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INFORMATION SERVICES INDUSTRY-SPECIFIC AND CROSS-INDUSTRY MARKETS

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Issues, Trends, and Events

I

Issues, Trends, and Events

A Introduction

Computer-aided engineering, computer-aided design, and computer-aided manufacturing (CAE/CAD/CAM) is the major component of the applications that are covered in the engineering and scientific market. While the report focuses on the CAE/CAD/CAM segment of the market because it is the largest and the most dynamic, the forecasts also include scientific applications for such uses as biological research, statistical analysis, and linear programming.

CAD/CAM includes design and drafting applications and also applications such as structural analysis and structural engineering. However, for the purpose of analysis, structural analysis applications are covered in a separate section.

CAD/CAM includes a wide range of applications:

- Mechanical design and drafting that includes finite element modeling and analysis, wireframe analysis, surface design, and solids modeling.
- Electronic design that includes circuit analysis, schematic capture, schematic design-rule checking, and integrated circuit layout.
- Architecture, engineering, and construction (AEC) that includes plant design, piping design and analysis, building design and management, mapping, and site engineering.
- Computer-aided manufacturing includes robot program design and simulation, and numerical control programming.

CAD can stand for either computer-aided design or computer-aided drafting.

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- Computer-aided design involves design rule checks on drawings that have been entered. The design rule checks performed include checking for typographical errors, simple design mistakes, and for incomplete drawings. Examples include checking for spacing for parts, electrical overloads, and unspecified sizes of parts.

In addition to designing products, engineers also analyze the designs to make sure the products perform as required. Computer-aided engineering (CAE) programs fulfill this role.

Sometimes the terms CAD and CAE are used interchangeably because they are both design automation tools. However, there are important differences between the two:

- CAE systems are used at the "front-end," where products are conceived. They are used by engineers to automate the analysis and simulation of the design. In analysis and simulation, a mathematical or software model of the design is created and tested under various conditions. The results of these tests show what a physical model would do under the same conditions.

- On the other hand, CAD systems are used to draw and analyze physical structures. They are typically employed at the "tail end" of the product development process where they are used to convert engineers' designs into production drawings. The engineering and scientific market is typified by work that spans many industry segments, yet is concentrated in manufacturing, both discrete and process.

Approximately 17% the total CAE/CAD/CAM turnkey systems is included in the engineering and scientific segment forecasts. The remainder is included in the discrete manufacturing, process manufacturing, utilities, transportation, federal government, and other sectors.

- Likewise, the CAM portion is excluded from the analysis and forecasts in the engineering and scientific section. User expenditures for CAM sales are included in the discrete manufacturing industry sector.

- Expenditures by architectural and engineering firms for applications that are designed specifically for that type of firm, as opposed to an application designed for engineers or architects in any type of firm, are included in the industry-specific services sector under architectural and engineering services.

B
CAD/CAM

There are three major groups of CAD/CAM turnkey systems:

- The first is a low-cost system that sells for less than $20,000. These systems are typically dedicated to a single task such as semiconductor

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design. The IBM PC AT is the primary hardware for these products. These systems are typically limited to drafting and two-dimensional (2D) design capability.

- The second group of systems have more than one graphics workstation linked together in a cluster. Such systems begin at around $100,000 and are suited to the needs of medium-sized firms with complex design needs.

- The third group of CAD/CAM systems comprises of the largest and most expensive equipment. These systems allow many designers to work on different portions of one project by using separate workstations that are connected to the central computer that updates and coordinates the whole design process. The high end of the market is growing at a slower rate than the other two groups.

The CAD/CAM market is characterized by the influx of microcomputer-based products into what had previously been a minicomputer and mainframe dominated market. PC CAD software has become a commodity product. PC-based systems have hurt sales of the high-end systems.

In addition to the move toward PC-based systems, the major trends in the CAD/CAM industry are the following:

- Move toward open architecture or industry-standard platforms.

- Emergence of systems to integrate mechanical design, engineering, and shop floor manufacturing systems.

- Integration of data management and computing systems. An effective data base management environment is necessary for the integration of a multi-vendor information system.

- Communications across disparate workstations and computer systems from multiple vendors. In order to address these communication problems, CAE/CAD/CAM vendors are making major shifts in their workstation offerings toward systems based on emerging industry standards.

- Distribution solutions in a hierarchical setting. The promise of a hierarchy of computing systems is that data management and archiving functions are performed at the host level and the interactive data management and design applications at the workstation level.

- Back-end processors at the departmental level.

- Move toward solids modeling and three-dimensional (3D) capabilities.

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- Introduction of more intelligence through the incorporation of expert systems.

- Greater involvement of senior management in the decision to buy a system. CAD/CAM systems have become capital-expenditure items, thus requiring the approval of senior management. This lengthens the sales cycle.

- Move toward component CAD/CAM systems. Companies that already have computers installed are reluctant to buy integrated CAD/CAM systems that may duplicate what they already own. Instead, they are likely to want separate CAD/CAM components such as software and graphics workstations that they can connect to their existing hardware.

Vendors of CAD/CAM systems are focusing on front-end and back-end design applications since the drafting function of CAD has become a commodity product. As a result, vendors are placing increased emphasis upon integrating formerly disparate applications.

Turnkey CAD vendors are facing increasing pressure to unbundle software giving users even more choices in assembling their systems. Traditional companies will find it difficult to keep up their revenue streams.

A recent development has been the appearance of consulting centers designed to help CAD users do their own integration. These centers provide users with the guidance, training, and consulting needed to get their systems up and running.

C

CAE in Electronics Industry

The need for CAE tools in electronic design resulted from the increasing complexity of large-scale integrated circuits and the electronic systems incorporating such components. This increasing design complexity has significantly lengthened the product development cycle while, at the same time, more competition in the electronics industry has shortened product life cycles.

- The primary user benefits of CAD/CAM/CAE systems are in producing products less expensively and, more importantly, developing them faster to take advantage of market windows.

- CAE is used to improve the quality of design by simulating operational performance and by reducing the turnaround time for various phases of electronics engineering, including defining overall system architecture, logic circuit layout, design-rule checking, and timing simulation.

- This implies that there will have to be significant links between the design function and the production function, and post-production issues such as product testing and field service. Engineers want the design to

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go smoothly from CAD to CAE and then to CAM in a fully integrated system.

There are about 3,000 chip designers in the world compared with about 400,000 systems designers. The integrated circuit designers were the initial purchasers of CAE tools. The trend is toward system design rather than chip design. CAE tools will be more gradually adopted by systems designers which will be accompanied by evolutionary changes in the characteristics of CAE tools and suppliers. Systems designers will require tools that are easier to learn and use and which address a broader range of electronic design applications. It takes a long time, even for a sophisticated IC designer, to learn how to use the current systems.

A key issue facing CAE vendors now is data management, that is, the ability to move data through a particular vendor's system as well as the ability to transfer data from one vendor's system to another. However, because of the sheer volume of data and the assortment of formats used, data management presents a formidable challenge to the industry.

Currently, three companies dominate the CAE tools marketplace: Mentor Graphics, Daisy Systems, and Valid Logic Systems. The market forces facing these three leading CAE vendors are:

- Customers are demanding easier-to-use systems that cost less.
- Start-up companies are offering PC-based systems.
- Established instrument, CAD/CAM, and computer companies are suddenly attracted to the CAE market.

Vendors that have either entered or have announced their intention of entering the CAE market include:

- Tektronix, a leading instrumentation company, who acquired CAE Systems, Inc. of Sunnyvale, California.
- Hewlett-Packard, which has floundered in its attempts to develop CAE software, purchased a CAE software company—Cericor Inc. of Salt Lake City, Utah.
- The CAD/CAM companies, led by Computervision, Intergraph, General Electric's Calma subsidiary, and Schlumberger's Applicon division, have already begun encroaching on the CAE market.
- AT&T and IBM, with their own advanced internal CAE tools, could each be a major force in the market.

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However, all has not gone well for these new entrants.

- Companies like Hewlett-Packard and Tektronix have barely gained a toehold in CAE.

- The established CAD vendors have had trouble moving into CAE as well. Both Computervision and Calma bought small CAE startups to help them move into chip design systems, but marketing and technical problems have hampered their product introductions.

It takes a major investment of both time and resources to successfully penetrate this market. The software involved is very complex and, as H-P and Tektronix have discovered, more difficult and time consuming than anticipated. One cannot rush into the market with a CAE application.

- In addition, an ever increasing number of product features are required to enter this market. Additional features that have been added recently to CAE systems include PCB layout, ATE (automatic test equipment) interfaces, silicon compilation, and standard cell layout.

- The newer CAE products integrate the once independent functions of design, design verification, layout, and test generation, thereby easing the bottlenecks in the design-to-production process.

D Structural Analysis

Structural analysis and modeling is of interest to a diverse range of customer segments, including the aerospace, automotive, and civil engineering industries. In general, engineering analysis involves the detailed simulation of structural behavior under a variety of operating conditions.

Typically, such analysis involves the use of "finite element modeling" (FEM) techniques for solutions. Finite element analysis, the most widely used of the structural engineering techniques, divides the structural unit being modeled into a discrete number of well-defined elements—the finite elements. These elements are assumed to be connected to each other in simple geometric shapes that individually lend themselves to analysis. The geometric shapes are then added together to form the essential structure of the object. Using this technique, the behavior of complex shapes, such as an airplane wing or an automobile fender, can be studied.

The commonality and generic appeal of FEM techniques applied to diverse applications had led to the development of industry standard software packages, such as ANSYS, NASTRAN, PATRAN, and STRUDL.

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- The most popular FEM software is MacNeal-Schwendler Corporation's MSC/NASTRAN, a continuously enhanced version of the original NASA structural analysis program currently licensed for a monthly fee to over 300 customers in aerospace, defense, energy, construction, and consumer products industries. The full-scale program is available from most RCS vendors that support engineering and can be leased by a corporation for use on its own mainframe or minicomputer.

- Dozens of other structural simulation packages are available either in the public domain or for a fee from third parties, generally designed to aid in problem solving applicable to specific disciplines of engineering analysis.

The STRUctural Design Language (STRUDL) is an outgrowth of work done on computerized engineering techniques at MIT in the 1950s and 1960s. The early programs were in the public domain. Several software and RCS vendors have used this code as the basis of their own proprietary offerings. Proprietary STRUDLs offer greatly enhanced capability for analyzing complex structures under a wide variety of conditions. These packages feature automatic model generation, graphics model verification, automatic load generation, complete building code compliance, and member (element) redesign.

E

Workstations

Today's workstation environment is marked by high-speed color graphics and the ability to run complex programs, making intense use of local CPU resources, while tapping shared resources via networking.

1987 marks a turning point with prices of workstations declining to affordable levels for many users. The low-cost workstations will dominate the market in terms of units sold.

Agreement among vendors, in the form of widely accepted standards, particularly in the area of window management, has spurred applications development by independent software vendors. A standard provides a stable framework within which new products can be developed with some assurance of being transportable to other environments.

There will be four major CAE/CAD/CAM workstation platforms accepted over the next few years:

- Unix workstation (Apollo, Sun, etc.)
- DEC MicroVAX family
- IBM PC family (PC AT compatible, PS/2 series)
- IBM workstation family (RT PC)

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F

Silicon Compilers

One new technology with a great deal of promise that has so far failed to take off in the market is silicon compilers. A silicon compiler is a computer program that automatically designs a chip based on engineering descriptions of what the circuit should do. These compilers go beyond the capabilities offered by present CAE systems by actually doing the design of the chip. Despite much promise, the market for silicon compilers has not grown as quickly as expected.

Silicon compilers began appearing in late 1984. Today, they are sold mainly by three small, private companies: Silicon Compilers Inc. (San Jose, CA); Seattle Silicon Technology (Bellevue, WA); and Silicon Design Labs (Liberty Corner, NJ).

One established semiconductor company, LSI Logic, has recently entered the market with a silicon compiler based on a different concept. Rather than accepting the compromises in design that current products trying to automate the design of all types of chips are forced to make, LSI is developing a different compiler for each of the dozen or so major types of chips.

The reasons this market has failed to take off at this point are:

- The electronics companies, their primary customers, have just begun to recover from a two year slump.
- While silicon compilers can do the design job faster than an engineer, they still do not do as good a job. Computer-designed chips waste more space on the silicon, making such chips more expensive to manufacture.
- However, silicon compilers have a bright future. Because chips are becoming so complex, engineers can no longer do the design without the aid of a computer. There must be a way for a designer to deal with all of the intricacies of a complex integrated circuit, and silicon compilers offer one the few, if not only, available solutions.

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Market Forecasts

II

Market Forecasts

The four largest markets for CAD systems are:

- Mechanical design—this is the largest area, encompassing the aerospace and automobile industries.
- Integrated and printed circuit board design—this primarily includes the electronics companies.
- Civil engineering—this includes the construction industry. The primary use is for piping design and layout. Key users are oil and chemical companies and construction contractors that design and build refineries and chemical plants.
- Mapping—this is used primarily by local and federal government agencies for municipal planning and public utility mapping. Natural resource firms are using CAD techniques for mapping seismic data on mineral deposits.

The largest market for CAE is for electronics design, particularly for integrated circuit design.

User expenditures for cross-industry engineering and scientific applications will grow 14% annually through 1992, increasing from $911 million in 1987 to $1.8 billion in 1992, as shown in Exhibit II-1.

One promising area is remote computing services based on a supercomputer. Supercomputer processing services, such as Control Data Corporation's Cybernet service, provide the processing capabilities necessary for a number of applications such as wind tunnel simulation.

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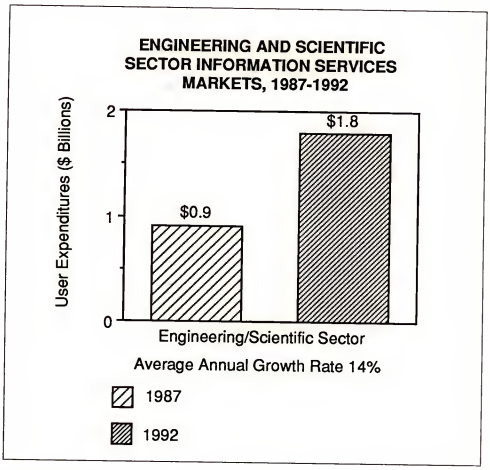
EXHIBIT II-1



Forecasts for user expenditures by delivery mode are shown in Exhibit II-2. Application software user expenditures will grow most rapidly at a rate of 25% as firms buy engineering/scientific software for their in-house computer systems. Appendix ES-A contains the forecast data base for each year, 1986-1992, by delivery mode.

The CAE/CAD/CAM industry is in a transition from the rapid growth of the early eighties to a period of slower expansion. The reasons for the slowdown in growth include the following:

- The initial period of rapid growth has slowed as the "early adopter" phase has run its course and vendors face a more difficult task of selling to a new level of customers. Unlike the early days of CAD/CAM, companies want their systems to fit into their overall corporate plans for automation.

- CAE/CAD/CAM systems are now considered as capital expenditure items. Purchases require senior management approval and as a result long purchase cycles. The capital spending slowdown in recent years depresses the market for CAE/CAD/CAM systems.

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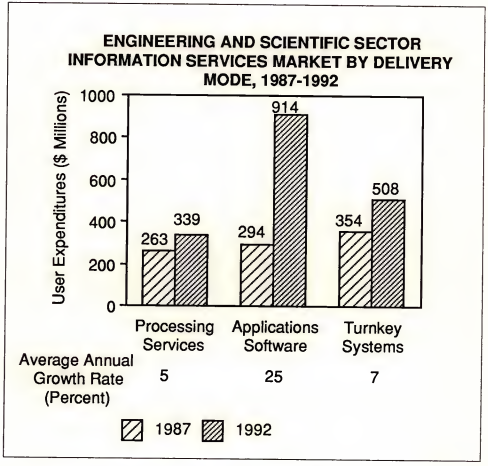
EXHIBIT II-2



- There has been a huge price erosion in the marketplace. Consequently, the dollar values do not provide an accurate picture of the industry. While industry growth is not significant in dollar terms, unit volumes have soared.

- The intense competition in the industry, particularly among the workstation manufacturers has led to "lower-than-anticipated" prices.

More rapid growth in the CAE/CAD/CAM industry will come from low-end systems where PC-based systems are proving to be an increasingly popular choice. PC-based CAD software such as two-dimensional drafting software are becoming commodity products. The CAE segment is a promising market due to the advent of low-cost entry level CAE workstations and the low penetration of the overall market.

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Competitive Developments

III

Competitive Developments

A Introduction

The engineering and scientific marketplace is characterized by new product introductions and extreme price competition to the benefit of end users.

With the introduction of the Macintosh II, Apple has the opportunity to capture a share of the low-end market.

IBM's introduction of the Personal System/2 series of personal computers has signified the emergence of a new front in the workstation arena. These computers offer good graphics, considerable processing power, and large memories.

1987 marks a turning point with workstations available at affordable prices. With prices dropping into the $5,000 range, workstations appear to be on a collision course with PC-based systems. Further price-cutting and MIPS one-upmanship between Sun, Apollo, and DEC promises to put affordable systems within the reach of more users. While Apollo and Sun are the leaders in the workstation market, they will have to contend with increasing competition from the major computer companies, DEC, Hewlett-Packard, and IBM. As customers look for integrated systems and vendor stability, the major computer companies are likely to be the beneficiaries.

DEC has changed its pricing policies to the disadvantage of its OEMs, including turnkey vendors. The company has revised its discount rates and made them the same for OEMs and volume end users. This makes it easier for some users to buy the hardware from DEC and "unbundled" software from a CAE/CAD/CAM vendor.

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B

Vendor Profiles

1. APPLICON (4251 Plymouth Road, Ann Arbor, Michigan 48106)

a. Products/Services

Applicon, an operating unit of Schlumberger Limited, offers turnkey systems for CAE/CAD/CAM/CIM applications. The company's major product offering Bravo3 is based on a broad range of integrated applications with a common user interface.

b. Markets Served

Applicon offers computer-aided tools to industries whose products are mechanical, electronic or a combination of both. These industries include semiconductors, consumer products, defense, automotive, aerospace, and metals.

c. Company Strategy

Rather than compete head-on with IBM, Intergraph, and Computervision at large accounts, Applicon has repositioned itself to focus on small and medium companies.

d. Recent Activities

In March 1987, Applicon announced several new products:

- Bravo3 Facilities software package for the graphic layout of facilities, equipment, and utilities for manufacturing plants.
- Bravo3 Tech Doc technical documentation software integrates graphics and text and produces camera-ready typeset quality documents.
- Design Review software, an easy-to-use application for viewing graphics data.
- Graphics Workstation GW4790, a high performance graphics workstation.
- Applicon also announced lower prices and unbundling of all Bravo3 software.

e. Future Directions

Applicon anticipates that electronics customers will account for 25% of its sales by 1988; they now represent less than 15% of revenues.

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2. AUTO-TROL TECHNOLOGY CORPORATION (12500 North Washington Street, Denver, Colorado 80233) Revenue (FYE 12/31/86): $62.4 million

a. Products/Services

Auto-trol manufactures and markets turnkey CAD/CAM systems. Auto-trol's systems integrate hardware, proprietary graphics software, and applications software. The hardware components of Auto-trol systems include the Advanced Graphics Workstation (AGW), the Advanced Raster Workstation (ARW), and the Advanced Personal Workstation (APW).

Graphics and applications software include Auto-trol Series 5000 Advanced Graphics software and Auto-trol Series 7000 Advanced Graphics software.

b. Markets Served

Auto-trol's primary markets are the architecture, engineering and construction, mechanical design and manufacturing, and technical publication industries.

c. Recent Activities

In April 1987, Auto-trol announced the availability of a publishing system interface based on PostScript, a page description language from Adobe Systems. The interface will offer technical illustrators the ability to address PostScript compatible imaging devices for proofing and final production of illustrations and presentation graphics.

In November 1986, Auto-trol announced a number of new products:

- Engineering Information Management System (EIMS), a project-oriented job accounting and file management system for the control and maintenance of CAD-based engineering data.
- Interactive Nesting System to enhance the automation of a manufacturing process.
- Empress/32, a general-purpose relational data base management system for use within engineering environments.
- Facility Layout, an addition to its family of products for Industrial Plant Design.

In addition to the above-mentioned new products, Auto-trol announced a joint marketing agreement with CIMCO/AIS (Austin, TX) for the sale of

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the latter's hardware and software for Direct Numerical Control (DNC) systems. Auto-trol also entered into an OEM agreement with Interleaf, Inc. (Cambridge, MA) acquiring the distribution rights for the Interleaf Workstation Publishing Software.

3. Computervision Corporation (100 Crosby Drive, Bedford, Massachusetts 01730)
Revenue (FYE 12/31/86): $494.7 million

a. Products/Services

Computervision offers turnkey CAD/CAM/CAE systems based on proprietary hardware as well as systems based on hardware from IBM, DEC, Prime and Sun Microsystems. The company has developed several integrated lines of CAD/CAM systems marketed under the names CADDStation, CDS 4000, Designer, Medusa, and Personal Systems. Computervision's best-selling product line is its CADDStation. CADDStation has emerged as the company's bread-and-butter product replacing the CDS 4000 series.

b. Markets Served

The company primarily serves five major industry groups: automotive, aerospace, mechanical machinery, electrical/electronic, and architecture/engineering/construction.

c. Company Strategy

In 1986 Computervision began a financial turnaround. The company became profitable after incurring losses for six quarters. Although the year ended with a loss, the last two quarters of 1986 were profitable. This trend continued into the first half of 1987.

Computervision's difficulties reflected difficulties in its product line that was based on proprietary hardware. With the introduction of CADDStation, Computervision has successfully ported its software to industry-standard hardware. Introduced in April 1986, CADDStation is a workstation based on 32-bit hardware technology from Sun Microsystems, the Unix operating system and the Ethernet local area network.

d. Recent Activities

In June 1987 Computervision announced that it had ported its Medusa CAD software to the Sun Microsystems platform.

In July 1987 Computervision announced the CADDStation 34, a graphics workstation featuring Sun's version of the Unix operating system.

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In August 1987, Computervision introduced TechPubs II, software packages designed to help users of its CADDStation family of 32-bit engineering workstations document their work.

e. Future Directions

The company plans to shift its emphasis from hardware to software.

Computervision plans to focus its research and development efforts in the areas of mechanical CAE, artificial intelligence, solid modeling, precise surface modeling, numerical control and computer-aided manufacturing applications, and advanced electronics design.

4. CONTROL DATA CORPORATION (8100 34th Avenue South, Minneapolis, Minnesota 55440)

a. Products/Services

Control Data's Computer Systems and Services Division designs, manufactures, and markets Control Data's CYBER line of computer systems. In the area of CAE/CAD/CAM Control Data specializes in CIM (computer-integrated manufacturing), that forms part of the Computer Systems and Services division. The company's principal CIM product line is its ICEM, Integrated Computer-Aided Engineering and Manufacturing. ICEM products integrate CAD/CAM activities under a single computerized design management and control system. The ICEM software runs on Control Data's CYBER 910 series of Unix-based integrated workstations.

b. Markets Served

Control Data's customers are primarily in the scientific and engineering computing environments, such as CAE and integrated manufacturing, utility, education, and petroleum industries.

c. Company Strategy

The company focuses on integrated solutions as it believes that its integration capabilities is its major strength.

d. Recent Activities

In July 1987, Control Data introduced the ICEM plus that provided major enhancements to its graphics workstations and software.

Also in July 1987, Control Data expanded the CYBER 190 family by introducing four high-performance 3-D graphics workstations.

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e. Future Directions

Control Data is moving from engineering applications into combining engineering and manufacturing for an integrated manufacturing approach.

5. DAISY SYSTEMS CORP. (700 Middlefield Road, Mountain View, California 94039)
Revenue (FYE 9/30/87): $100.9 million

a. Product/Services

Daisy Systems designs, manufactures, and markets turnkey CAE systems to automate the electronic design engineering process. Its tools are used for the design and layout of application-specific integrated circuits (ASICs), printed circuit boards (PCBs), and integrated circuits (ICs).

b. Markets Served

Daisy's products are primarily used by the military/aerospace, semiconductor, telecommunications, and computer industries.

c. Company Strategy

In 1986 Daisy created the Customer Support Division combining the training, technical publications, field service, and customer hot-line operations into one division. The creation of this division is part of Daisy's efforts in improving its customer service.

Once considered a star performer and a pioneer in the CAE workstation market Daisy has fallen far and fast. The company's problems resulted from its decision to use a proprietary system. The company has since embarked on a strategy of developing systems based on industry-standard hardware.

d. Recent Activities

The company is continuing its efforts to implement the transition to industry-standard platforms. In March 1987, Daisy introduced a line of CAE workstations based on Intel's microprocessors (80286 and 80386) and EGA graphics standards. The workstations are called the Personal Logician 286, Personal Logician 386, and Logician 386. In the mid-range Daisy is considering the Sun Microsystems Sun-3 and Sun-4 as platforms.

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e. Future Directions

It will take about a year for Daisy to offer CAE systems based on a broad line of industry-standard hardware including IBM, DEC, and Sun. Daisy has the resources (cash reserves: $75 million in August '87) to achieve its objectives.

The company plans to increase its emphasis on improving and formalizing procedures, particularly in the manufacturing, quality control, and project management areas.

6. INTERGRAPH CORPORATION (One Madison Industrial Park, Huntsville, Alabama 35807)
Revenue (FYE 12/31/86): $605.7 million

a. Products/Services

Intergraph designs, develops, and markets turnkey CAD/CAM/CAE interactive graphics and data base management systems. The company's systems are based on the DEC VAX line of minicomputers and on a proprietary series of engineering workstations.

b. Markets Served

Intergraph's systems are used in mechanical and electronics CAD/CAM; architecture, engineering, and construction (AEC); mapping and earth sciences; energy exploration, utilities, and electronic publishing industries.

c. Company Strategy

Faced with declining demand for large turnkey systems Intergraph has implemented bold changes during the past few years. The company has placed increased emphasis on workstation products and has shifted its focus to its hardware capabilities. In 1986 Intergraph made a strategic decision in developing its own workstation. The company's decision to develop its own hardware was based on its being a large DEC OEM and the inevitable tension resulting from the two companies becoming competitors in the marketplace. (DEC's corporate direction has changed as the company moves into the end-user market, while reducing its dependence on OEM sales.)

d. Recent Activities

In 1986 Intergraph announced the InterPro 32C, a workstation based on the Clipper Microprocessor (developed by Fairchild Semiconductor) and the Unix operating system. With this hardware, Intergraph entered the

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generic stand-alone workstation market and thus competing with Apollo, Sun, and DEC. The company hopes to see the system accepted as a general-purpose workstation and plans to pursue OEMs.

In January 1987, Intergraph acquired a 50% interest in Bentley Systems (Lionville, PA), a computer graphics software development company.

In September 1987, Intergraph purchased Fairchild Semiconductor's clipper operations (Advanced Processor Division) from National Semiconductor. (National Semiconductor had acquired Fairchild Semiconductor.) Intergraph plans to continue to sell the clipper on the open market.

e. Future Directions

Intergraph is promoting the concept of distributed processing for design applications.

7. THE MACNEAL-SCHWENDLER CORPORATION (815 Colorado Boulevard, Los Angeles, California 90041)
Revenue (FYE 1/31/87): $27.1 million

a. Products/Services

MacNeal-Schwendler markets computer software products for mechanical CAE applications. The company's principal product is MSC/NASTRAN, a computer program used by designers and engineers to analyze the strength characteristics of structures or products prior to construction or manufacture. MacNeal-Schwendler also offers a complete line of mechanical CAE products for personal computers. According to the company, MSC/NASTRAN is the most widely used finite element analysis program in the world.

b. Markets Served

The company's products are used in the aerospace industry and other industries including automotive, ship building, industrial and office equipment, nuclear, petrochemical, and architecture and engineering.

c. Company Strategy

MacNeal-Schwendler plans to build on its success as a leader in finite element analysis.

d. Recent Activities

In January 1987, MacNeal-Schwendler began shipping MSC/pal, a finite element analysis software product for the Macintosh.

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In March 1987, MacNeal-Schwendler announced that it had agreed to develop a new version of its MSC/NASTRAN program for Alliant Computer Systems' FX/Series of minicomputers. (Alliant Computer Systems is based in Littleton, MA.)

Also, in March 1987, MacNeal-Schwendler introduced ADCAD2 Version 2, software that enables users of popular PC-based CAD programs to easily transfer drawing files to and from MSC/pal 2, the company's finite element analysis program for minicomputers.

In June 1987, the company introduced a version of its MSC/pal 2 software for the IBM PS/2 series of personal computers.

e. Future Directions

The company plans to expand its software product line for personal computers.

8. MENTOR GRAPHICS CORPORATION (8500 Southwest Creekside Place, Beaverton, Oregon 97005)
Revenue (FYE 12/31/86): $173.5 million

a. Products/Services

Mentor Graphics designs, develops, manufactures, and markets turnkey CAE systems for use in the design, analysis, physical layout, and testing of integrated circuits and electronic systems. Mentor markets its data base and applications software on engineering workstations supplied by Apollo. The company's principal product line is the IDEA Series of engineering workstations. Mentor also offers CAE software products for personal computers.

b. Markets Served

Mentor markets its products to customers in the aerospace, computer, telecommunications, semiconductor, and consumer electronics industries.

c. Company Strategy

Mentor has emerged as the leading vendor in the CAE field. Mentor's strategy in developing systems based on industry-standard hardware seems to have paid off. The company has no immediate plans of developing applications for multiple platforms. Mentor claims that "its customers are concerned not as much with the underlying computer platform as they are with the depth and breadth of the software applications that run on it."

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d. Recent Activities

In June 1987, Mentor introduced the Domain Series 4000 Workstation, a series of products for electronic computer aided design. The systems based on Apollo workstations are available under the names Idea Station for schematic capture and local simulation, Chip Station for custom VLSI (very large-scale integration) circuit design and layout, and Board Station for printed circuit board design.

e. Future Directions

Mentor hopes to stay ahead by moving beyond CAE to diversify into related fields that are part of the automated design market. These areas include CAD, publishing, packaging and software engineering. One niche that Mentor is focusing on is design for printed circuit boards.

9. TEKTRONIX, INC. (P.O. Box 500, Beaverton, Oregon 97077) Revenue (FYE 5/31/87): $1,395.9 million

a. Products/Services

Tektronix offers test and measurement instruments, display products, and communications products. The company's Design Automation Group focuses primarily on the design, simulation, verification, and analysis of digital integrated circuits systems and subsystems generally associated with computer technology. The products include CAE, computer-aided software engineering (CASE) products, microcomputer development products, logic analyzers, and semiconductor test systems. Tektronix CAE systems facilitate transfer of design data from schematic capture and design verification through layout, fabrication, and final testing for printed circuit board (PCB) and application-specific integrated circuit (ASIC) design.

b. Markets Served

Tektronix's customers are in the electronics, communication, computer, government, and education industries.

c. Company Strategy

Tektronix's approach to CAE is to provide integrated design, evaluation, and testing for electronic systems development.

d. Recent Activities

In fiscal 1987, Tektronix introduced over 60 new products including oscilloscopes and a new series of graphics terminals.

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e. Future Directions

Tektronix will continue to take advantage of its four-decade experience in test equipments. The major challenge facing Tektronix is tying together its instrument-type products into the CAE area.

10. VALID LOGIC SOLUTIONS INC. (2820 Orchard Parkway, San Jose, California 95134)
Revenue (FYE 12/31/86): $60.9 million

a. Products/Services

Valid Logic designs, manufactures, and markets turnkey CAE applications for electronic systems design and integrated circuits design.

b. Markets Served

The market for Valid's products includes two groups of electrical engineers; systems engineers and integrated circuit designers. Valid has sold its systems to customers in the computer, semiconductor, telecommunications, instrumentation, and aerospace and military industries.

c. Company Strategy

Valid's strategy lies in integrating the operations of Valid and Telesis to realize the maximum synergies possible (Valid acquired Telesis - See "Recent Activities."). Valid plans to develop applications for Sun workstations while Telesis plans to develop applications for the DEC MicroVAX. Historically Valid has used DEC hardware and Telesis has run on Sun workstations.

d. Recent Activities

In February 1987, Valid acquired Telesis Systems Corp. (Chelmsford, MA), another player in the CAE industry. Telesis develops and markets electronic design automation workstations used for printed circuit board design.

In June 1987 Valid introduced two new products, ValidCOMPOSE and Allegro. ValidCOMPOSE is an integrated circuit design tool for developing chip architectures. Allegro is a rules-driven printed circuit board design system.

Also in June 1987, Valid ported its electronic design automation tools to Sun's Unix-based workstations.

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e. Future Directions

In the interview with Electronic Business (June 15, 1987) Douglas Hajjar, president and CEO of Valid (formerly president and CEO of Telesis) stated, "There's no doubt that in the near future a company that has a Unix-based Sun platform and a MicroVAX-based platform with IBM PCs in the front end, all running full CAE and PCB capability with software links into manufacturing and testing - there is nobody in the marketplace today that can touch that kind of company. And that's exactly what we will have in a very short period of time."

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New Opportunities

IV New Opportunities

A CAD/CAM

There are three major areas of opportunity in the CAD/CAM market: three-dimensional capabilities, integration, and solids modeling.

Three-dimensional modeling and design represents a significant opportunity. These capabilities are needed in the mechanical, electrical, and chemical fields. Applications include: three-dimensional mechanical design, fluid and air flow, and modeling of molecules in three dimensions.

The next major opportunity in the market is the emergence of genuine integration of CAD and CAM, and in linkages between CAE and computer-aided testing, developments that promise to compress the process of design, testing, and manufacture.

- Integration is important because it streamlines the product development cycle. A circuit board, for examples, evolves from a schematic design into a layout of physical parts and is then rendered as an assembly drawing and transferred to manufacturing. At the same time, the board's mechanical housing must be designed and fitted. With an integrated data base, this activity becomes a single flow of information since all of these functions share a common data base. Thus, engineers at each step can work from the same model, speeding the communication of design progress and automatically ensuring parts accuracy and compatibility.

- Costly R&D efforts will be required to succeed in developing and bringing such products to market.

Solid modeling software is an emerging application that is expected to dominate design applications by the end of the decade. In the past, the computing power needed for solid modeling was often prohibitive, but as

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hardware prices declined and processing power increased, this allowed the capabilities of solid modeling to be available to more engineers. Solid modeling software enables designers to describe the volume and mass of mechanical parts on the computer—a considerable improvement over the edges and corners provided by other kinds of CAD software.

B

CAE

The opportunities in the CAE market revolve around price, improved data management, and performance.

- A drawback to CAE systems is price. What is needed are systems in the $10,000-20,000 price range with the same performance and functionality as the systems that average about $50,000. This will bring the systems into a price range that many more engineers can afford. There appears to be a threshold at about $20,000 where large companies to think of buying a workstation for every engineer. Currently, engineering workstations are typically shared by a number of engineers.

- One of the problems associated with CAE systems is the lack of sophisticated data management. Most CAE systems have only limited facilities for relating information files. Once a hierarchical DBMS can be integrated into a CAE workstation, the designer will be relieved of much routine work, with a key benefit being the ability to do modular design.

- Another need by chip designers is for faster circuit simulation.

C

Workstations

New opportunities in the workstation market lie in the commercial sector such as banking and finance. As an example, Sun has introduced a workstation for financial applications for stock brokerages and other investment banking companies.

D

Other

The following are emerging research areas that will need software packages:

- Biochemistry.
- Combined chemical and structural engineering.
- Cryogenic and space related research.
- Graphics for biology.
- Hydrology.
- Linkage between automated design and machine tool control.
- On-line simulation of biological and chemical processes.
- Parametric design for a family of products.
- Process synthesis.
- Strategic Defense Initiative ("Star Wars").
- Rock stability.

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In addition, other applications that are needed include:

- Drilling simulation for underground modeling.
- Improved laboratory management systems.

Demand for computerized design and simulation tools will increase in biological and genetic engineering as new technical advances increase the complexity of these fields.

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Conclusions and Recommendations

Conclusions and Recommendations

Rapid technological advances will continue to characterize the CAD/CAM/CAE industry and competition will continue to be intense.

Communications are key to creating a productive system whether a company is trying to share data among its various types of workstations, pass data to a remote location, or tie into a corporate data base.

The winners in the turnkey market will be those vendors that offer products in the form of an open architecture with independent workstations ranging in power and capability that can all be hooked up to a common data base.

In the future, current capabilities offered on workstations will be available on PCs. The implications of this are lower prices, greater unit sales, and potentially declining revenues for some vendors. However, the offering of greater capabilities on lower priced systems will serve to overcome a threshold level in the market by opening up the market to new users and new applications.

To address the needs of the environment, a company should offer a hierarchy of solutions. A vendor should provide an entire spectrum of solutions that all work with a consistent user interface.

Offering an inexpensive two-dimensional product on a PC will provide the vendor with the opportunity to sell the customer a more expensive three-dimensional product when the customer outgrows two-dimensional.

The cost of entry into the market for sophisticated engineering programs such as NASTRAN is substantial and will limit the introduction of new competitive products.

The CAD/CAM market will eventually develop into a data base battle, giving IBM the advantage over other CAD/CAM vendors. This will

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occur when the CAD capabilities become a commodity and the data base consequently takes on greater importance.

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ES-A

Appendix: Forecast Data Base

Appendix: Forecast Data Base

This appendix contains the following forecast information, as shown in Exhibit ES-A-1.

- Market size by delivery mode for each year, 1986-1992.
- Market growth rates for 1986-1987.
- Average annual growth rate (AAGR) for each delivery mode for the five-year period 1987-1992.

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EXHIBIT ES-A-1

ENGINEERING AND SCIENTIFIC USER EXPENITURE FORECAST BY DELIVERY MODE, 1986-1992

Segmentation by Delivery Mode	($M) 1986	1986-1987 Growth (Percent)	($M) 1987	($M) 1988	($M) 1989	($M) 1990	($M) 1991	($M) 1992	1987-1992 AAGR (Percent)
Remote Computing/Batch	247	6	263	281	297	309	327	339	5
Application Software									
- Mainframe/Mini	186	28	239	306	388	480	589	713	24
- Micro	42	31	55	73	95	126	162	201	30
Total Application Software	228	29	294	379	483	606	751	914	25
Turnkey Systems	322	10	354	380	418	451	479	508	7
Cross-Industry Total	797	14	911	1040	1198	1366	1557	1761	14

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ES-B

Appendix: Forecast Reconciliation

ES-B

Appendix: Forecast Reconciliation

This appendix contains the following information:

- Exhibit ES-B-1 which indicates the changes made in this year's forecast as compared to last year's.
- An explanation of any significant changes that were made to the forecasts.

INPUT has reduced the five-year growth rate (AAGR) for turnkey systems from 15.1% to 7.1%. There is intense price competition among the major hardware vendors, Sun, Apollo, and DEC. Also, the marketplace is witnessing a trend away from turnkey systems and toward industry-standard hardware and "unbundled" software.

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EXHIBIT ES-B-1

ENGINEERING/SCIENTIFIC SEGMENT - DATA BASE RECON-

Delivery Mode	1986 Market		
	1986 Forecast ($M)	1987 Report ($M)	Variance of 1987 Report (Percent)
Remote Computing/Batch Serv.	263	247	6
Application Software			
- Mainframe/Mini	186	186	0
- Micro	42	42	0
Total Application Software	228	228	0
Turnkey Systems	322	322	0
Cross-Industry Segment Total	813	797	2

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EXHIBIT ES-B-1 (Cont.)

CILIATION OF MARKET FORECAST BY DELIVERY MODE

1991 Market			1986-1991 AAGR Forecast in 1986 Report (Percent)	1987-1992 AAGR Forecast in 1987 Report (Percent)
1986 Forecast ($M)	1987 Forecast ($M)	Variance of 1987 Forecast (Percent)		
335	327	2	5	5
545	589	-7	24	24
162	162	0	31	30
707	751	-6	25	25
648	479	35	15	7
1690	1761	-4	16	14

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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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