,970	34%
Western Europe	755	33	25	46	40	25	360	44	1,180	36
Japan	375	53	17	53	13	-	270	54	670	54
Total	$ 3,780	33%	$115	44%	$125	31%	$1,800	44%	$ 5,820	36%
1991										
United States	6,960	21	395	39	200	22	3,680	26	11,235	23
Western Europe	4,870	45	280	62	165	34	2,575	48	7,890	46
Japan	2,085	41	120	47	40	25	1,100	33	3,345	38
Total**	$13,915	30%	$795	47%	$405	27%	$7,355	33%	$22,470	31%

* PERCENT AAGR FROM PREVIOUS PERIOD
** NUMBERS MAY NOT TOTAL DUE TO ROUNDING

on into 1991, with the larger system, multistation segment of this marketplace maintaining superiority.

- The costly and complex software development activities which are at the center of all successful CAD/CAM systems have resulted in the vast majority of organizations opting for turnkey systems. The cost which must be incurred in terms of time and investment in software for internal development of systems precludes all but the largest organizations from developing their own systems.

- The rapid decline in the cost of CPUs and memory in the last decade has allowed CAD/CAM technology in the form of low-cost turnkey systems (systems with initial full-function delivery capability of less than $100,000) to be available to many more customers. These customers were previously priced out of the market, but have within the last two years, begun to purchase low-cost systems, the functionality of which lies primarily in the CAD area, with only very limited capabilities currently available in integrated CAM.

- Proprietary turnkey vendors are expected to feel the impact of nonproprietary turnkey vendors who are major computer vendors acting as system integrators and offering software obtained from outside sources as packaged CAD/CAM systems with their hardware.

- IBM is stepping up its activities in marketing Lockheed's CADAM software. CDC, Prime, Perkin-Elmer, and others are now offering MCS's AD-2000 or Anvil 4000 (or variations). All major computer vendors are expected to have CAD system offerings by the end of 1982.

- These vendors can be a serious competitive threat to the established proprietary turnkey vendors because of the computer vendors' typically more extensive resources and marketing organizations.

2. SOFTWARE

- Software products for use on in-house systems have not been a major factor within the CAD/CAM marketplace to date.

  - There are a limited number of CAD/CAM graphics software products in the marketplace today. One such system is the Anvil 4000 software offered by Manufacturing and Consulting Services of Cost Mesa, California.

    . This system, previously known as AD-2000, is a sophisticated system for mechanical, architectural, and mapping applications and has, according to users interviewed, established its major area of strength in the numerical control (NC) portion of its application structure.

    . In general, users are of the opinion that the in-house adaptation of software packages such as Anvil 4000 requires a significant amount of in-house software support in which most companies are hesitant to invest.

  - The incompatibility of the various hardware configurations used by the major vendors complicates the universal applicability of software products across vendors. This leads to high installation and support costs for vendors, users, and integrators.

  - To date, major areas of success in the marketing of software products for CAD/CAM have been in the areas of providing analysis tools.

    . Examples of products in this class are McNeil Schwindler's Nastran (finite element analysis program), and Structural Dynamics Research Corporation's (SDRC) Supertab (finite element mesh generation program).

- Some success has also been experienced with the integration of NC software with turnkey CAD/CAM systems; examples are APT, as provided by a variety of sources, and Manufacturing Data System's Compact II NC software.

- The CAD/CAM market has not generally been attractive to vendors contemplating the development of full capability CAD systems, extensive analysis programs, or integrated CAM applications due to the high cost of development and the relatively small market size.

- This situation could change dramatically if user expenditures in CAD/CAM increase faster than INPUT forecasts.

- Two potential sources of impetus to the software segment are large companies deciding to market systems initially developed for internal use (such as the Lockheed CADAM system) and an increase in the trend for vendors of specialized packages (such as analysis or numerical control) to integrate their products into other vendor's CAD systems.

3. REMOTE COMPUTING SERVICES (RCS)

- The use of remote computing services for interactive graphics-based CAD systems has been limited. Until recently, CAD applications on RCS networks required very high data transmission rates which were prohibitively expensive.

- Intelligent workstations and communicating turnkey systems (both single and multiple workstations) capable of networking with the RCS vendors' mainframes will be able to operate at more economical data rates.

- Another key inhibiting factor is the cost of RCS services for a moderate to high volume user (as compared to an in-house system). RCS will be attractive to small users or users who require special processing such as intensive analysis or access to specialized data bases.

- RCS vendors can be expected to offer on-site hardware ranging from intelligent workstations to full function systems. Such services will be classified as user site hardware services.

- RCS revenues for CAD and integrated CAD/CAM applications will remain a small portion of the total RCS market. INPUT estimates that RCS revenues for industry specific processing services in the discrete manufacturing sector were $315 million in 1980, and are forecasted to reach over $1 billion in 1985 which is approximately 10 times the integrated CAD/CAM forecast.

- As analysis processing and basically standalone CAM applications become more integrated with the CAD function, INPUT will revise its forecasts accordingly.

- Users interviewed by INPUT indicate that RCS services, with the exception of specialized application areas, are not generally in their plans for future purchases. There is a strong desire in the user community to have in-house control of CAD/CAM operations, including all software and hardware components.

4. HARDWARE

- Hardware revenue forecasts include systems, workstations, and system add-ons (peripherals and memory) purchased for systems to support user developed software, user integration of independent and in-house software, and user integration of CAD systems and CAM software. Add-ons and stations purchased from turnkey vendors are included in turnkey revenue forecasts.

- The primary use of separately purchased hardware varies by application area:

  - Electronics users will purchase hardware for in-house developed design and analysis systems.

- Mechanical uses will be divided among systems for independent CAD software packages, systems for analysis, and systems for integrated CAM processing.

- Architectural and other uses will be primarily for analysis, followed by independent CAD packages.

- System add-ons are estimated to comprise 15% of the total hardware market.

- Systems are estimated to comprise 55% of the total hardware market and consist of the central processor, memory, disk storage, peripherals, and interfaces: a mix of 45% medium-scale systems (DEC VAX 11/750-class processors), 45% large-scale systems (IBM 4341-class processors), and 10% small systems (16-bit processors) has been assumed.

- Workstations are estimated to comprise 30% of total hardware forecasts, assuming the station portion of total system costs to be 30% of large-scale systems and 40% of medium-scale systems.

D. APPLICATION FORECASTS

- The combined forecasts for all application areas are shown in the Appendix.

- Each application is discussed in the following sections.

1. MECHANICAL ENGINEERING DESIGN AND ANALYSIS

- The revenue forecasts for the mechanical applications are shown in Exhibit III-5.

- The mechanical segment of the CAD/CAM market is by far the largest single application area.

EXHIBIT III-5

REVENUE FORECAST BY DELIVERY MODE -
MECHANICAL APPLICATIONS
($ millions)

DELIVERY MODE	1980	1986	AAGR (percent)	1991	AAGR (percent)
Proprietary Turnkey	$ 230	$1,410	35%	$5,410	31%
Nonproprietary Turnkey					
Hardware	50	455	44	1,720	30
Software	10	100	47	375	30
Total Turnkey	$ 290	$1,965	38	$7,505	31%
Software	7	80	49	655	53
RCS	12	60	30	235	32
Hardware	100	870	43	4,685	40
Total*	$ 410	$2,975	39%	$13,080	34%

*Numbers may not total due to rounding

- Approximately 40% of the entire potential market for CAD/CAM products and services is contained within the mechanically oriented manufacturing community. A significant amount of this potential, and particularly new potential which will develop in the next 10 years, is resident within the manufacturing and production functions. These functions are integrated with CAD in only the largest companies.

- The largest single market sector within the mechanical area is represented by the automobile/aerospace industries which presently represent approximately 20% of the systems installed to date.

  - The automobile/aerospace industries will continue to be the major consumers of CAD/CAM products and services during the next five years as the need to produce lighter, higher performance, more fuel efficient vehicles continues.

  - The automobile/aerospace industries are also the primary center of in-house development activity as these industries continue the trend toward becoming "user integrators," and continue to develop high-performance systems to specifically meet their in-house requirements. These companies will be at the forefront of a trend toward direct purchase of hardware and software components for integration into systems of in-house design.

  - Competitive advantage and inability to obtain suitable systems to meet current technology requirements are the primary underlying reasons for in-house development activity in these leading technology companies.

- The majority of turnkey vendors are focusing an increasing share of their product development and marketing efforts on the mechanical sector. This is due to the potential size of this marketplace, and the fact that no present offering from existing vendors approaches meeting the total needs of manufacturing companies for integrated CAD/CAM capabilities. These integrated capabilities will eventually extend beyond the design process, into a totally

integrated design-production-management system planned around a complete manufacturing data base.

- Significant advances in data base management, networking, solid modeling, and interfaces to manufacturing and production control are required before the productivity potential associated with the application of computer technology to the total product development cycle may be realized.

- Justification of total manufacturing oriented systems will require methodologies which go far beyond those used by even the largest automotive/aerospace companies in the current environment. INPUT's research in the mechanical area has shown that for maximum payback to be obtained from implementation of integrated CAD/CAM systems, a more total justification methodology must be employed. In many, if not most cases, a justification methodology will be required which will allow for increased expenditures in the design cycle aimed at reduction of total costs of manufacturing production and field maintenance.

2. ELECTRONIC ENGINEERING DESIGN AND ANALYSIS

- User expenditure forecasts for this application are shown in Exhibit III-6.

- The electronic applications of CAD/CAM technology are segmented according to the complexity of the device being produced. The two major segments are:

  - Integrated circuits (IC).

  - Printed circuit boards (PCB).

- The increase in complexity associated with products within the electronics area effectively precludes the use of manual methods thus making CAD/CAM systems mandatory for production within an acceptable timeframe, and with competitive product performance.

EXHIBIT III-6

USER EXPENDITURE FORECAST BY DELIVERY MODE -
ELECTRONICS APPLICATIONS
($ millions)

DELIVERY MODE	1980	1986	AAGR (percent)	1991	AAGR (percent)
Proprietary Turnkey	$ 150	$ 470	21%	$ 800	11%
Nonproprietary Turnkey					
Hardware	12	35	20	225	45
Software	3	15	31	50	28
Total Turnkey	$ 165	$ 520	21%	$1,075	16%
Software	4	25	36	100	32
RCS	7	25	24	45	11
Hardware	65	730	49	1,730	19
Total*	$ 245	$1,300	32%	$2,950	18%

*Numbers may not total due to rounding

- The 8,000 workstations installed within the electronic applications area represent approximately 14% of the total potential installed base of 59,000 workstations in 1980.

- The integrated circuit application in general, and the VLSI portion in particular, are the most mature and penetrated turnkey segments of the CAD/CAM market. The criticality of CAD/CAM systems in electronics plus their higher level of penetration will result in earlier market saturation as reflected in the AAGR drop in 1986-1991 compared to 1980-1986.

- There is a considerable amount of in-house development activity within the large commercial IC houses.

  - Presently available turnkey systems are rapidly becoming inadequate in meeting the demands imposed by the design of increasingly dense VLSI chips.

  - The complexity and processing requirements for VLSI design analysis are forcing electronics users to turn to large in-house mainframes and in some cases to develop their own analysis software.

3. ARCHITECTURAL/ENGINEERING DESIGN AND ANALYSIS

- User expenditure forecasts for this application area are shown in Exhibit III-7.

- The architectural/engineering sector of the market is the least penetrated of the three application areas covered in this report.

  - A total of 3,000 workstations exist in 1980 compared to a total potential set of 60,000 workstations.

  - Architectural/engineering firms in particular have been slow in adapting CAD/CAM systems to their design and drafting work. These firms are in general not found to be capital investment oriented companies

EXHIBIT III-7

USER EXPENDITURE FORECAST BY DELIVERY MODE -
ARCHITECTURAL APPLICATIONS
($ millions)

DELIVERY MODE	1980	1986	AAGR (percent)	1991	AAGR (percent)
Proprietary Turnkey	$ 80	$ 580	39%	$2,805	37%
Nonproprietary Turnkey					
Hardware	14	120	43	865	49
Software	3	25	42	195	50
Total Turnkey	$ 100	$ 725	40%	$3,865	40%
Software	2	6	20	17	23
RCS	5	25	31	85	28
Hardware	35	140	27	675	37
Total*	$ 140	$ 895	37%	$4,640	39%

*Numbers may not total due to rounding

and, as such, the justification of high-priced turnkey systems has been more difficult.

- The primary area of this market where CAD/CAM technology has been adopted is with the major design/build firms. The largest of these companies have made substantial investments in CAD/CAM systems. Some in-house development and purchase of outside capabilities have begun within these firms during the last two years.

- The architectural/engineering application is, in general terms, an offshoot of the mechanical application area. Many of those processes used within architectural/engineering applications are also applicable to the mechanical segment.

  - Major differences do occur in terms of symbol libraries used by architectural/engineering companies, and formats and drafting rules applied by these companies in comparison to those used in the mechanical sector for part and tool drawings.

  - Piping routing systems, such as in the COMPEDA PDMS system, are examples of specific applications developed for use in the architectural/engineering sector. These systems are used primarily for petrochemical process plant design applications, and as such are used by major chemical and oil companies, as well as design/build firms who are heavily involved in the design of process plants for companies of this type.

- There is a significant amount of drafting activity within this application area.

  - The architectural/engineering industries are the largest single employers of drafting personnel.

- Drafting is the most fully developed function of the CAD/CAM turnkey systems, and is readily applicable to the architectural/engineering portion of the market.

- The quality and formatting of drafting output are considered to be critical factors in this market segment because the majority of companies using the technology provide drafting/documentation as the product of their activities.

4. OTHER APPLICATIONS

- User expenditures on mapping applications comprise the major share (approximately 80%) of the "other" category. Forecasts are shown in Exhibit III-8.

- While this category is not a major share of the total CAD market, it will grow at approximately the overall industry rate.

- Major users are oil companies, utilities, and state and local governments. The government sector is the most price sensitive and, as system price/performance improves, could create an increased demand for CAD systems over current projections.

EXHIBIT III-8

USER EXPENDITURE FORECAST BY DELIVERY MODE -
OTHER APPLICATIONS
($ millions)

DELIVERY MODE	1980	1986	AAGR (percent)	1991	AAGR (percent)
Proprietary Turnkey	$ 95	$ 455	30%	$1,000	17%
Nonproprietary Turnkey					
Hardware	17	105	35	390	30
Software	4	10	16	80	52
Total Turnkey	$ 115	$ 570	30%	$1,470	21%
Software	0	8	-	20	20
RCS	0	17	-	40	19
Hardware	0	55	-	265	36
Total*	$ 115	$ 650	33%	$1,800	22%

*Numbers may not total due to rounding

IV MARKET FORCES

IV MARKET FORCES

- The CAD/CAM market continued its rapid growth during 1980 in the aggregate, with some softening of demand for turnkey systems becoming evident within the electronic applications. Economic conditions in 1981 and early 1982 can be expected to slow the growth rate.

- Large commercial IC houses who have traditionally been large consumers of turnkey systems have responded to the inability of present systems to handle the complexity of the new chips under development. Response has taken the form of extensive in-house development using turnkey systems as intelligent nodes of larger systems.

- Consolidation and standardization programs are underway by the major users of mechanical CAD/CAM turnkey systems. Major purchasers, such as automotive and aerospace companies, have continued to develop and enhance in-house integrated capabilities and are, on the whole, devoting their resources to the expansion of the use of those systems which most directly meet their specific application needs.

- Many of the large traditional customers for turnkey systems are standardizing on the use of specific turnkey vendors.

  - These systems are in many cases being used in a complementary manner to in-house developed systems.

- The result of this trend will be an increasing difficulty for vendors not currently selling to a major customer or offering compatible systems interfaces to penetrate the account.

- The mechanically oriented market for CAD/CAM products and services is being targeted by most traditional and newly arrived vendors as the portion of the market they must penetrate if they are to sustain growth rates comparable to those experienced over the last few years.

  - Efforts have been undertaken to downsize products in terms of functionality and cost in order to expand the size of the potential market. Many of these downsized systems are now being configured in a manner so that they may act as remote processors to central systems previously installed.

  - The number of competitors vying for the available dollars in the mechanical market will continue to increase as it has over the last year. INPUT forecasts that no traditional vendor will have sufficient presence in the marketplace to effectively preclude entry by new vendors, or to dominate the marketplace (on a basis of total system sales) within the 1980-1986 period.

- Users report that little, if any, progress is being made in integrating CAD with CAM, thus delaying the realization of the full productivity improvement potential of CAD/CAM.

  - It is generally agreed that the traditional turnkey vendors will not be the source of the required software breakthroughs needed for total systems integration of CAD and CAM. The relatively small size of most turnkey vendors is felt to preclude simultaneous large-scale R&D efforts, and efforts on the part of the vendor to maintain an effective market presence in the face of steadily increasing competition.

- Integrated systems will become the province of the large mainframe vendors and turnkey vendors who have been acquired by large corporations.

- INPUT's survey of users has revealed that, for the most part, they continued to justify their systems through efficiencies gained in the design and drafting portions of their engineering operations.

- Most major customers for turnkey CAD/CAM systems recognize the great benefits to be gained through the integration of manufacturing functions. However, the Manufacturing and Production functions of corporations have not been traditionally participating members in the justification or purchase cycles for CAD/CAM systems.

- INPUT forecasts that the involvement of these manufacturing and production groups will accelerate dramatically in the next five years, with initial impetus coming from major mechanical users in aerospace, automotive, and their support industries.

• The initial hope for a quick technology fixed to the productivity problems being experienced in the United States, Europe, and Japan is giving way to a more realistic assessment of an evolutionary process of incremental productivity improvement. As each process within the product development life cycle is operationally defined prior to the effect of computer technology on it, justification methodologies based on a clearer understanding of overall productivity will evolve.

• One of the most critical factors in the CAD/CAM industry has been and will continue to be software.

  - Rapid advances in hardware technology have taken some of the pressure off software development by easing memory constraints, simplifying peripheral communications by putting more intelligence in devices and controllers, etc.

- However, while hardware technology has eased some problems, new pressures have developed as users more fully use their systems and are demanding more systems capabilities, more applications, and the flexibility to configure and interconnect more complex systems.

- The key to vendor success and the continued growth of the total market will be the introduction of more sophisticated and flexible software.

- Market growth cannot be sustained at the projected rates if vendors produce inflexible, highly customized software which requires the user to expand significant resources to adapt it to his needs.

• It is somewhat difficult to forecast market penetration for the CAD/CAM market, given the reality of present systems being only components of future systems which will address the entire spectrum of processes contained in the product life cycle.

- Present turnkey systems are not capable of being the hub around which a total CAD/CAM system is built, and should not be expected to fulfill that role.

- As distributed, data base-oriented systems are developed in the future, the base of potential users for these systems will increase dramatically.

• System and software vendors will face a severe test as users become more sophisticated in the use of their CAD/CAM systems.

- Vendors have been able to be graphics specialists and only lightly involved in applications, but this is changing rapidly. A prime example is the electronics industry where user requirements in VLSI have outpaced vendors' abilities to supply software.

- A key market force will be the ability of vendors to develop and support specialized software. This will most likely force vendors to specialize

in a more limited number of industries rather than attempting to market and support all applications.

V COMPETITIVE CONSIDERATIONS

V COMPETITIVE CONSIDERATIONS

A. INTRODUCTION

- The 1980 CAD/CAM turnkey market was dominated by eight vendors whose revenues account for approximately 80% of the total revenues of turnkey system vendors. These eight vendors are:

  - Computervision.
  - International Business Machines (IBM).
  - Applicon.
  - Auto-trol Technology.
  - Calma (a subsidiary of General Electric).
  - Intergraph.
  - Gerber.
  - McDonnell Douglas Automation Company (McAuto).

- The 1980 revenues for the above vendors are presented in Exhibit V-1.

EXHIBIT V-1

TURNKEY VENDOR REVENUES AND
MARKET SHARE ESTIMATES

VENDOR	1980 REVENUES ($ millions)	MARKET SHARE (percent)
Computervision	$190	28.4%
IBM	71	10.6
Applicon	66	9.9
Auto-trol	53	7.9
Calma	50	7.5
Intergraph	50	7.5
Gerber	19	2.8
McAuto	12	1.8
Other	159	23.6
Total	$670	100.0%

- Some vendors participate in all application areas while others confine their activities to a single application or sub-application area.

  - The dominance or significant market penetration in specific application areas which has been achieved by certain vendors will be the basis of growth for those companies over the next 10 years. INPUT forecasts that within the turnkey areas of application specialization, there will be very few new entries who will become predominant within their market segment.

- Exhibit V-2 presents the 1980 distribution of revenues according to application area for each of the eight dominant vendors in the turnkey market segment.

B. OVERVIEW OF LEADING TURNKEY VENDORS

1. COMPUTERVISION

- Computervision occupies a unique position among the turnkey vendor community in that it is the only truly vertically integrated organization for both hardware and software.

  - A question exists in both the vendor and user communities as to whether Computervision has integrated its product line on a vertical hardware basis too soon in a field where technological breakthroughs occur with ever increasing speed.

  - The emergence of low-cost 32-bit processor technology across broad lines of compatible equipment, such as with the DEC VAX line, presents real opportunities for companies who can integrate systems using components developed by much larger hardware vendors. The use of these new hardware technologies will be most important in large user situations where major corporations will be establishing integrated manufacturing systems and remote distributed networks.

EXHIBIT V-2

DISTRIBUTION OF 1980 REVENUES
FOR MAJOR CAD/CAM VENDORS
($ millions)

VENDOR	ME-CHANICAL	ELEC-TRONIC	ARCHI-TECTURAL	OTHER	TOTAL
Computervision	$100	$ 55	$25	$ 10	$190
IBM	69	0	2	0	71
Applicon	33	24	4	5	66
Auto-trol	21	5	20	7	53
Calma	14	25	4	7	50
Intergraph	0	0	26	24	50
Gerber	19	0	0	0	19
McAuto	12	0	0	0	12
Other	22	56	19	62	159
Total	$290	$165	$100	$115	$670

- As hardware becomes lower in cost, INPUT believes that it will be more difficult for Computervision to maintain its stance of profitability without substantial changes in management philosophy. The software element of future CAD/CAM systems will be the primary area of growth in terms of technology and refinement, with basic hardware capabilities becoming lower in cost and more generally used across a broad level of product lines.

- There are many users and competitors who feel that Computervision will be unable to simultaneously move to the next generation of computers, while at the same time developing the necessary new software and maintaining an effective marketing presence in all application areas in which it has chosen to compete.

• Computervision's strength lies in the mechanical applications area where it is clearly the dominant vendor in the total number of systems installed to date.

- Computervision's leadership position in this sector will be severely challenged in the next two years, as many vendors focus on the mechanical market.

- IBM poses a major and almost certain threat to Computervision for leadership of the mechanical market segment. While Computervision leads in number of systems installed, the typical IBM CADAM installation being installed today is targeted to support 20 or more workstations in its eventual configuration compared to 6 to 8 for Computervision.

- Business in the mechanical sector in dollar volume has traditionally stemmed from very large companies such as automotive/aerospace companies, which purchase a high volume of systems and stations and seem to be gravitating toward developing larger scale capabilities in terms of number of stations to be driven from one central processing unit.

- INPUT projects that by 1986 Computervision will hold a secondary role in the mechanical market, with IBM sales in that sector being roughly twice those of Computervision.

2. INTERNATIONAL BUSINESS MACHINES (IBM)

- IBM has rapidly gained market share in 1980 and 1981 through increased sales of the CADAM system which is based on hardware from IBM and software from Lockheed.

  - The typical CADAM installation is much larger than the systems associated with other traditional turnkey vendors. It is estimated that the average number of workstations currently employed on CADAM systems is 10 to 15, versus an average of four stations per system on configurations provided by other turnkey vendors.

  - IBM continues to be an aggressive competitor in the mechanical sector, and will become a dominant force at the high end of the market in the 1982-1983 timeframe.

- IBM has recently announced an exclusive licensing arrangement with Bell Northern Research for implementation of its software for the design of printed circuit boards.

  - It is obvious from recent development that the wait for IBM's full-scale entry into the CAD/CAM market is over.

  - IBM is also seeking out improved mechanical 3-D and solids modeling capabilities from existing sources of developed software in Europe and the United States.

- The availability of plug-compatible processing units and system components for IBM graphic based systems accentuates the marketing and growth capabilities for these systems. An example of this plug compatibility can be found in

the offering of terminals from Adage and Vector General, which are plug compatible with IBM's 3250 graphics stations (manufactured for IBM by Sanders).

- INPUT estimates that by early 1982, IBM could replace Computervision as the dominant vendor for CAD/CAM products within the mechanical portion of the market. This is based upon equivalent purchased prices of systems, accepting that in many cases IBM systems and the CADAM software offered with them are provided on a lease basis.

  - The use of hardware and software lease arrangements by IBM must be considered in evaluating the level and value of systems being sold and installed. IBM maintains a significant advantage in the marketplace through its capability to provide a variety of lease plans from its captive leasing company, as opposed to smaller turnkey vendors who do not enjoy this marketing advantage.

- IBM brings to the marketplace a mature and professional marketing organization coupled with its service force which has set standards for performance. Other vendors in these markets will be hard pressed, given their limited resources on a comparative basis, to meet the growth rates which most of these companies target for the next five years.

- While certain capabilities of CADAM are perceived by users to be limited, CADAM enjoys a reputation for being the easiest system to train operators on, and as such is viewed as being an inexpensive drafting and design tool (per station cost on a relative basis in configurations including over 10 workstations).

3. APPLICON

- Applicon competes most effectively within the mechanical and electronic segments of the market. The main thrust recently has been directed at the much larger mechanical market.

- Their market presence and product capabilities should be sustained and enhanced by their associations with Fairchild (electronics) and Manufacturing Data Systems (numerical control software and services) under the corporate umbrella of their parent, Schlumberger.

- Applicon's most significant recent announcement has been the introduction of a solid geometric modeling capability, an effort to more effectively meet the needs of the mechanical market.

- Applicon will mount a more serious attack in architectural/engineering applications, but has a late start in that area. The relatively unpenetrated nature of that market gives Applicon the opportunity, at this point, to make some gains, but INPUT forecasts that it will not assume a role of dominance in that area.

- Applicon's market position in the electronic turnkey sector is significant in 1980 terms, with Applicon and Calma being roughly tied for second place behind Computervision. INPUT forecasts that Applicon will achieve second position in this marketplace in 1986, with Computervision being the number one vendor.

  - However, INPUT also forecasts that the electronic segment will be the slowest growth area of the turnkey market over the next 10 years and, as such, the growth which Applicon can expect from this sector will be minimal as opposed to opportunities derived from other market segments.

4. AUTO-TROL TECHNOLOGY CORPORATION

- Auto-trol provides turnkey systems based on Univac and DEC minicomputers.

- The mechanical and architectural segments are those in which Auto-trol competes most effectively. However, it is considered to be among the most vulnerable to the increased competitive environment which will characterize the mechanical market during the next few years.

- The success of Auto-trol in implementing the AD-2000 software acquired from MCS is yet unmeasured in the general marketplace. There is a feeling among the user groups in general that Auto-trol has had difficulty, as apparently have several other companies such as Tektronics, in implementing this software in a general user environment. Auto-trol has assumed all maintenance and enhancement responsibilities for this software, and as such has purchased full rights to the initial version of the software obtained from MCS.

  - Auto-trol is perceived within the architectural/engineering world to be a leader in excellence of drafting output quality. This reputation in the architectural/engineering marketplace will continue to serve Auto-trol well over the period from 1980 to 1986.

  - INPUT forecasts that by 1986 Autotrol will be one of the four major vendors within the architectural/engineering marketplace if it is able to resolve its financial and resource problems.

5. CALMA

- Calma, which was acquired by General Electric Company, participates primarily within the electronics portion of the market. INPUT estimates that 80% of their installed base falls within this sector.

  - Calma is attempting to move into the mechanical and architectural areas and anticipates that the resources available from the new parent will facilitate this shift in emphasis.

  - Calma could be a formidable competitor in the mechanical sector if they can successfully leverage the resources and manufacturing know-

how of GE. They can also benefit from a tie-in to the GE Information Services RCS network to provide integrated, distributed manufacturing and analysis processing.

6. INTERGRAPH

- Intergraph operates within the architectural and mapping areas of the CAD/CAM market.

  - Intergraph is well situated within this limited market, and will continue to gain market share as the other vendors fight it out for dominance in the mechanical market.

  - Users feel that in general, Intergraph's adaptation of color display technology and development efforts to establish centralized data base capabilities will help in its efforts to maintain a role of dominance or near dominance in the architectural/engineering sector over the next five years.

7. GERBER

- Gerber Scientific is now directing its new application development efforts toward the electronic application area in general, and the printed circuit board field in particular.

  - The Gerber PC800 system is designed to address the needs of LSI and multilayer PCBs.

- Gerber systems technology provides the mechanically oriented IDS-80 systems for design, drafting, and NC tape generation.

  - Gerber's present hardware configuration of 16-bit computers from Hewlett-Packard will be a limiting factor as it competes with other vendors offering 32-bit minicomputer-based capabilities.

- Gerber appears to be losing market share in the mechanical marketplace which has traditionally been its stronghold.

8. MCAUTO

- The Unigraphics systems supplied by McAuto have recently improved its market position substantially, as the system placement rate has dramatically increased in 1981.

  - The Unigraphics system is available on a variety of hardware vehicles including Digital Equipment Corporation (DEC), Data General, and Hewlett-Packard.

  - McAuto's association with the manufacturing community through its parent McDonnell Douglas Corporation enhances the image of the product in that it can incorporate the needs of the engineering and manufacturing disciplines through direct experience.

- McAuto's recent acquisition of marketing rights to architectural/engineering software supplied by Applied Research of Cambridge provides for a unique new product entry by this company in that market sector. INPUT predicts that this product line, which has been marketed on a limited scale to date within the United States, will experience substantial growth over the next five years given that McAuto's marketing capabilities are firmly placed behind it.

C. GENERAL COMPETITIVE ENVIRONMENT

- It has been a common complaint among users that the products offered by the vendors demonstrate a serious lack of understanding of a detailed application process and require far too much adjustment on the part of the system users.

- This situation will change as more vendors enter the field with software capabilities purchased externally or developed in-house for their own use and targeted at specific applications and industries. This will give them an edge over vendors who have developed more generalized packages.

- New vendors entering the marketplace in the last several years are finding some success with the marketing of low-cost turnkey systems where fully functional systems are priced at $100,000 or less.

  - Noteworthy examples of successful companies in this field are Sigma Design, with roughly 50 systems installed by mid-1981, and AM Bruning, which has acquired small systems capabilities from Grafcon in Tulsa, Oklahoma.

  - The larger turnkey manufacturers do not appear to be actively pursuing this low-cost marketplace, but are downsizing their systems to allow them to access the market gap between their present systems and the low-cost systems.

- A partial list of the vendors participating in this market segment include:

  - Scientific Calculations.

  - Nicolet Cad.

  - Data Technology.

  - Sigma Design.

  - Holguin.

  - Interactive Computer Systems.

- Ferranti Cetec.
- Redac.
- Design Aids, Inc.

- Other vendors now participating in the market but whose entry has been too recent to have had an impact include:
  - Control Data Corporation.
  - AM Bruning.
  - Perkin-Elmer.
  - Prime.
  - Manufacturing and Consulting Services Inc.
  - Calcomp (a subsidiary of Sanders).

- INPUT forecasts that the companies named in the above two lists will experience some fallout in the market during the next five years. Certain of the companies do not appear to be investing significant enough resources to capture any meaningful portion of the market in their target areas. Additionally, it is highly probable that several of these companies will be acquired during the period by larger companies who wish to leverage the smaller companies' specialized knowledge into new or expanded markets.

- As the number of vendors offering CAD/CAM products and services proliferates the potential user will be presented with an ever increasing variety of products with varying levels of performance and quality.

- The strategy employed by the vendors at the high end of the market will be to continue adding function rather than passing along the reductions in hardware prices which will occur during the next decade.

- This will provide a continuing opportunity for new market entrants with specialized systems for narrow subsets of the major application areas. It should be noted, however, that these specialized vendors cannot be expected to capture any significant portion of overall market share, but will rather be dealing with subsets of markets which are too small or too specialized to attract attention from major vendors.

D. COMPETITIVE AND MARKET DYNAMICS

- The 1980s will be the most significant years since the development of CAD systems.

  - The technology has been established as a proven tool to dramatically improve the productivity of skilled technical people and allow the development of new products.

  - The industry has grown to the point where it is attracting new users and vendors at all levels of need and capabilities.

  - The use of CAD is progressing rapidly beyond the initial design, drafting, and analysis capabilities and is entering a new period where CAD will be linked with computer-aided manufacturing and management systems for even greater efficiencies.

- Some of the dynamics of this new period are explored in this section as they apply to the competitive and overall market situations.

I. OVERVIEW

- The vendor picture has become very dynamic and will continue to be so for the next three to five years after which it will stabilize.

- Vendors are aggressively entering the market at all levels:

  - Small companies are entering the market at a rate of nearly one per month generally with small, standalone systems for specialized applications.

  - Mid-range computer vendors such as Prime and Perkin-Elmer are licensing full function CAD systems to sell in conjunction with their hardware products as nonproprietary turnkey systems.

  - Large mainframe vendors are also entering the market or significantly adding to their existing capabilities and are taking the same licensing approach as the mid-range vendors.

- This is a significant challenge to the older CAD/CAM vendors who had only a limited number of competitors during the market development years of the mid- to late 1970s.

- The small vendors typically deal with a much smaller market segment, so they do not pose a direct threat to the established major system suppliers. However, they are a downstream threat because they intercept new users entering the market; this can delay their purchase of larger systems as well as complicate later sales efforts.

- Mini and mid-range computer vendors will compete head-on with the traditional turnkey suppliers in the four to ten station system area. These vendors will not be significant competition for their first several years as they build staff, expertise, and credibility, but they will have the effect of fragmenting the marketplace and delaying potential customer decisions.

- Mainframe computer vendors pose the greatest threat to existing turnkey vendors.

  - They have the corporate resources, field organization, and market visibility to mount a serious attack on the marketplace.

  - Their larger systems (15 or more workstations) will be directed at major corporations who will also be prospects for distributed and integrated systems.

  - These vendors have an edge on the proprietary turnkey vendors in the integration area because of the mainframe companies' experience in linking diverse applications into major data base systems.

- Prime and Perkin-Elmer have announced CAD/CAM systems in the mid-range arena and should be followed shortly by Hewlett-Packard.

- DEC could be a significant competitor in this segment, but it remains to be seen whether its internally powerful OEM organization will tolerate competition with its customers in the turnkey business such as Applicon and Intergraph.

- IBM already has a significant market presence in the large system area and is aggressively adding to its organization. It will continue to add products to its core software, Lockheed's CADAM, such as its recent announcements of PCB design software and a geometric modeler.

- IBM is rumored to be upset with Lockheed over its licensing of CADAM to IBM competitors such as Fujitsu in Japan. IBM technically did not have an exclusive license to CADAM, but in effect it was exclusive because no significant competitors were offering it.

- It is entirely possible that IBM will announce an exclusive CAD/CAM system in 1982 or early 1983 to replace CADAM.

- CDC is in the market entry phase with its product, CD-2000, but will require several years and continued corporate backing to establish a solid position as a viable competitor.

- Univac has been successful in the last three years in the manufacturing sector with its UNIS software and should be able to leverage this presence with a CAD/CAM offering. However, it will experience the usual start-up problems with staffing, organization, and identity.

- Honeywell and Burroughs will join the mainframe CAD/CAM ranks, but in INPUT's opinion they will fit into the lower tier of a three-tier vendor structure with IBM at the top and CDC and Univac in the middle.

- The RCS market will be almost as dynamic as turnkey, but on a smaller scale.

  - McAuto is aggressively staffing its field and headquarters groups and has successfully rejuvenated its Unigraphics turnkey system. It has broadened its product line and can accommodate a range from stand-alone systems to distributed, RCS-based systems in both the mechanical and architectural areas.

  - Boeing Computer Services, CDC, and United Computing can all be expected to take the same approach.

- It will be several years before the results will be clear, but the full range of offerings (from pure RCS and turnkey to RCS with vendor supplied user site hardware) by RCS vendor, if successful, could expand the market potential for RCS.

2. SPECIALIZATION

- Early CAD/CAM system vendors could afford to cover multiple applications because the systems were not as widely or intensively used as they are today.

- Users are progressing beyond basic applications into more sophisticated uses and are developing needs to extend into new application areas such as manufacturing planning and control.

- The resource strain this is placing on the multi-application vendors will intensify and force them to specialize on one or at most two broad application areas.

- The current attitudes of some turnkey vendors that all their software must be a proprietary development will not be affordable for them by the mid-1980s given the increasingly demanding and competitive nature of the market.

- The forces for specialization will result in a broader market for specialized software vendors who will both sell directly to end users and license their products to hardware and system vendors.

- Specialized vendors will be found in a broad range of areas including analysis, industry-specific designs, industry specific CAM applications, system and software interfaces for integration, and system utilities, as well as software and services to modify existing products to unique customer needs.

- The INPUT forecasts of the software market did not consider a high level of specialization but were based more on the existing software market. If specialized vendors are attracted to the CAD/CAM market, it could represent a sizable increase in user expenditures for software.

- Increased demand will also result in major users bringing applications to the market that were originally developed for in-house use. These applications will typically be licensed to equipment vendors rather than marketed directly.

3. CONSOLIDATION

- The intense competition in CAD/CAM will force a consolidation of vendors for a number of reasons:

- Smaller vendors or those who have spread themselves too thin with multi-application development and support will lack the financial resources to fund expansion.

- Larger companies will acquire smaller, more specialized firms for their expertise and products to round out their product line.

- Large corporations are becoming interested in CAD/CAM as a means of developing a full spectrum of products to offer a total solution to their customers. Recent activities by General Electric and Schlumberger are examples of this.

- INPUT predicts that consolidation will become very active over the next three to four years and then level off to a more normal rate by 1985.

- Some potential acquisition situations among the proprietary CAD/CAM vendors are:

  - Auto-trol - substantial funding may be required for product enhancements and additions to its field force for improved support and market expansion.

  - Computervision - total vertical integration (proprietary development of all hardware and software) may prove to be too great a burden in a more competitive market resulting in either acquisition or a change to outside suppliers.

  - Gerber Scientific - showing signs of losing market share and may require more resources to stay in the market than its parent can afford or is willing to commit.

  - Intergraph - its focused market approach is apparently successful, but could make it a very attractive candidate for takeover.

4. INTERNATIONAL VENDORS

- U.S. companies are the dominant world suppliers of CAD/CAM systems today.
  - Computervision's CAD/CAM exports in 1980 were approximately $70 million with some 76% of this going to Europe and 24% to Japan.
  - Applicon's FY 1981 exports to Europe were approximately $12 million (16% of their gross revenues).
  - Nearly all other suppliers have European offices or affiliates and many are now establishing operations in Japan.
- Activities in Europe are increasing as the market begins to develop. Some sophisticated products have been developed there but have not done well due to the limited marketing activity.
- Some European software products are entering the U.S. market now through licensing agreements with U.S. computer vendors.
- Direct European entries into the U.S. market are expected to come primarily from acquisitions of or mergers with U.S. companies. An example of this is the Ferranti-Cetec acquisition of a 14% share in Vector General.
- It is not expected that European vendors will represent a significant force in the U.S. market in the early 1980s.
- Japan has no significant internal CAD/CAM industry at the present time and relies on imported or user developed systems. INPUT expects this situation to change rapidly over the next five years.
- Japanese companies have been very successful in developing and applying sophisticated manufacturing systems. Research and development in such areas as geometric modeling, data management systems, standardization of engi-

neering data bases, process planning and experience in the planning, monitoring, and control of automated processes will result in sophisticated systems for export.

- There is an ample home market for CAD/CAM systems, but major Japanese companies such as Fujitsu, Hitachi, and NEC can be expected to enter the U.S. CAD/CAM market in the next several years. Their initial targets will be the large, sophisticated firms such as electronics, aerospace, and transportation.

- While they will not be able to obtain a significant share of the U.S. market by the mid-1980s, they could pose a threat in the highly specialized, large company segment of the market. They will have a significant impact on foreign vendor efforts in Japan.

APPENDIX: DATA BASE

APPENDIX

USER EXPENDITURE FORECAST BY APPLICATION, FOR CAD/CAM - ALL DELIVERY MODES

($ millions)

APPLICATION	1980	PERCENT OF TOTAL MARKET	USER EXPENDITURES 1981	1982	1983	1984	1985	1986	PERCENT OF TOTAL MARKET	GROWTH 1980-1986 (percent)	USER EXPENDITURES 1991	PERCENT OF TOTAL MARKET	GROWTH 1986-1991 (percent)
Mechanical	$410	45%	$ 570	$ 795	$1,105	$1,540	$2,140	$2,975	51%	39%	$13,080	58%	34%
Electronics	245	27	320	425	560	745	985	1,300	23	32	2,950	13	18
Architectural	140	15	190	255	350	480	655	895	15	37	4,640	21	39
Other	115	13	155	205	275	365	490	650	11	33	1,800	8	22
Total	$910	100%	$1,235	$1,680	$2,290	$3,130	$4,270	$5,820	100%	36%	$22,470	100%	31%